An investigation into the effects of different media combinations on the learning achieved in carrying out computer-based practical tasks

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An investigation into the effects of different media combinations on the learning achieved in carrying out computer-based practical tasks

Petros Romanidis

A Doctoral Thesis

Submitted in partial fulfilment of the requirements for the award of

Doctor of Philosophy

of

Loughborough University

25th September 2006

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Abstract

Four different computer-based media combinations – Text-only, Text + Diagrams, Spoken Text + Diagrams, and Text + Video material – have been created to instruct participants how to carry out the practical task of removing and installing both a video card and a CPU chip in a computer system. The four presentations are based upon identical teaching material. Tests were constructed to measure the amount of knowledge gained both in the theoretical and in the practical parts of the experiment. An interactive facility was provided which allowed participants to move forwards and backwards in the material so that the effects of interactivity (or lack of it) could be investigated in relation to the media combinations used. In addition, student learning style was measured and the effects of the four presentations on students with different learning styles were investigated. A practical domain was chosen because most previous work has mainly been on theoretical domains (such as statistics) or on animated examples of simple systems (such as braking systems).

Two experiments have been designed and carried out. The first experiment was a pilot study which used 24 participants. Its results were used to improve the design of the second experiment by improving the material presented and the knowledge tests and adjusting the complexity of the questions used in the test. The second experiment was a more extensive one in which 80 participants took part.

These results showed that text-only material was not as effective in delivering the teaching material to the participants compared with the other presentations. However, when interactivity was introduced, the text-only participants were able to improve their performance considerably by moving extensively between scenes. The addition of video material did not improve the learning performance in the completion of the practical tasks, in comparison with the other media combinations and this may have been due to a redundancy effect. Finally, learning style (regarding the sensing/intuitive learners) did result in significant learning performance differences, but these were not due to the media combinations used. An examination of performance of sensing and intuitive learners over the theoretical and practical aspects of the test suggested that the difference may be due to intuitors’ preference for theoretical material and sensors’ preference for practical material.

Further research work is proposed to investigate further the effects observed.
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<td>Analysis Of Variance</td>
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<td>CBI</td>
<td>Computer-Based Instructions</td>
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<td>CIP</td>
<td>Cognitive Information Processing</td>
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<td>CPU</td>
<td>Central Processing Unit</td>
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<td>S+D</td>
<td>Sounds + Diagrams</td>
</tr>
<tr>
<td>Sig.</td>
<td>Significance</td>
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<tr>
<td>Std.</td>
<td>Standard</td>
</tr>
<tr>
<td>STM</td>
<td>Short-Term Memory</td>
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<tr>
<td>T+D</td>
<td>Text + Diagrams</td>
</tr>
<tr>
<td>T+V</td>
<td>Text + Video</td>
</tr>
<tr>
<td>TO</td>
<td>Text-Only</td>
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</table>
Acknowledgements

Firstly, I would like to thank my supervisor Professor James Alty, who helped me all the way to carry out this research. Without him, none of this would be accomplished. His previous work on the field together with his suggestions played an important role in the development and completion of this research. Particularly, I am obliged to him for all those long meetings that we had, in which he always succeeded in being helpful and, most importantly, pleasant. That is why I will always consider him as an efficient professor and as a good friend.

I would also like to thank my family, who were always there for me supporting me both financially and psychologically. I know that they also got tired from the whole procedure, but I hope that in the end they are as happy and satisfied as I am, for completing this work.

Being under pressure for a long time during these years would be unbearable, if I did not have all the support from my close friends, here in Loughborough and back to Thessaloniki. I owe them a lot for carrying my thoughts away from work and for having all this great time whenever we were together.

Finally, I will never forget the people who are not here any more to share these moments with me. This work is dedicated to a special person, who really influenced my decision for doing a PhD. Aunt Veta, this is for you.
Chapter 1  Introduction

1.1 Aims of the research

The aim of this research was to examine the effects of different computer-based media combinations on learning. It does this by delivering to learners the same teaching material via computer-based presentations that consist of different media combinations. This research also aims at compensating for areas of previous relevant empirical work that need further investigation such as the lack of emphasis on practical work and the effects of individual differences such as learning styles. Suggestions are also made as to how the work can be extended and generalised.

The research examines three aspects - learning, media, and the use of media in learning. A pilot study is carried out and the results are then combined to improve the design of the main experiment. Both studies involved the delivery via various media combinations of a teaching material that consists of the instructions on how to fulfil a learning task. The task chosen is a practical task – that of replacing components in a computer system.

1.2 Learning

One of the key areas examined is learning. Learning is a procedure which has attracted the efforts of many researchers to analyse it and understand it. Since these efforts focus mainly on the human memory, they are part of cognitive science (Saettler, 1990). Human memory clearly plays a major role in learning. This can be seen in the definition of learning:

"Learning is the act of deliberate study of a specific body of material, so that the material can be retrieved at will and used with skill" (Norman, 1982, p.3).

Thus, the main factor in a learning procedure involves accessing and using knowledge and information stored in the human memory. An examination of the way human memory functions can throw light on how learning has actually been achieved.
The focus is on two theories that have been developed after extensive research on human memory. These theories are the Dual Coding Theory (Paivio, 1986) and the Cognitive Load Theory (Chandler and Sweller, 1991; Sweller, 1999) and they both attempt to predict the way memory functions in order to store, access, or delete information. Based on these predictions, the two theories can be applied in the research of learning, and have been used as guidance on how information should be presented and conveyed to learners.

Apart from the work on the human memory, research on learning also includes a survey on learning styles and the current methods that are applied within specialised questionnaires in order to identify the learning style of learners. The aim here is to reveal the meaning of the term ‘learning styles’, along with their role in learning and how they could be used in order to contribute in learning.

1.3 Media

The second part of the research examines media. Media is the plural of the word ‘medium’, which is defined as “a means or instrumentality for storing or communicating information” (WordReference.Com English Dictionary, 2006). In terms of learning, a medium can be defined as a mechanism used to transfer information to learners. Modality refers to the nature of the information being transferred (for example, text or image). Media are particular instances of these transfers (for example, text on paper or text on screen).

Successful transfer of information is the one that results in learning. The empirical results of research have examined the usefulness of various media combination in educational domains and comparisons are made between these results. Relevant research can be referring to media used in their original form, like in educational books, or in their computer-based form, as used in computer presentations.

The above research examines the effects of text presented using a single medium and the effects of combining text with other media, either in computer-based environments or not (e.g. textbooks). Much of this research uses the principles of Dual Coding Theory and
Cognitive Load Theory, and either supports or criticises their validity in terms of learning.

1.4 Use of media

The third part of this research examines the use of the computer-based media, focusing on their use in computing environments, in particular, how the practical nature of a task might affect the choice of media used to deliver the instructions, and the learning achieved.

The term 'multimedia' can refer to textbook-based multimedia, lecture-based multimedia and computer-based multimedia (Mayer, 2001). In all cases, the term 'multimedia' refers to the combination of media, which, in terms of learning, is meant to improve the comprehension of information material. Textbook-based multimedia consists of text and diagrams. Lecture-based multimedia involves, for instance, the voice of the lecturer and the text, images and diagrams presented via the projection on the screen. Computer-based multimedia, on the other hand, refers to the combination of media which are presented via a computer. Nowadays, most people, when they come across the term 'multimedia', they tend to think more of the computer-based multimedia, due to the broad use of multimedia presentations via computers (Mayer 2001). Since the thesis focuses on computer-based multimedia and its effects on learning, when the term multimedia is used, it will mean the computer-based multimedia, unless otherwise stated.

Multimedia presentations are the result of multimedia design. Their advantage over lecture-based multimedia lies on the ability of multimedia designers to combine media in a more convenient and creative way, which gives them alternatives of transferring information and allow the learners to proceed at their own pace and interact when required with the material. Although results have led to a number of conclusions about multimedia design, there are still questions to be answered such as:

- Why do particular media affect learning differently?
- Which media are better at delivering particular teaching materials?
Which individual differences are likely to affect the learning of teaching materials delivered via particular media combinations? Why?

1.5 Focus of the research

The thesis therefore:

1. examines current theories of memory and their relevance to the design process,
2. reviews current empirical work in multimedia design directed towards learning,
3. examines current theories in multimedia design,
4. carries out two experiments for testing the effects of different media combinations on learning in practical tasks,
5. compares the results of the experiments with other experiments on multimedia learning,
6. investigates how students with different learning styles are affected by different media combinations.

Current research deals mostly with the effects of adding images to written text or speech on learning. The teaching material is often theoretical, such as teaching information material from statistics, mathematics or other fields that involve problem solving. Empirical results support the existence of two independent and interrelated channels within human memory (Paivio, 1967; 1991; Paivio and Csapo, 1973; Nugent, 1982; Mayer and Anderson, 1991; Severin, 1967), which is the basis of Dual Coding Theory (Paivio, 1986). They also suggest that multimedia designers should take into account the principles of Cognitive Load Theory when including text and diagrams within a multimedia presentation (Mayer, 2001). Little work exists on the effects of different media combinations on learning in practical tasks.

The learning achieved is measured by requiring participants to answer a questionnaire used as a test to evaluate the learning that they gained by watching the presentation. Multimedia design, applied in this experimental work, includes media combinations which engage both memory channels, while trying to comply with the design principles.
stated by Cognitive Load Theory and Mayer's Cognitive Theory. The Text-Only presentation serves as a basis of comparison, to record improvements in learning performance, if any.

1.6 The experiments and hypotheses examined

The practical task chosen is that of replacing components (CPU and video card) in a computer system. This task was chosen because it is a useful task (which might motivate the students) and because it is a task which involves a number of practical steps. Four media combinations were chosen – Text-Only, Text + Diagrams, Sound + Diagrams and Text + Video Sequences. The first three were chosen because they have already been used extensively in experimentation on learning. The latter was added because it was felt that video material might be useful in understanding practical tasks.

Additionally, the learning styles of learners were measured and an investigation was carried out to ascertain how the different learning styles might affect the learning achieved.

Two experiments were carried out, the first serving as a pilot experiment which aided in improvements in both multimedia design and the construction of the learning test of the major experiment.

The hypotheses examined are:

1. The learning achieved by students when using media combinations will be superior to that achieved using text alone.

2. The learning achieved by students will not be significantly different between the Text + Diagrams presentation and the Sound + Diagrams presentation if the text is placed adjacent to the relevant diagrams.

3. The addition of video material in the media combinations will result in improved learning by students in the practical task compared with other media combinations.
4. There will be differences in the learning achieved by students with different learning styles using the same media combinations.

1.7 Organisation of the thesis

The thesis is organised into nine chapters.

Chapter 1 introduces the thesis and presents how it is organised.

Chapter 2 describes the work done by Dewey, Lewin, and Piaget, who explain how learning is achieved through learning cycles. It also discusses the concept of learning style, the different ways in which it has been defined and measured, and an assessment of the most appropriate way of measuring learning styles in this thesis.

Chapter 3 discusses the various theories about memory (in particular Dual Coding Theory and Cognitive Load Theory) and their relevance to the work in this thesis.

Chapter 4 examines the field of multimedia learning, the major experiments carried out and the results obtained. It focuses on the empirical work of Mayer and his colleagues which led to the construction of Mayer’s Cognitive Theory, which is also described. The chapter also describes the empirical work of Alty and his colleagues, which is relevant to this work. Finally, it discusses the criticism that media combinations have received regarding their ability to affect learning.

Chapter 5 discusses the first (pilot) experiment carried out in which the multimedia presentations used to support the practical task are designed. All the features of the experiment are described, including the criteria for participation, the contents of the teaching material, the two types of learning test and the scoring mechanism applied in both of them, and the scenario for carrying out the whole experiment.

Chapter 6 analyses the results from this pilot experiment which are used to make modifications to the design of the full experiment. Analysis includes the learning performance of the participants across the four multimedia presentations, the effects of prior knowledge in the results and the validity of the questions included in the two types of learning test.
Chapter 7 discusses the design and implementation of the second experiment. All improvements and their relationship with the pilot experiment are described.

Chapter 8 presents the results of the second experiment and discusses the implications of the results. Results are statistically analysed and compared with results of previous experimental work. Analysis includes the learning performance of the participants in the written and practical part of the learning test across the four presentations, the interaction with the presentations in terms of re-examining information and the learning performance of participants with different learning styles across the four presentations.

Chapter 9 summarises the work that has been carried out and provides the major conclusions to the work. The drawbacks and advantages of this work are discussed. Suggestions are also made for future work which could be carried out.
Chapter 2  Learning cycles, learning styles and inventories

2.1 Introduction

This chapter examines the relevant research on learning. Learning is a large research area which involves research on:

- human memory
- factors that aid or inhibit learning
- learning models, styles and inventories

Much of the research which focuses on learning in various environments, either in designated areas like school environments or at home by watching a multimedia presentation on a personal computer, is based both on theoretical and empirical approaches. Theoretical studies endeavour to understand how a learning process occurs and are characterised by descriptions of the cycles of activity in which learning is achieved. Empirical research provides evidence to support or criticise these ideas (their own or other researchers' beliefs on how learning is achieved) and can identify new principles that define the way material should be presented and conveyed to learners in various environments.

Previous research carried out on the types of learning styles that learners use (as part of the research on learning) is important as this could be a major factor that may affect learning in e-learning environments which has usually not been taken into account in most of the empirical research previously carried out. Learning models are models based upon theories of how people learn and retain material. Learning styles are the ways in which a learner acquires, retains and retrieves information based upon learning models (Felder and Henriques, 1995). A learning style indicates how a person learns or prefers to learn (Keefe, 1991); therefore, learning styles are likely to be important within a teaching environment. Taking learning styles into account when designing instructional methods should lead to an optimum learning result or, at least, exclude instructional strategies that could hinder learning.
The thesis is only concerned with how a particular learning style might affect learning outcomes when information is presented in particular media combinations. Many of the learning preferences that a learner might have (words or images, voice narration or textual description, top-down or bottom-up approach, working in groups or alone) are likely to be affected by many factors such as family environment or childhood. There are also other factors, which play an important role in learning. These could be personal disabilities that force people, as far as learning is concerned, to receive information in a different way compared to other learners (one example is dyslexia). However, these factors, whilst important, are beyond the scope of this thesis.

Finally, learning inventories are techniques (usually questionnaires) which seek to identify learning styles.

2.2 Learning

Learning processes are a subject of considerable debate among researchers, who try continuously to identify all those factors that affect, in a positive or negative way, the procedure of learning. Once identified, these factors can be applied in the design and construction of teaching methods that should be used in schools or other teaching environments.

This research into learning processes has resulted in the construction of ‘learning cycles’, which describe the process of learning. Kolb has provided the most descriptive learning cycle model (Kolb, 1984). This model is based on the experiential theory of learning (as opposed to the behavioural theory of learning which is characterised by traditional educational methods). The experiential approach uses ‘methods that for the most part are based on a rational idealist epistemology’ (Kolb, 1984, p.20). According to Kolb, experiential learning owes its name to two factors. First of all, to the work of Dewey, Lewin, and Piaget, from which originated experiential learning, and secondly, to the emphasis on the main role that experience plays in the learning process. Dewey, Lewin and Piaget have constructed their own learning cycle process (Dewey, 1938; Lewin, 1935; Piaget, 1970). Kolb provides firstly a description of the Lewinian model, followed
by the other two models, so that emphasis is given on the similarities of the other two models (Dewey's and Piaget's model) to the Lewinian model.

Lewin's learning cycle model is shown in Figure 2.1 (Kolb, 1984). The model suggests that a learning cycle consists of four stages which follow each other in a sequence. Concrete Experience is the opening stage of the cycle followed by reflection that a learner has on that experience. Reflection is likely to be followed by the construction of rules which characterise the experience (Abstract Conceptualisation), and, thus, to the construction of ways of modifying the next experience that will occur (Active Experimentation), leading in turn to the next Concrete Experience (Atherton, 2005) and the cycle begins again. A full learning cycle may occur 'in a flash, or over days, weeks or months, depending on the topic' (Atherton, 2005). The model is addressed to action research and laboratory training, in which learning is "facilitated best by an integrated process that begins with here-and-now experience followed by collection of data and observations about that experience" (Kolb, 1984, p.21). Kolb regards as one of the most important features of this model, its emphasis on the immediate personal experience, which is the necessary occurrence on which the learning cycle of Lewin depends. Furthermore, Kolb considers that a second important feature of Lewin's model is information feedback which 'provides the basis for a continuous process of goal-directed action and evaluation of the consequences of that action' (Kolb, 1984, p.21).

![Figure 2.1: Lewin's learning cycle model](image-url)
Dewey’s learning cycle model is shown in Figure 2.2 (Kolb, 1984). The circle describes the process that intervenes between impulse (the opening stage of the circle) and purpose (the final stage of the circle). Between these stages the learning cycle includes

- observation of surrounding conditions followed by
- knowledge of what has occurred in similar occasions (where knowledge has partially been gained by recollection of data and partially by notifications by those with wider experience) followed by
- judgment that assembles everything that has been observed and recollected in order to identify their significance.

Judgment, as the last part of the cycle that leads to purpose, is likely to provoke the creation of a new impulse that will start a new sequence of learning cycles, until the whole process reaches the state of purpose. According to Dewey, difference of a purpose from an original impulse is identified in “its translation into a plan and method of action based upon foresight of the consequences of action under given observed conditions in a certain way” (Dewey, 1938, p. 69). Dewey’s model is very similar to Lewin’s in the sense that it considers learning to be a process that integrates experience and concepts, observation, and action (Kolb, 1984).

Figure 2.2: Dewey’s learning cycle model
The third model of learning cycle is constructed by Piaget and it is demonstrated in Figure 2.3 (Kolb, 1984). The model consists of four stages that describe the human’s learning evolution from the age of birth to about the age of 14-16. The first stage (0-2 years) is called the ‘sensory-motor stage’, where the child is mainly concrete and active, in terms of learning style. Learning in this stage is mainly as enactive, through feeling, touching and handling. The second stage (2-6 years) is called the ‘representational stage’, where the child begins to convert actions into images, while retaining concreteness as a feature of his/her learning style. Learning in this stage is mainly iconic, through observation and image-handling. The third stage (7-11 years) is called the ‘stage of concrete operations’, where the child starts to increase his/her independence from the immediate environment by developing the power of reasoning. Learning is characterised by the logic of classes and relations. The fourth stage (12-15 years) is called the ‘stage of formal operations’, where the child, in terms of learning style, is active again, like in the first stage, but now in a larger scale and greatly affected by the reflective and abstract power that preceded it. In general, according to Piaget’s model, the learning process is based on the child’s interaction with the environment, which is very similar to the learning cycles’ models of Dewey and Lewin (Kolb, 1984).

Figure 2.3: Piaget’s learning cycle model
Through these learning cycle models, Kolb has outlined the characteristics of experiential learning:

- Learning is best conceived as a process, not in terms of outcomes.
- Learning is a continuous process grounded in experience.
- The process of learning requires the resolution of conflicts between dialectically opposed modes of adaptation to the world.
- Learning is a holistic process of adaptation to the world.
- Learning involves transactions between the person and the environment.
- Learning is the process of creating knowledge.

Thus, according to Kolb, experiential learning is defined as “the process whereby knowledge is created through the transformation of experience” (Kolb, 1984, p.38). Within this definition emphasis is given on four aspects of the learning process. Firstly, experiential learning is distinguished from behavioural learning through the process of learning and adaptation to the world as opposed to contents and outcomes. Secondly, knowledge is a transformation process, being continuously created and recreated. Thirdly, learning transforms experience. Fourthly, in order to understand learning, we have to understand the nature of knowledge and realise its limitations.

2.3 Learning styles

Kolb believes that learning is effective when people have developed specific abilities (Kolb, 1984). Based on Lewin’s learning cycle, these abilities are:

- concrete experience abilities
- reflective observation abilities
- abstract conceptualisation abilities
- active experimentation abilities
In other words, learners should involve themselves in new experiences, observe experiences from many perspectives, create their own symbolic theories by conceptualising their observations on experiences and, finally, apply these theories in problem-solving situations (Kolb, 1984).

Obviously, it is very difficult for learners to achieve perfection in all four abilities, in terms of being concrete and abstract, or active and reflective at the same time. People have to bring forward one of these abilities whenever they find themselves in a learning situation. Moreover, while a child evolves to become an adult, with experiential learning being a major factor to aid in this evolution, unconsciously he/she makes preferences upon developing some of these abilities more than others, building his/her learning style.

People have different learning styles, in terms of conceiving, retaining and processing information. By developing Kolb's learning abilities, some in a greater level, people unconsciously obtain preferences over information material. Specialising this discussion on students, it has been noticed that some students prefer facts, data and algorithms, whereas others prefer theories and mathematical models. Some students feel more comfortable when information is in visual form, like diagrams, pictures and schematics, whereas others get more from information when this is in verbal form, either written or spoken explanations. Furthermore, some students perform better within a group of students being active and interactive, whereas others prefer working individually (Felder, 1996).

Learning styles are important and have to be taken strongly into account within a learning environment. Providing a student with information in a less preferred form is likely to lead to negative learning results, especially if this is to happen constantly. This, on the other hand, does not imply that a student should be presented with information material solely in a form that suits his/her learning style, because this can be a restraining limit in terms of developing cognitive factors, like creativity, which are really important in a professional level. Ideally, one should develop all learning skills by having the chance to deal with information material that covers partially all aspects of learning preferences. In this way, students are able to process information effectively, while at the same time developing and improving abilities that are staying behind due to learning preferences.
which favour the development of specific abilities. Thus, according to Felder, “an objective of education should be to help students build their skills in both their preferred and less preferred modes of learning... The goal is to make sure that the learning needs of students in each model category are met at least part of the time” (Felder, 1996). This teaching behaviour is known as “teaching around the cycle” (Felder, 1996).

Learning styles were designed to classify people, and specifically students, in categories depending on their learning preferences. Kolb’s learning styles are based on the four abilities that he diagnosed for effective learning. In fact, Kolb identified two dimensions in the learning process. The first dimension is defined by concrete experiencing and abstract conceptualisation occupying its two ends. The second dimension is defined by active experimentation and reflective observation taking place at its two ends (Kolb, 1984). Kolb’s set of learning styles divide learners into four types, depending on the combination of their preferences to the two learning dimensions (concrete or abstract, active or reflective):

- Type 1: concrete – reflective.
- Type 2: abstract – reflective.
- Type 3: abstract – active.
- Type 4: concrete – active.

Type 1 learners have “Why?” as a characteristic question. This type of learner responds well to explanations of how information material is related to their experience, interests and future career. Type 2 learners have “What?” as a characteristic question. Learners of this type prefer information to be presented in an organised and logical style and benefit if they are given time for reflection. Type 3 learners have “How?” as a characteristic question and they are described as willing to work actively in a well-defined task and in a trial-and-error manner. Type 4 learners have “What if?” as a characteristic question. These learners like to apply course material in new situations to solve real problems (Stice, 1987).

Another learning model is the Herrmann Brain Dominance Instrument. This model divides students into four categories, derived from four different modes of thinking,
which are based on the task-specialised functioning of the physical brain (Felder, 1996). These four modes or quadrants have learning styles associated with them (Herrmann, 1990) for example:

- **Quadrant A** (left brain, cerebral). Logical, analytical, quantitative, factual, critical.
- **Quadrant B** (left brain, limbic). Sequential, organised, planned, detailed, structured.
- **Quadrant C** (right brain, limbic). Emotional, interpersonal, sensory, kinesthetic, symbolic.
- **Quadrant D** (right brain, cerebral). Visual, holistic, innovative.

A further model is the Felder-Silverman learning model (Felder and Silverman, 1988) classifies student learning styles as:

- Sensing learners, who are concrete, practical, looking towards facts and procedures or intuitive learners, who are conceptual, innovative, looking towards theories and meanings.
- Visual learners, who prefer material to be presented in a visual mode, like diagrams, pictures and flow charts or verbal learners, who prefer written or spoken explanations.
- Inductive learners, who prefer presentations that move from a specific to a more general point of view or deductive learners, who prefer presentations that move from a general to a more specific point of view.
- Active learners, who like trying things out and working within a group or reflective learners who like thinking things through and working alone.
- Sequential learners, who are linear, working and learning step by step in an organised manner or global learners who are holistic, working and learning in large leaps.

Learning styles are a useful academic tool, even though they are still undergoing evaluation of their validity and readiness to be used for academic purposes. Choosing the appropriate learning model to apply in a teaching environment, like a classroom, needs
thorough evaluation of the model and associated styles to approve of its usefulness to the students that are part of the teaching environment. Depending on the characteristics of each learning style included in the model, teachers can design a teaching method that achieves in 'teaching around the circle', as it has already been discussed.

When a teaching environment is course-oriented, for example for students of mechanical engineering, research on learning styles has shown more organised results, which help professors to apply a specific teaching method that applies to the needs of the students.

Since the work in this thesis will involve an assessment of the learning achieved by students in an e-learning environment, learning style will be used as a variable in the experimentation.

People are therefore characterised by individual differences that in learning environments are defined as learning styles. The attempt to create procedures for identifying learning styles has led to the development of what are called 'learning style inventories'. An inventory is a technique (often involving questionnaires) for identifying learning styles. It is therefore important to examine the various learning style inventories to enable the most appropriate one to be chosen to be used in the empirical work carried out in this thesis.

The fact that using a learning style model and its associated inventory to identify the learning styles of learners is still regarded by some researchers to be of doubtful importance, makes the selection of a learning model an even more critical procedure. However, when research is related to learning and to the various factors that affect learning in a specific learning environment, then this procedure is essential and it is worth being included within empirical work. As far as multimedia learning is concerned, a review of experimental work that has been carried out on this research area has shown that researchers have not included learning styles within their research. The reasons why researchers have ignored learning styles is possibly because they believed that learning styles were not likely to play an important role in the final results of their research or because they mistrusted learning style models and their ability to properly assign learning styles to people.
2.4 Choosing the appropriate learning model

Considering the fact that research on learning styles has its origins in the beginning of the 19th Century (for instance Betts’ inventory was introduced in 1909 (Coffield et al., 2004)), it is of no surprise that there is already a large number of learning styles identified. There are some general and some more specific criteria which have guided the procedure of choosing the most appropriate learning model for the experimental work of this thesis. Coffield et al (2004) have identified 71 learning style models and have broadly categorised them into the thirteen major models (shown in Table 1) together with their assessments of the models. These models are classified in five categories:

- Learning styles that are based on the four modalities: visual, auditory, kinaesthetic and tactile.
- Learning styles that are based on the cognitive structure.
- Learning styles that are one component of a relatively stable personality type.
- Learning styles that are flexibly stable learning preferences. Learning styles that are based on learning approaches, strategies, orientations and conceptions of learning.

Table 2.1 The 13 major learning style models identified by Coffield et al (2004)

<table>
<thead>
<tr>
<th>Test</th>
<th>Assessment</th>
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<tbody>
<tr>
<td>Apter (2001)</td>
<td>Merits further research in an educational context</td>
</tr>
<tr>
<td>Dunn and Griggs (2003)</td>
<td>Lack of independent research on the model. Forceful claims about impact are questionable.</td>
</tr>
<tr>
<td>Herrmann (1990)</td>
<td>Although largely ignored offers promise. Is more inclusive and systematic.</td>
</tr>
<tr>
<td>Honey and Mumford (2000)</td>
<td>Widely used but needs to be redesigned to address weaknesses.</td>
</tr>
<tr>
<td>Jackson (2002)</td>
<td>Has promise for wider use and consequential refinement</td>
</tr>
<tr>
<td>Kolb (1999)</td>
<td>Problems about reliability, validity and learning cycle</td>
</tr>
<tr>
<td>Myers and McCaulley (1985)</td>
<td>Not clear which 16 elements are most relevant</td>
</tr>
<tr>
<td>Riding and Rayner (1998)</td>
<td>Potential value not well served by an unreliable instrument</td>
</tr>
<tr>
<td>Sternberg (1999)</td>
<td>An unnecessary addition to the many models</td>
</tr>
<tr>
<td>Vermunt (1998)</td>
<td>A rich model with potential use for post-16 education where text-based learning is important.</td>
</tr>
</tbody>
</table>
The above classification of learning styles can guide researchers on which model could be the most appropriate to be used for the experimental purposes of their research. However, although learning style inventories that belong to the same category share many similarities, as many of them are strongly affected by others of the same category, they are likely to produce different results, depending on the circumstances under which they are used. In addition to this, based on the research carried out by Coffield et al., it is important which model is used, regardless to Felder's conclusion which stated that "which model educators choose is almost immaterial, since the instructional approaches that teach around the cycle for each of the models are essentially identical" (Felder, 1996). Thus, there are more issues to be considered when choosing a model. The most important is that choice should depend heavily on the research area of the experiment and the characteristics of the people taking part in the experiment, such as age and knowledge background. For example, research has shown that the learning style models of Dunn and Dunn, Gregorc, and Riding should not be used in education or business (Coffield et al., 2004).

Choosing the most appropriate learning style model from these seventy one models to carry out an empirical investigation into the effects of different media combinations on learning outcomes for different learning styles is not simple. Coffield et al. examined each major model for evidence that it could show internal consistency, test/re-test reliability and construct and predictive validity. They concluded that only three of the thirteen models came close to meeting the criteria — the models of Allinson and Hayes, Apter, and Vermunt — whilst a further three of the major models — those of Entwistle, Herrmann, and Myers-Briggs — met two of the criteria.

A further indicator of the appropriateness of various models is how they have been used in previous experimental work, since this can reveal the advantages and drawbacks of using a specific model. In addition to this, Coffield et al. point out that it is important to take into consideration whether the learning models are likely to be used for either commercial or academic purposes, so that the broad use of a model does not necessarily guarantee its reliability and validity for use in academic environments. What is more, models are characterised by their theoretical importance in the field, which can be reflected by their influence on other models.
Selection of the appropriate model should go further and take into account more specific features as well. Models that are strictly intended for academic environments are likely to be represented by questionnaires that are better applied in more practical academic areas, such as engineering. Therefore, they are likely to include questions that might not apply to all kinds of students. For instance, questions which are based on experiential learning such as “When solving a problem do you have to study each part of it in detail?” will be better addressed to students of the Department of Mathematics than students of the Department of Political Studies. As a result, it is necessary to take into consideration the type of learners who will take part in a learning task, when choosing an appropriate learning model and its questionnaire.

The above criteria can be well summarised in a top-down approach towards the procedure of choosing the appropriate learning model, which is demonstrated in Figure 2.4.

![Figure 2.4: The four-level procedure of choosing an appropriate learning model](image-url)
The procedure consists of four levels, which become less generalised as someone moves from the first level down to the fourth level. As a result, the closer to the fourth level the procedure moves to, the more important the criteria become. For instance, evaluating a learning model for being theoretically important in its field is a complex procedure that requires a thorough scan of most of the learning models that belong to the same area and involves a subjective evaluation of which will be superior. Being a leading model in a field, in terms of general acceptance by other researchers and of being introduced earlier compared to other learning models, is usually a good indicator of superiority. Decisions on the reliability and theoretical importance of a model are part of Levels One and Two. On the other hand, Level Three and especially Level Four deal with the learning style questionnaire that represents a learning model and, therefore, they are more straightforward. It is crucial that a learning model, and by extension its learning style questionnaire, is suitable to be applied firstly to the academic field within which a learning task is carried out (for instance examining the learning styles of undergraduate students in the department of Chemistry) and secondly to important features that are part of the learning task (for instance a certain time limit upon which the learning style inventory should be filled in). Thus, the procedure of choosing the appropriate learning model becomes more definite in the last two levels.

In general, these four levels can be divided into two categories. Firstly, there are levels that strictly refer to the learning style model or its corresponding inventory. These are Level One, which refers to learning models, and Level Four, which refers to learning style questionnaires. Between these levels, Level Two and Three refer to both models and questionnaires. For instance, Level Two examines if a learning model has been repeatedly selected by other researchers, which obviously implies that they have used its corresponding questionnaire for the learning tasks of their research. Level Three examines if the learning theory of a model is likely to apply for a certain type of learners, which implies that its questionnaire consists of questions that are meant to be answered by this particular type.
2.5 Felder-Silverman learning style model

The learning style model that will be used within this experimental work is the Felder-Silverman model and the inventory that corresponds to this model is the Felder-Soloman learning style inventory.

Initially, the model was based on five bi-polar dimensions (Felder and Silverman, 1988; Felder, 1993).

- Processing, with poles active – reflective.
- Perception, with poles sensing – intuitive.
- Input, with poles visual – verbal.
- Understanding, with poles sequential – global.
- Organisation, with poles inductive – deductive.

Later the fifth dimension, named as organisation, was abandoned, because Felder’s model does not recognise any difference between inductive and deductive students. Based on the classification of learning style models made by Coffield et al. (2004), the Felder and Silverman model considers learning styles as flexibly stable learning preferences. The model has been influenced originally by the learning style model of Kolb, which is verified by their classification in the same category. Furthermore, many models are influenced by other major models, in terms of design and construction (Coffield et al., 2004). The close relationship between the two models is demonstrated in Figure 2.5 (Kovacic, 2004). In the figure, it is seen that there is a matching between the poles sensing–intuitive of the dimension of Perception in the Felder–Silverman model with the corresponding dimension in the Kolb model, and, in addition to this, a matching between the poles active-reflective of the dimension of Processing in the Felder-Silverman model with the corresponding dimension in the Kolb model.
The Felder-Silverman learning model (Felder and Silverman, 1988; Felder, 1993) has been chosen to be used in experiments as a result of using the procedure above and because it meets a number of important requirements:

- Firstly, the model belongs to the elite of learning models, being frequently used by many researchers in their learning tasks (De Vita, 2001; Fowler, McGill, Armarego and Allen, 2002; Kolari and Savander-Ranne, 2002; Montgomery, 1995; Paredes and Rodriguez, 2002; Zywno, 2003; Zywno and Waalen, 2002). Being influenced by Kolb’s learning theory, which has played an important role in the design of learning style models, the Felder-Silverman model is considered as theoretically important in the field of practical learning fields, for which it is intended for.

- Secondly, it has been used in related experimental work (e.g. Alty, 2002; Beacham, Elliott, Alty and Al-Sharrah, 2002; Alty, Al-Sharrah and Beacham, 2003; Beacham and Alty, 2006) and statistical analysis in that work showed that particular learning styles that were identified using the Felder-Soloman questionnaire did significantly affect the performance of participants. This fact,
together with the excellent validation results that the questionnaire has received (Zywno, 2003), have supported the reliability of the model and its learning style questionnaire.

- Thirdly, the questionnaire has been effectively used in engineering education (Felder, 1996). However, its design safely allows its use by learners of theoretical studies as well. This is very important, because participants in the experimental work of this thesis are people from various academic backgrounds, either from a theoretical or practical background. The questions are based on general learning experiences, which, in some cases, examine if learners prefer theoretical or practical thinking, for instance, concepts and ideas against facts and data.

The suitability of a learning style questionnaire can be also determined by factors, which are requirements usually related to the nature of the learning task. The factors that influenced this decision to choose the Felder-Soloman questionnaire were:

- It should be a test that must be completed in a reasonable time.
- It should be a test that is aimed at adults (not children).
- It should be a test that is easy to take with minimal instruction.
- It should be a test that is pleasant and informative for those who take the test.

Furthermore, the test needs to be completed just before the experiment starts, thus requiring minimal mental effort to be wasted by participants, so that their participation in the main part of the experiment, in terms of motive and interest, is not affected. This also makes it possible for participants to complete the test on-line by email. In addition to this, the subjects of the experiments in this thesis will be university students and staff. This justifies the necessity of choosing a learning style test that is designed for adults. Based on the short time limits within which the test should be completed, it is necessary that the test is simple to complete, without the need for giving extensive instructions to the learners regarding any special method of completing the test and measuring their learning style. Also, the content of the test should enable learners to take it seriously, enjoy it, and realise the learning benefits of completing it, without it being a boring procedure.
The average duration of completing the Felder-Soloman test is around ten minutes. It is a test that is intended for people whose learning experience includes at least undergraduate studies. The test consists of multiple-choice questions that include two possible answers. The final score upon which the learning style is determined is easy to calculate. Finally, the type of questions which are included in the test refer to learning and life experiences of people, which makes it a pleasant and informative procedure.

The test has also been used by many other researchers. As part of his research on learning and teaching styles, Kovacic justified his choice of the Felder-Soloman test by writing:

"Firstly, it covers all four learning styles dimensions and is based on a sound theoretical model. Secondly, the instrument has been widely tested and used successfully in helping to guide the design, development and use of effective learning environments. Thirdly, this instrument is simple to use and the results obtained from this study are easy to interpret and can be applied easily" (Kovacic, 2004).

2.5.1 The Felder-Soloman learning style inventory

Depending on the bi-polar dimensions that form the Felder-Silverman model, an instance of a learning style originating from answering the questions included in the Felder-Soloman test could be an active/reflective, intuitive/sensing, visual/verbal and sequential/global learner, featuring one pole from each dimension of the learning model. The Felder-Soloman learning style inventory is better known as the Index of Learning Styles (ILS). The test was designed by Richard Felder and Barbara Soloman (Felder and Soloman, 1999).

ILS is a test consisting of 44 questions that have been designed based on the experiential learning theory that is included in the learning model of Felder-Silverman. Each question belongs to one of the four dimensions of the Felder-Silverman model, thus there are 11 questions for each dimension. Questions are accompanied by double-choice answers, each one related to one of the two poles that form a specific dimension. Whenever a learner chooses one answer, the corresponding pole is credited with one point. Felder's
questionnaire forces participants to make a choice between the two pole options. An alternative would have been to offer 'don't know' or 'neither of these two' options. However, this would lead to a very broad spread of results. The fact that there are eleven questions for each dimension allows for marginal errors.

An instance of a question belonging to the dimension of Processing is the one below:

- I understand something better after I
  (a) try it out.
  (b) think it through.

Choosing (a) to be the answer to the question gives one point to the pole of Active, otherwise, choosing (b) as the answer, gives one point to the pole of Reflective. An instance of a question belonging to the dimension of Perception is the one below:

- I would rather be considered
  (a) realistic.
  (b) innovative.

Answering (a) gives one point to the pole of Sensing, whereas answering (b) gives one point to the pole of Intuitive. An instance of an Input question is the one below:

- When I think about what I did yesterday, I am most likely to get
  (a) a picture.
  (b) words.

Similarly, answering (a) gives one point to the Visual pole, whereas (b) gives one point to the Verbal pole. Finally, an instance referring to the Understanding dimension is represented by the question below:

- Once I understand
  (a) all the parts, I understand the whole thing.
  (b) the whole thing, I see how the parts fit.
The (a) answer gives one point to the Sequential pole, whereas the (b) answer gives one point to the Global pole.

The last part of ILS consists of the scoring sheet, where learners have the opportunity to discover their learning style, depending on the answers that they gave to each question. The mechanism is quite simple and it is easy for learners themselves to understand it and reach the final results. Learners write down in the scoring sheet all the points that each pole was credited. One half of the poles (Active, Sensing, Visual, Sequential) are credited by (a) answers which are given to questions belonging to their dimension, whereas the rest of them (Reflective, Intuitive, Verbal, Global) are credited by (b) answers which are given to questions belonging to their dimension. For each dimension the procedure is the same. For all 11 questions of each dimension learners add the points given to (a) and (b) answers, and, in the end, they calculate the difference between them (they can never be even, due to the odd number of questions per dimension). Therefore, results will favour either (a) or (b) answers, and, based on the size of each difference, learners are likely to have a mild preference (1a-3a or 1b-3b), which is basically translated as being well balanced, have a moderate preference (5a-7a or 5b-7b) or have a strong preference for one of the two poles of each dimension (9a-11a or 9b-11b). For instance, if results for each dimension are 1a, 3b, 9a, 7b, then learner is found to have a mild preference for being active and intuitive, whereas he/she has a strong preference for being visual and a moderate preference for being global, taking into account that the sequence of the four dimensions in the scoring sheet of ILS is: Processing, Perception, Input, Understanding.

The whole Index of Learning Styles test can be viewed in Appendix A.

### 2.5.2 Distribution of learning styles across subjects

When it comes to multimedia learning where participants in experiments are divided into certain groups which experience different media combinations, it is essential that within these groups there is a kind of balance between students with different learning styles. Obviously, it is not likely to achieve a balance across groups for all four dimensions of the Felder-Silverman learning model. Past results on students' learning styles (using the Felder-Soloman test) are shown in Table 2.2 (taken by Kovacic (2004) and adding the
results of Alty et al.) which summarises the results of various research that has been carried out on learning styles of students, based on the Felder-Soloman test.

Table 2.2: Results of various research on learning styles

<table>
<thead>
<tr>
<th>Research</th>
<th>Dimension of Processing</th>
<th>Dimension of Perception</th>
<th>Dimension of Input</th>
<th>Dimension of Understanding</th>
<th>Number of participants</th>
<th>Educational background</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alty et al. (2003)</td>
<td>Active: 75%</td>
<td>Sensing: 64%</td>
<td>Visual: 89%</td>
<td>Sequential: 66%</td>
<td>44</td>
<td>Computer Science</td>
</tr>
</tbody>
</table>

The distribution of learning styles varies, depending on the academic background of students and the number of students who filled in the test. The results included in Table 2.2 show a tendency of the dimensions of Processing and Perception to provide with balanced numbers between active and reflective and between sensing and intuitive learners, respectively. As far as the other dimensions are concerned, Understanding is less balanced, whereas Input is clearly dominated by visual learners. Since previous research (Alty, 2002; Alty, Al-Sharrah and Beacham, 2003) has shown that sensing and intuitive learners significantly differ in their learning performance, when it comes to the effects of various media combinations on learning, this suggests that groups should be balanced between these two types of learners (as far as this research is concerned).

2.6 Learning styles of participants in the two experiments of the thesis

All participants in the experiments carried out in this thesis will therefore be required to complete the Felder-Soloman (ILS) questionnaire before starting the real part of the experiment. Groups of participants will be formed according to their results on the ILS
test, and the experimental groups will be balanced, as far as practicable, between these two types of learner. A carefully balanced experiment between sensing and intuitive learners will enable a valid analysis of their learning performance in each group to be made, in order to identify any effects that different media combinations or the type of learning task itself have on these learners.
Chapter 3  Theories about memory

3.1 Introduction

Learning, as a research area, is part of cognitive science, a specialised field of psychology. Cognitive science started to develop in the late 1960s. It followed chronologically from the development of behaviourism and attempted to emphasise cognitive processes, in contrast to behaviourism, which attempted to explain learning without making use of mental processes, depending only on human responses. Thus, cognitive science examines issues such as perception, memory, attention, problem solving and the application of cognitive processes to instructional design (Saettler, 1990).

One of the main goals of this field of psychology is to explore knowledge in its most general sense, that is, to analyse the structure of knowledge and understand its role in various learning tasks (Dabbagh, 1999). To assist in realising this goal, computers were initially used to represent the processes of the mind in concrete terms of inputs and outputs. The use of computers in cognitive science, according to Driscoll (1994), led to the development of Cognitive Information Processing (CIP) theory, which describes the structure of the components of the mind for processing information and the procedures for activating those components (Dabbagh, 1999). Furthermore, it suggests that effective instruction, in terms of learning, should focus on the prior knowledge of the learner, so that the learner can relate new information to information he/she already knows. The CIP theory led to the development of many memory models which attempted to explain the “component processes by which knowledge is (1) coded or represented, (2) stored, (3) retrieved or accessed, and (4) incorporated or integrated with previously stored information” (Saettler, 1990, p.323).

Theories, that form research on memory behaviour, are restricted in producing predictions (rather than rules or mathematical formulas), because there is no absolute way to define the functions of human memory. Experimentation that examines the cognitive behaviour of learners is the main path that researchers of cognitive science use to construct possible models of function and architecture of human memory. Further
experiments are used to support these suggestions, wholly or partially, leading to the
development of new models, or to identify limitations in existing models.

One memory model is the dual-coding model, which was developed by Paivio in 1971. The model is based on Dual Coding Theory (Paivio, 1971; 1986). The theory is an outcome of extended research by Paivio on the structure of human memory and the way it functions. The suggestions of the dual-coding model have been a constant subject of discussions. The empirical work reported in this thesis depends heavily on the suggestions of Dual Coding Theory, so a description of the basic features of the theory will be given.

3.2 Dual Coding Theory

The basis of Dual Coding Theory is the conceptual-peg hypothesis of word and imagery effects in memory and, as an extension, in knowledge. This hypothesis suggests the existence of cognitive processes, which became the basic assumptions of the theory (Paivio, 1986).

The basic assumption of the theory refers to the existence of two modality-specific symbolic systems, the verbal and the nonverbal system (or ‘imagery’ system as it is also called by Paivio), which “are experientially derived and differentially specialised for representing and processing information concerning nonverbal objects, events and language” (Paivio, 1986, p.55). This is regarded by Paivio as the general empiricist assumption of the theory. What is more, the two systems serve cognition and, since they are derived from experience, the processes and functions (taking place within or between them) are influenced in a great extent by experience.

Dual Coding Theory makes a distinction between symbolic systems and sensory-motor systems, and assumes that there is an orthogonal relation between them. As it is declared in the empirical assumption of the theory, internal representations retain modality distinctions. Thus, the term ‘orthogonal relation’ implies here that a retained modality of a verbal or nonverbal representation is related to one of the five modalities in the sensory-motor system. For instance, information presented by the two systems can come in
modalities such as visual (printed words versus visual objects), auditory (spoken words versus environmental sounds) and haptic (tactual and motor feedback from writing versus manipulation of objects). However, the orthogonal pattern is not totally complete, because modalities such as gustatory, olfactory and affective can only be nonverbal, since there are not linguistic symbols that could be constructed from tastes, smells, or emotional experiences (Paivio, 1986).

The above leads us to the theory’s guiding theoretical assumption, which says that “internal (mental) representations have their development origin in perceptual, motor and affective experience and that they retain those experientially derived characteristics so that representational structures and processes are modally specific rather than amodal” (Paivio, 1986, p.55). For instance, for a visually impaired person, the word ‘dog’, will be internally distinguished between its aural modality (if the person heard the word ‘dog’) and its haptic modality (if the person used the Braille system to read the word).

According to Paivio, “human cognition is unique in that it has become specialised for dealing simultaneously with language and with nonverbal objects and events. Moreover, the language is peculiar in that it deals directly with linguistic input and output (in the form of speech and writing) while at the same time serving a symbolic function with respect to nonverbal objects, events and behaviours. Any representational theory must represent this dual functionality” (Paivio, 1986, p.53). This is, perhaps, the most important statement of Paivio, in terms of describing the theory. Dual Coding Theory is based on the above quality of human cognition, not only by dividing memory into two symbolic systems, but by identifying within them characteristics that contribute in learning, as well. These characteristics basically include the structure of the two systems, which allows them to function independently and simultaneously.

Paivio refers to the nonverbal system as ‘imagery system’, because its basic functions include the analysis of scenes and the generation of mental images. The verbal system deals with representations, such as auditory, visual words and writing patterns of these words (Ryu et al., 2000).

Dual Coding Theory has a hierarchical conceptual structure. At the most general level, the theory is about symbolic systems, that is, cognitive systems that serve a symbolic or
representational function. The general level divides into verbal and nonverbal symbolic subsystems, which in turn expand into sensory-motor (visual, auditory, haptic) subsystems at the next level. The lowest level consists of the hypothetical representational units of each system, called logogens and imagens.

3.2.1 Unit-level assumptions

Figure 3.1 (Paivio, 1986) summarises the structures of both symbolic systems, showing all types of connections, which can exist within and between the two systems, along with those between the two systems and the sensory system, which connects with the outside world.

Figure 3.1: The dual-coding model

The logogens and the imagens are the representational units that form the lowest level of Dual Coding Theory's conceptual hierarchy. This level is basically described by three interrelated assumptions regarding imagens and logogens. First of all, the representational
units in each system are modality-specific, perceptual-motor analogues. This derives from the fact that symbolic representations are assumed to retain their modality, as it has been already discussed.

The second assumption suggests that units are hierarchically organised structures. Hierarchy among logogens is based on grammar rules, whereas, in imagens, it is based on object categories, for instance 'animals'. However, object categories can influence the hierarchy of logogens too. This is not the case for imagens, assuming that grammar rules could play a role in the structure of the imagens' hierarchy, although it could be argued that 'vivid' adjectives and verbs can cause the generation of mental images.

In addition to this, according to the third assumption, functional structure between units differs so that component information in higher-order nonverbal units is synchronously organised, a fact that permits parallel processing up to some information limit, whereas verbal components are sequentially organised (implying sequential constraints on processing between units). Sequential and synchronous processing in logogens and imagens respectively is the most important difference between the two classes of units. The structure of logogens and imagens influences the whole structure and the functions of the two symbolic systems.

The sequence in which verbal representations are accessed is constrained by grammar rules as it is mentioned in the second assumption, for instance first comes the subject, then the verb and the object of the sentence. Furthermore, Chan Lin (1994) supported the synchronous and sequential processing of imagens and logogens respectively through the example of recalling a face. If the visual process is followed, then the face is perceived at once as a whole that consists of distinctive sub-elements (eyes, nose, and mouth). A verbal process, on the other hand, requires a sequential approach of all sub-elements individually. Another striking example of sequential processing in logogens is the alphabet. People are able to process the alphabet sequentially from the first letter to the last one, but they face major difficulties doing the same task backwards, that is moving from the last towards the first letter of the alphabet.

As far as the terms 'logogens' and 'imagens' are concerned, these might cause misunderstanding, as it might be implied that they describe fixed entities, which
correspond to static objects and words. However, Dual Coding Theory considers the role
of these units to be more flexible rather than fixed, which enables the internal
representations to be distinguished from the corresponding verbal (visual and auditory
words) and nonverbal (images, objects, events and emotions) entities. What is misleading
too is the term ‘unit’, which implies a discrete entity of fixed size and character. Imagens
and logogens “are assumed to vary in size but they are nonetheless unitary in the sense
that they can function as integrated information structures or response generators for
some purposes. This is a kind of componential approach in which the components are
concrete, modality-specific entities that can also combine to form more complex entities”

3.2.2 System-level assumptions

There are a number of basic assumptions, regarding the construction and the functions of
the two symbolic systems, which are considered as the core of the theory.

- The functional independence but interconnectedness of the two systems
- The probabilistic nature of inter-unit relations between and within systems
- Processing mechanisms and different levels of processing (representational,
  referential, associative) within and between systems
- Differential specialisation for synchronous and sequential inter-unit processing
  within systems
- Automatic and conscious processing in both systems

These assumptions are analysed in the following sections.

3.2.2.1 Relations between the two symbolic systems

In Dual Coding Theory, the assumption regarding the independence and
interconnectedness of the two systems is the most important one. The two systems are
independent in the sense that each system can be active without the other being active. In
addition to this, both systems can be active in parallel. However, the preferred view used by Dual Coding Theory proponents is that one system makes the other system become active, instead of information flowing from one system to the other. The fact that one system is activated by the other implies interconnectedness, which is incomplete or partial in the sense that the pathways, which connect the two systems, are only available between certain representations in each system. As a result, picture naming is not done automatically and, similarly, concrete nouns or descriptions need not be corresponded to certain images. Due to this structural and functional relation between the two systems, they can act independently and additively in processing information (Paivio, 1986).

Information processed through both systems causes an additive effect on recall (Mayer and Anderson, 1991; Paivio and Csapo, 1973). In one of his studies, Paivio (1975) presented participants with a series of pictures, a series of words and a combination of pictures and words. Results showed that people recalled more items that were presented successively as a picture-word combination, than as words alone or pictures alone.

The additivity hypothesis was proposed by Paivio (1967; 1991) to justify the superiority of concrete words over abstract words (Paivio, 1963; 1965; 1967) and the image superiority effect (Nelson, Reed and Walling, 1976; Paivio, Rogers, and Smythe, 1968). In addition to this, Paivio and Csapo (1973) presented participants with words and pictures and asked them to name or generate images. During this procedure, participants were unexpectedly asked to recall words or the names of the pictures that had been previously presented to them. Recalling words was doubled when these were related to image generation, compared to words that were just pronounced. What is more, words related to image generation were recalled almost as well as named picture. In another case, concreteness of the paired associates, allowed participants to integrate the two items into one image (Paivio and Foth, 1970; Rowe and Paivio, 1971).

Moreover, as far as image superiority is concerned, Paivio (1975) presented participants with a number of words and pictures and found out that recalling of images was better than recalling of words. Pictures are more likely to evoke mental representations stored in both verbal and non-verbal systems than words (Dabbagh, 1999). This superiority of images over words was initially related to the ability of images to access meaning faster.
than words (Nelson, 1979; Smith and Magee, 1980). Rieber (1994) moved on further and supported image superiority in terms of the ability of image representation to be processed concurrently, hence the faster access, instead of the sequential process of verbal representations.

The connection between two representations in the verbal and the imagery system is not necessarily one-to-one, but it can be one-to-many as well, in both directions. For example, the word table might evoke the image of many tables (image representations) stored in the imagery system. Similarly, a picture of a table might evoke many words (verbal representations) stored in the verbal system. The exact image or description, which is going to be evoked, depends on two factors: (a) the stimulus context and (b) the function strength of the different interconnections between the two systems (Paivio, 1986).

In general, the assumption about the interconnectedness of the two systems serves the dual-coding model, as far as concrete and discrete objects are concerned. Their names or attributes can be internally related to the object quickly and reliably. However, this cannot be claimed for verbal representations, which refer to abstract nouns. There are many factors that play a major role in how abstract nouns can be related to an imagery representation, such as previous experience and personal characteristics.

3.2.2.2 Relations within the two symbolic systems

Within the two symbolic systems, the verbal system is assumed to have an associative structure, as far as its representational units and its processes are concerned. This means that words and their context, which act as a stimulus, evoke logogens in the verbal system, which in turn are related to other logogens. Furthermore, there is a hierarchy, which usually describes this association. For example, the word ‘animal’ can act as a category and it can be related to the instances of this category, such as the word ‘cat’. These hierarchies are regarded as linguistic, meaning that the represented words, which act as a category, refer to verbal objects. “The dual coding analysis goes beyond the purely verbal-associative accounts of language phenomena” (Paivio, 1986, p. 65).
The imagery system, on the other hand, cannot be described, in terms of structure, in the same way as the verbal system. The imagens reflect in a way our knowledge of the world. This knowledge is characterised by continuity. This means that one sees a picture in his/her mind as a whole object and each part of which can be seen and analysed separately from the whole object. For example, we can imagine a scene as a whole, but it is possible to imagine the mountains as a separate object, which is part of the scenery and, what is more, extend the imagery to a broader setting (Paivio, 1986).

Interestingly, we can imagine places we have never been before, but due to the knowledge of world, there are features that let us build an 'imaginary representation' of these places. This fact reveals a relation of verbal and imagery system, hence a relation of logogens to imagens. An example, which can also support this relation, is the fact that questions about our house, our country or a familiar person, evoke the corresponding images. The related images are activated as a result of processing mechanisms taking place within the two symbolic systems (Paivio, 1986). These mechanisms are going to be discussed in the following section.

3.2.2.3 Processing operations

This section deals with the functional properties of the two representational systems that enable the use of the appropriate representational information in cognitive tasks or overall behaviour. These properties consist of processing mechanisms, which are 'responsible' for activating and retrieving information from the two representational systems, either in direct or indirect way (Paivio, 1986). These mechanisms are supposed to take place at the unit level (Ryu et al., 2000).

Activation of representations. Internal representations are often thought of as mental models (Glenberg and Langston, 1992). The overall probability of activating verbal and nonverbal representations basically depends on two major factors: the stimulus variables and the differential individual variables. As far as the stimulus variables are concerned, these can be identified as the attributes of the target stimuli (i.e. verbal or nonverbal, concrete or abstract etc.) and the contextual stimuli, such as the instructions of a task (Ryu et al., 2000).
According to empirical studies, activation of nonverbal representations is highly dependent on the concreteness and the image-arousing value of words and images. Naturally, these values are higher in images than in words and in concrete words than in abstract words (Paivio, 1986).

On the other hand, verbal representations are activated by different means. First of all, appropriate words can evoke verbal representations. They can also be activated by tasks that involve word processing. Finally, another way to activate verbal representations is to deal with a task that should be carried out verbally (Paivio, 1986).

To summarise, it can be concluded that mental representations, verbal or nonverbal, can be aroused by appropriate stimuli, either by its attributes or by instructions and other contextual stimuli, and by different individual variables, such as prior knowledge. It is important to know how mental representations can be activated, and obviously used to construct response in terms of behaviour or knowledge, especially in tasks such as problem solving.

**Different levels of processing within and between systems.** According to Paivio, there are three types of processing, within and between the two representational systems: representational, referential and associative (Paivio, 1986).

Representational processing involves direct activation of logogens and imagens by verbal and nonverbal stimuli respectively. For example, the word ‘cat’ activates the corresponding verbal representation, whereas the image of a cat activates the corresponding nonverbal representation.

Referential processing involves indirect activation of logogens (internal representation of the word ‘cat’) by nonverbal stimuli (image of a cat) and imagens (internal representation of the image of a cat) by verbal stimuli (the word ‘cat’). The activation is indirect because, in the first place, the nonverbal stimulus activates initially an imagen (representational processing), which, in turn, activates a logogen (referential processing). Similarly, the verbal stimulus activates a logogen (representational processing), which, in turn, activates an imagen (referential processing).
Associative processing is about activations occurring within the two systems. Thus, a verbal representation evokes another verbal representation within the verbal system, and a nonverbal representation evokes another nonverbal representation within the nonverbal system. In this type of processing, mental representations are related in terms of category-relationship. Especially in the verbal system, relationships are constructed in terms of grammar rules as well. For instance the logogen of the word ‘animal’ can be related to the logogen of the word ‘cat’ and this, in turn, can be related to the logogen of the word ‘dog’. The functions taking place in the nonverbal system, regarding associative processing, are similar.

During a task, one, two, or all three levels of processing may be involved in the accomplishment, in order to achieve good perception of stimuli and retrieval and use of prior knowledge. Picture recognition requires representational processing. Picture naming requires both representational and referential processing. Furthermore, when we are asked to associate a word to what we see in a picture, for instance a house door, then, through representational processing, we activate the corresponding nonverbal representation of a ‘house door’. Then, through associative processing, another nonverbal representation is activated, for instance the representation of a ‘house window’ (probably belonging to the category ‘house’). Finally, through referential processing the verbal representation of the word ‘window’ is activated. The sequence of the processing levels might be different, depending on different individual experience.

3.2.2.4 Organisational and transformational processes

According to Paivio, organisation of memory can be interpreted in terms of structure or process. The idea of structural organisation suggests the existence of semantic memory structures and schemata, according to which information is organised, so that it can be semantically retrieved, when necessary. On the other hand, processing organisation suggests that memory retrieves information without affecting the storage structure (Paivio, 1986). What supports this suggestion is that it is quite certain that there must be a kind of constructing process within the verbal system, as far as input is concerned. What is more, language behaviour implies a processing mechanism in output as well.
The organisation of the two memories, verbal and nonverbal, is different, following the different structure of the representational units in the two systems. Consequently, verbal memory is organised in a sequential basis, whereas nonverbal memory is organised in a synchronous basis.

Another system-level assumption of Dual Coding Theory suggests the theoretical process of transforming representational information. According to this assumption, we are capable of handling symbolic information in an active manner, so that we can transform it. Transformation of information is done in different ways in the two systems, depending on the constraints associated with verbal and nonverbal representations. The nonverbal system is a more efficient transforming system (Paivio, 1986).

The verbal system is characterised by sequential structure of information. Thus, transformations can take place in terms of changes in temporal order or substitution of verbal units with others, which occupy a specific place in time. These sequential changes could mean a simple reordering in a list of words or syntactical changes.

The nonverbal system, on the other hand, is characterised by synchronous structure and this allows transformations at a broader level. There can be spatial transformations as well as transformation of sensory properties of information units.

3.2.2.5 Automatic and conscious level processing in both systems

Paivio claims that consciousness has more than one meaning within Dual Coding Theory. On the one hand, consciousness aids mental images and verbal processes in being internally experienced. On the other hand, however, Paivio argues that consciousness itself can help to distinguish verbal and nonverbal systems from one another, but it does not reveal any substantial clues concerning the functional differences of the two systems (Paivio, 1986). Research showed that distinction for the systems should be based on evidence of independent behaviour, whereas functional characteristics can be identified through “performance under experimentally controlled conditions” (Paivio, 1986, p.73).
3.3 Effects of Dual Coding Theory on text comprehension and recall

Many studies have been carried out on the effects of added pictures within a text. According to Dual Coding Theory, the presence of images within a text causes an additive effect on recall. Part of these studies refer to the principles of Dual Coding Theory as a theoretical basis for the results, whereas other studies report the positive effects of pictures in text comprehension and recall, without making any references to the theory.

In a study with children, Levie and Lentz (1982) found that when text is accompanied by pictures that are related to the textual content, it is learned better compared to its text alone form. They also calculated that children that read the illustrated text learned approximately one third more than those that read the plain text.

Peeck (1974) asked Fourth-grade children to read a story with or without illustrations. He then carried out a learning test, consisting of multiple-choice questions and verbal recognition tests. The results showed that retention was higher in children that read the illustrated story.

Dual-coding effects were recorded in texts that contained assembly instructions as well (Stone and Glock, 1981). College students that read instructions accompanied by illustrations describing the assembly procedure, made fewer errors in construction tasks than those who read the text-only version. What is more, dual-coding is likely to help people learn spatial information (Dwyer, 1967; 1978; Garrison, 1978).

Dual Coding Theory does not only account for effects caused when text is accompanied by pictures, but when it stands alone as well. Textual content is likely to create image representations that help readers recall information. In two studies, Sadoski (1983; 1985) had Third-, Fourth- and Fifth-grade students read aloud stories, carrying out several recall and comprehension tasks afterwards. One of the tasks involved reporting any mental images that the students experienced during reading the story. In the study of 1983 the story was illustrated, whereas in the 1985 study it was not. The results showed that students who read the story without illustrations reported more images, than those who read the illustrated one. Students who read the illustrated story did not distinguish mental images from text illustrations. The results also showed that in both studies imagery was
related to total recall and deeper levels of comprehension, such as identifying the theme of the story.

In another study (Sadoski et al., 1990), college students read a 2,100-word story and were asked to inform of any imagery reports immediately and after two days. The results showed that imagery reports were well recalled even after two days, whereas verbal recalls diminished after the delay. Other studies urged students to construct imagery of their own, sometimes providing them with instructional methods of imagery making, depending on the textual information of stories (Anderson and Kulhavy, 1972; Gambrell, 1982; Gambrell and Bales, 1986; Gambrell and Jawitz, 1993; Pressley, 1976; Steingart and Glock, 1979). In general, the results showed that imagery helped students recall and understand the content of a text. What is more, imagery is aided by concreteness of the textual content, since images are more likely to be evoked through concrete words (Anderson, 1974; Corkill, Glover and Bruning, 1988; Sadoski, Goetz and Fritz, 1993; Wharton, 1980), as has already been discussed.

Information provided through pictures should be relevant to the textual information, so that it can support text comprehension. When pictures play a ‘decorating’ role within a text, for instance for entertaining purposes, they do not serve the dual-coding model and therefore they do not improve text comprehension (Levie and Lentz, 1982; Sewell and Moore, 1980). Furthermore, Evans and Denney (1978) found that recalling short phrases, which were accompanied by pictures, improved as pictures were becoming more related to the phrases. Similarly, Bahrick and Gharrity (1976) found that captions helped people recall them when they were related to their accompanying pictures, but provided no recalling effects when these were unrelated. These studies show that the mere presence of illustrations within a text is not enough to aid learning. Pictures should support the information included in a text, so that they can construct referential connections between verbal and non-verbal representations (Paivio, 1971; 1991; Clark and Paivio, 1991), improving recalling and comprehension of textual information.

Improvements in learning by the coexistence of text and supporting images is related to the referential connections between verbal and nonverbal representations, as suggested by the dual-coding model, rather than the repetition of information. In studies carried out by
Levin, Bender, and Lesgold (1976) and Paivio and Csapo (1973), participants performed better in recall tests when they were presented with words and their corresponding pictures, than when words alone or pictures alone were presented to them twice.

Implications of the dual-coding principles are not only met in text comprehension tasks. Effects of the theory on cognitive tasks which are performed in computer-based environments will be discussed in the sections that involve multimedia learning.

**3.4 Evaluation of Dual Coding Theory**

For this thesis the dual-coding model should be evaluated in terms of problem solving, instructional design or other similar tasks within science. In this case, textual information usually involves abstract words used in scientific texts, such as 'hypothesis' or 'theory'. Taking into consideration the assumptions of the dual-coding model, abstract text will be better understood by inexperienced readers if it is accompanied by images, which support the meaning of the abstract words and sentences.

At a theoretical level, the dual-coding model appears to be a very useful tool for instructional design, since it helps memory to process efficiently information presented in more than one mode. This is an outcome of the assumption of the theory that the two systems are capable of being active either alone or in parallel. In addition to this, connection is available between the two systems, allowing the development of relations between their units.

These relations are enabled through a number of processes, which allow connectivity and further processing within and between systems. The variability of these processes makes the construction of connections between mental representations a flexible procedure that helps the recalling of words, images or events, according to the task and personal experience. Thus, a word can evoke a significant image or an image can evoke one or more words that can lead to the solution of a problem.

It is widely claimed that the ability to produce closely reasoned thoughts was a major factor that influenced human evolution. It is the logogens therefore (that is the memory's ability to produce verbal representations) that allow more abstract thoughts to take place.
Thus, words and logogens, in general, are superior to images and imagens, for abstract reasoning. However, for spatial reasoning, Dual Coding Theory suggests that there is image superiority over words. Paivio justifies this superiority on the ability of the nonverbal system to process an image at a synchronous level, meaning that a picture can be seen as a whole and analysis of its attributes can be made, whereas analysis of verbal information is restrained to a sequential level (which is advantageous in abstract reasoning). Dual Coding Theory also gives support to the well-known observed superiority of image recognition over verbal recognition. This image superiority can be used to support abstract reasoning and should be taken into consideration in instructional design.

It could be said that the use of images in instructional material has a double role. Firstly, they can have a complementary role in understanding complex text (such as those used in instructions, in a procedure's description, in a description of a task etc), by illuminating the parts of the text which are difficult to understand (for instance a diagram that shows numerical relations between two attributes, or an image that shows the flow of a procedure). Secondly, as mental representations, they can evoke all those verbal representations which are necessary to recall a textual description. Consequently, the selection of the appropriate images in a textual description is crucial, as it can lead to an efficient storage and, therefore, to a successful retrieval of information.

The theory has received criticism through a number of studies carried out by researchers at the same field. Criticism includes equal processing in time when recalling word pairs, picture pairs and mixed picture-word pairs (te Linde, 1982) and failure to prove superiority of concrete verbal material over abstract verbal material (Marschark and Paivio, 1977; Paivio, Walsh and Bons, 1994; Ryu et al., 2000). What is more, image superiority has been questioned for its validity, as better recalling of images compared to words is reduced if words are 'deeply' or 'imagery' encoded (Anderson, 1978), or, in other words, involving elaborative encoding. However, Paivio and Lambert (1981) asked bilingual subjects to write down the name of presented pictures in English and to translate concrete nouns from French to English. An unexpected free-recall test resulted in picture-generated words being recalled twice as good compared to translated words. Although it could be not definitely supposed that elaborative encoding was taking place when
translating words, it was then shown that translated words were remembered twice as good compared to simply copied English words, a fact that strengthened the findings of Paivio and Lambert's experiment.

Picture superiority is also questioned by propositional theory. The main principle of the theory suggests that visual information is transformed into a semantic form which is stored in Long-Term Memory (Rieber, 1994). Propositional theorists argue that picture superiority is not based on a dual-coding model, but it is due to the fact that people process images more fully than words, which "results in more propositional information ... when visual representations are provided than when information is given only in verbal form" (Rieber, 1994, p.114).

What is more, the dual-coding model has also been criticised by a number of studies which have shown that images are actually remembered by their meaning and not by their attributes (Driscoll, 1994), implying that words and images are stored in the same way within human memory. The above criticism has been supported by other researchers as well (Anderson and Bower, 1973; Norman and Rumelhart, 1975; Pylyshn, 1973), who challenged the concept of dual-coding by bringing forward the existence of a single, abstract memory.

Furthermore, the theory has received criticism on the fact that it does not take into consideration different abilities that people have. For instance, Simpson (1995) suggested that age is a factor that plays an important role in terms of determining the use of modalities, arguing that in young children information is usually processed visually.

Regardless of the criticism that Paivio's model has received, Dual Coding Theory is still valid and seems to be as relevant today as it was some thirty years ago, despite the advances of new technology and the changes in education (Paivio, 1991; Sadoski and Paivio, 2001). In general, the dual-coding model accounts for many memory processes and empirical research has supported the assumptions of the theory. The encouraging signs are that design in many fields, such as instructions, textual descriptions and problem solving is based on the additive effects on recall of having text accompanied by images, and this seems to improve knowledge acquisition, as research has demonstrated. Apart from text comprehension, suggestions of the dual-coding model have also been
applied in other situations as well, such as constructing mnemonic techniques in primary and secondary language learning (Atkinson, 1975; Atkinson and Raugh, 1975; Paivio, 1980) and on study skills (Clark and Paivio, 1991; Kulhavy and Kardash, 1988).

3.5 Cognitive Load Theory

Cognitive Load Theory has arisen out of the results of studies carried out within the field of cognitive science. The theory is based upon limitations in working memory.

3.5.1 Introduction

The dual-coding model is one of many models developed in the attempt to explain how human memory works, in order to find answers in crucial questions such as how knowledge is gained. Dual Coding Theory does not provide all the answers that will help multimedia designers to convey information as efficiently as possible. Dual Coding Theory indirectly proposes a way of dealing with the abstract information that is frequently encountered in scientific design, by supporting text or speech with images. However, it does not emphasise other limiting factors which affect memory. It is well-known that memory can be thought of as involving Short-Term Memory (STM) and Long-Term Memory (LTM). Short-Term Memory is now more commonly referred to as working memory (Baddeley and Hitch, 1974) in order to “reflect the change in emphasis from a holding store to the cognitive system’s processing engine” (Sweller, 2002). Miller (1956) identified some limitations of STM, for example its capacity is limited to 7+2 chunks of information. Cognitive Load Theory has been developed to take account of such limitations (Chandler and Sweller, 1991; Sweller, 1988; 1994; 1999; Sweller, van Merrienboer, and Paas, 1998).

Working memory, as its name implies, is that part of memory that processes and organises information received from the senses, from perceptual memory and from Long-Term Memory. According to Cooper (1998), working memory is “the vehicle which enables us to think (both logically and creatively), to solve problems and to be expressive”. Information can only be learned if it is first successfully processed in
working memory. Two of the most well known attributes of working memory are its extremely limited capacity (Miller, 1956), and its extremely limited duration (Peterson and Peterson, 1959). As a result of these limitations, it is difficult to absorb new information especially if it is complex or large in size. Effective instructional methods must respect these limitations or the learning experience may be affected. The only occasion when information in working memory is not affected by these limitations is when the information material originates from Long-Term Memory.

Long-Term Memory is that part of memory, where successfully processed information is stored. The two limitations applying to working memory, referring to its capacity and its duration, are taking effect when novel information is processed in a novel way (Sweller, 2002). Well-learned information is stored in Long-Term Memory, which suffers from neither of these two limitations (Ericsson and Kintsch, 1995). The capacity of Long-Term Memory is thought to be unlimited, allowing a massive quantity of knowledge, information and data to be stored and used through working memory, whenever this is necessary. When Long-Term Memory is connected to working memory we are conscious of its contents. Common experience suggests that Long-Term Memory information is not always accessible and is retained even in this case and may be rediscovered through appropriate stimuli presented to working memory. This characteristic of Long-Term Memory to hide its contents is a major reason why research on this part of the memory was limited (Sweller, 2002). Thus, a modal model of memory would look like the one illustrated in Figure 3.2 (Cooper, 1998). The model also includes the sensory memory which processes stimuli coming from our senses, for instance sights, sounds, smells, tastes and touches (Cooper, 1998).
Information in Long-Term Memory can be thought of as organised into schemas, a memory structure which has also been mentioned by Paivio (1986). A schema is a structure that contains information about facts organised into categories and processes which can be applied to those facts. For instance, numbers form one type of schema. Piaget (1928) and Bartlett (1932) carried out initial work that formed a basis for further research on the role of schemas within memory. As a consequence of this research, schemas became central in modern cognitive theory during the 1980s (Sweller, 2002). In addition to this, schemas are thought to play an important role in general problem solving and expert problem solving, based on the results of many research dealing with cognitive tasks (Chase and Simon, 1973; Chi, Glaser and Rees, 1982; De Groot, 1965; Gick and Holyoak, 1980; 1983; Larkin et al., 1980).
Schemas that aid in problem solving depend on relevant experience and once constructed, they become a valuable tool of knowledge. Human beings can replay schemas in their minds. Thus, schemas are thought to be an important factor in learning. What is more, the existence of such schemas forms a very important distinguishing feature that separates novices from experts in various fields. Schemas help experts to categorise problems and solve them more effectively (Cooper, 1990). Such schemas, on the other hand, are absent from the Long-Term Memory of novices. Due to this absence, novices are obliged to resort in general search techniques, such as trial-and-error, or means-ends analysis (Chi, Glaser and Rees, 1982; Larkin et al., 1980).

Apart from the existence of schemas within the Long-Term Memory of experts, it is believed that there is another fact that defines the difference between experts and novices in a problem-solving situation. This is the high level of automation, which can be demonstrated by experts (Cooper, 1998). Automation is defined as the ability to perform tasks without concentration (Cooper, 1998), and it is based on the construction of schemas. Thus, by continuous practice, learning can become automated, leading to processing of information that involves decreasing memory load (Sweller, 2002). Reading is a striking example that demonstrates the positive results of automation. Whereas in the beginning, letters and words are processed individually, after a period of practice this reading becomes an unconscious activity, which does not put any load on memory. Differences between conscious and automated processing, along with the beneficial results in problem solving by automation have been demonstrated by Schneider and Shiffrin (1977), Shiffrin and Schneider (1977) and Kotovsky, Hayes and Simon (1985).

### 3.5.2 The theory

Cognitive Load Theory is concerned with the role of working memory in the learning process. In addition to this, “cognitive load is the total amount of mental activity imposed on working memory at any instant in time” (Cooper, 1998). The basic proposal of the theory suggests that when this amount of mental activity exceeds some limits, then information cannot be absorbed properly, and this has negative results on the
accomplishment of any cognitive task. Cooper (1995) goes further and refers to the difference between novices and experts, which, as mentioned above, it is thought to be due to the existence of schemas in experts.

What is more, Cognitive Load Theory distinguishes effective instructional material from ineffective material, according to cognitive resources required. Instructions are thought of as being effective when they support the mental activities required for schema acquisition, and this facilitates information to be properly absorbed and ready for future use. Instructions that put an undue strain on cognitive resources and, therefore, inhibit the acquisition of schemas are regarded as ineffective. Instructional material that includes redundant information can cause working memory to overload and prevent it from processing any more information material.

Cooper (1998) divides cognitive load into intrinsic and extraneous, relating both of them to instructional design. Intrinsic cognitive load is due to the nature of the information itself, involving its complexity and difficulty to be learned. Intrinsic cognitive load cannot be affected and modified by instructional design. On the other hand, extraneous cognitive load is due to the instructional material used to present information to learners. Extraneous cognitive load can be modified by instructional design, for instance, presenting complex information through text and diagrams is likely to decrease extraneous cognitive load (compared to text-only presentation) and will facilitate learning.

Depending on the amount of intrinsic and extraneous load, there are three cases that are likely to occur during a learning task:

1. Intrinsic cognitive load is low (the information content is easy to understand), which means that mental resources are sufficient to enable a learner to learn, 'whatever' the amount of extraneous load, which depends on the instructional design used to present information. This is illustrated in Figure 3.3 (Cooper, 1998):
2. Both intrinsic and extraneous cognitive load are high, which means that information material is difficult to understand and the instructional design used to present this material does not facilitate learning. Consequently, total cognitive load exceeds mental resources and learning is very likely to fail. This is illustrated in Figure 3.4 (Cooper, 1998):

3. By reducing extraneous cognitive load, for instance by presenting information through a more effective instructional design, the total amount of cognitive load falls lower than the amount of available mental resources and learning can be achieved. This is illustrated in Figure 3.5 (Cooper, 1998):
The principles of Cognitive Load Theory can be summarised as follows (Cooper, 1998):

- Working memory is extremely limited.
- Long-Term Memory is basically unlimited.
- Learning is achieved when working memory is successfully engaged in the comprehension of instructional material, so that information can be efficiently encoded into Long-Term Memory. In other words, learning is accomplished only when information that is to be learned is finally stored in the Long-Term Memory.
- If the capacity of working memory is overloaded and, consequently, exceeded, learning will be ineffective.

3.5.3 Applying the theory

Much modern instructional design does result in a high cognitive load, which can lead to negative effects, in terms of learning. This has been already demonstrated by research on existing instructional techniques (Chandler, 1995; Kalyuga, 2000). What is more, research has shown that redesigning instructions by applying the rules generated by the assumptions of Cognitive Load Theory can enhance learning (Chandler, 1995; Mayer, 2001; Sweller, 2002). Finally, application of the theory has been reported to be especially beneficial when elements of complex information interact with one another (Cooper, 1998). Such information can really overload working memory, so methods based on the theory should be applied to help memory process and absorb more information.
Cognitive Load Theory is therefore concerned with enhancing learning by focusing on the attributes of working memory. The two most well-known attributes are those of limited capacity and duration. The theory predicts that learning will be enhanced if, during the procedure of learning, the working memory remains as little loaded as possible, allowing more information to be effectively processed and encoded into Long-Term Memory.

3.5.4 Instructional techniques based on Cognitive Load Theory

Cognitive Load Theory has been tested in research carried out on instructional design. The results reveal that the assumptions of the theory (regarding the working memory and its attributes) are empirically verifiable and a number of techniques have been identified which should inform instructional techniques (Cooper, 1998). These techniques are the following:

- The goal-free effect
- The worked-example effect
- The split-attention effect
- The modality effect
- The redundancy effect

3.5.4.1 The goal-free effect

The goal-free effect is a technique that is quite different from conventional problem solving approaches. Conventional problem solving requires a specific goal and a classical strategy of means-ends analysis. The solution begins with the goal and works backwards to the problem givens and then forward again to the goal (Cooper, 1998; Larkin et al., 1980). Cooper (1998) illustrates this with an example problem "given that \( x=y+3, \ y=z+1 \) and \( z=2 \), find the value of \( x \)". Finding the value of \( x \) is the goal of the problem and conventional problem solving would begin from this goal, that is \( x=y+3 \). Realising that it is necessary to find the value of \( y \), the solver would work backwards reaching the
problem given of \( z = 2 \). Going forward again, the solver would substitute the value of \( z \) to find \( y \) (\( y = 2 + 1 \)) and then find the value of \( x \). Although this is a very effective method for finding the answer, Cognitive Load Theory suggests that the technique causes high levels of memory load, which might be better used in time to solve the problem (Owen and Sweller, 1985; Sweller, 1988; Sweller and Levine, 1982). The memory overload is mainly caused by the fact that solvers have to focus their attention at the same time on many states, such as the current state, the goal state, differences between them, procedures to reduce those differences and any possible sub-goals that may lead to solution (Cooper, 1998). The goal-free approach, proposed by Cognitive Load Theory, suggests that problems should not impose a goal. So, once the problem givens have been listed, there should only be a statement such as "find what you can". In this case, the solver focuses on the only numerical data (\( z = 2 \)), which is the beginning of the problem's solution, and moves forward to find the value of \( x \). Thus, the solver avoids procedures (moving backwards from the goal to the numerical data in this instance), normally carried out in a conventional problem solving, thereby reducing the load on the memory. The goal-free effect has been suggested that it reduces the cognitive load and it aids learning (Owen and Sweller, 1985; Ayres, 1993). However, this technique is rather impractical for problems with large problem spaces, where there are more alternatives and problem givens.

3.5.4.2 The worked-example effect

Another technique proposed by the Cognitive Load Theory, which contrasts with conventional problem solving, is the worked-example effect. According to this effect, it is suggested that problem solvers should be provided with worked examples before dealing with real problems. Worked examples create schemas inside the Long-Term Memory, which reduce the load on working memory during problem solution (Cooper, 1998). Cognitive resources are only engaged to remember and recognise a worked example in order to solve a similar problem (Cooper, 1990; 1998). The approach creates a three-step procedure. Firstly, problem solvers identify the problem as being of a particular type. Secondly, they remember the steps that have to be followed in order to
solve this type of problem. Finally, problem solvers perform sequentially each step, until reaching the solution of the problem (Cooper, 1998). The worked-example effect is a technique that does not put unnecessary load on working memory and is suitable for problems with bigger state spaces (Cooper, 1998). The worked-example effect has been a very useful technique in solving problems belonging to the domain of mathematics (Cooper and Sweller, 1987; Zhu and Simon, 1987; Paas and van Merrienboer, 1994).

3.5.4.3 The split-attention effect

The split-attention effect is best explained with the following example. The solution to a problem of calculating an angle is presented to a student in two ways. The first one separates diagram with textual solution, as shown in Figure 3.6 (Sweller, 2002).

![Diagram](image)

\[
\begin{align*}
\text{Angle } ACB &= 180^\circ - \text{Angle } BAC - \text{Angle } ABC \\
\text{Angle } ACB &= 180^\circ - 85^\circ - 40^\circ \\
\text{Angle } ACB &= 55^\circ \\
\text{Angle DCE} &= \text{Angle } ACB = 55^\circ
\end{align*}
\]

Figure 3.6: One way of solving the problem of calculating an angle

The second solution integrates the diagram and the textual solution, by inserting the text in the appropriate places inside the diagram, as shown in Figure 3.7 (Sweller, 2002).
Neither the diagram nor the text can stand alone, but together they provide adequate information for the understanding of the problem's solution. In the first approach, the diagram and text are separated and the student has to split attention, between the different spatial position of pictorial and textual information. Normally, the student reads each step of the textual solution and then he/she attempts to find the correspondence between the text and the diagram. This causes the working memory to overload, since the student needs to keep the textual information in working memory, while examining the diagram. In the second approach however, where text is placed inside the diagram, the student does not have to search for the corresponding pictorial information contained in the diagram, since any textual information is directly related to the diagram. As a result the load on working memory is reduced and more cognitive resources are available for learning. In general, the split-attention effect suggests that when information is presented in diagrams and text, they should be physically integrated, so that the procedure of relating information of one type to another is done directly and with almost no searching. Examples of this effect have been identified in various instructional materials (Bobis, Sweller and Cooper, 1993; Cerpa, Chandler, and Sweller, 1996; Chandler and Sweller, 1992; 1996; Mayer and Anderson, 1991; 1992; Mwangi and Sweller, 1998; Sweller, et al., 1990; Tarmizi and Sweller, 1988; Ward and Sweller, 1990) and alternative instructional design has been suggested in most cases.
3.5.4.4 The modality effect

The modality effect is another instructional technique proposed by the Cognitive Load Theory. In all the previous effects, the basic intention was to try to reduce the cognitive load on working memory. According to the modality effect however, better results could be obtained if we increased the capacity of working memory by using dual modality in the presentation of information instead of a single one (Sweller, 2002). The technique is based on Dual Coding Theory. As it has been already discussed, the dual-coding model divides memory into two parts (or systems), one responsible for processing nonverbal information and the other for verbal processing. The modality effect suggests that instructional designers should utilise both verbal and nonverbal (diagrams, pictures, even animation) to represent and convey information. The information presented in these two formats should be supportive, meaning that the verbal information should support and explain nonverbal information and vice versa. Furthermore, instructions should respect the split attention effect as well, trying to keep verbal and nonverbal information strongly related, both mentally and physically. Thus, the information in total is processed by two cooperative systems, leading to a lower cognitive load and more efficient learning. Many cases of research have demonstrated the modality effect (Jeung, Chandler and Sweller, 1997; Mayer and Moreno, 1998; Moreno and Mayer, 1999; Mousavi, Low and Sweller, 1995; Tindall-Ford, Chandler and Sweller, 1997).

3.5.4.5 The redundancy effect

Both split attention and modality effects assume that both presentations of information cannot stand alone, meaning that, for example, neither a textual description nor a diagram can provide the learner with adequate information, when they are presented alone (so they have to co-exist in order to achieve their effect). When added verbal or nonverbal information does not provide increased knowledge and interferes with learning, then added information in the specific format is regarded as redundant (Sweller, 2002). For example, when a diagram describes fully and adequately a procedure (perhaps with the contribution of brief textual description embedded within the diagram), then adding the same information in textual format is redundant. Redundancy is not usually considered as
negative by many people, who assume that even if information is repeated, it cannot have a negative effect on learning. However, Cognitive Load Theory suggests that redundancy interferes with learning, because it causes a greater cognitive load on working memory, thereby wasting valuable cognitive resources and leading to poor levels of learning (Sweller, 2002).

Kalyuga (2000) has carried out a characteristic study that revealed the negative effects of redundancy. In this study, Kalyuga describes a task for students with no substantial experience on a topic that is presented in three different formats: a) diagrams and visual text, b) diagrams with auditory text and c) diagrams with visual and auditory text. In all three formats, the diagrams with visual and auditory text made students find the task more difficult and led them to poorer performances, demonstrating the negative effects that redundancy can have on learning. The redundancy effect which is caused by the co-existence of textual and auditory information (of identical content) has also been identified by other empirical work (Kalyuga, Chandler and Sweller, 1999; 2000; Mayer, Heiser and Lonn, 2001). What is more, Chandler and Sweller (1991) have suggested that when text and diagrams present the same information that is redundant and it is not supporting information presented in the other mode (for instance adding text that describes a self-explanatory diagram), then it is better to present information using only one mode, either text or diagrams. Furthermore, the redundancy effect is also met when, reading a tutorial on how to use a computer application (mental activity) is accompanied by physical activity when using the computer (Cerpa, Chandler and Sweller, 1996; Chandler and Sweller, 1996; Sweller and Chandler, 1994). In general, it is not advisable, in terms of instructional design, to include non-essential information within information material, because this is a typical example of redundancy that causes unnecessary cognitive load on working memory (Cooper, 1990).

3.5.4.6 The effects of element interactivity and imagination

Apart from the above five effects, Sweller also names two more, which are the element-interactivity effect and the imagination effect (Sweller, 2002). The element-interactivity effect suggests that the benefits of considering split attention, modality and redundancy
effects in instructional design can only be obtained when the instructional material is highly interactive, imposing a high cognitive load on memory. Unless the material is interactive enough, then instructions do not impose any important cognitive load on memory, and improvements in the design (from taking into account the effects of split attention, modality and redundancy) will not make a noticeable reduction in the cognitive load of working memory. In general, the element-interactivity effect is caused by the interaction between the effects of split attention, modality and redundancy and the complexity of the information material (which is measured by element-interactivity). Chandler and Sweller (1996), and Sweller and Chandler (1994) used high element interactivity (that is, complex) material, in order to demonstrate the split attention and redundancy effects, which, however, disappeared as soon as complex material was replaced by low element-interactivity material. Similar research (Tindall-Ford, Chandler, and Sweller, 1997) showed that the modality effect could be recorded only through the use of high element-interactivity material.

The imagination effect is closely connected to the existence of schemas. The conversion of a novice into an expertise initially involves continuous learning which will gradually include automation of the obtained schemas. This procedure is carried out until continuous studying of the material leads to the desired levels of performance. The imagination effect offers an alternative procedure by suggesting that learners should ‘imagine’ the procedures that have already been learned (the ‘imagination’ procedure takes place in working memory, which, in case the information material is complex, is impossible to be carried out by novice learners, due to the lack of schemas). Practising in ‘imagining’ the learned procedures, combined with the already obtained schemas, should aid in having automation (Sweller, 2002), which characterises an expertise. This effect has been demonstrated by Cooper et al. (2001) to be valid only on learners with adequate prior knowledge, since it had no influence on novice learners.

3.6 Evaluation of Cognitive Load Theory

In general, the Cognitive Load Theory emphasises the role of working memory, taking into consideration its attributes of limited capacity and retention. Instructional techniques
based on the instructional effects that follow from the theory have produced positive results when applied in real-life situations. The only technique that seems to have a limited application range is the goal-free effect, since it can help in solving small-spaced problems. A characteristic example from real life where Cognitive Load Theory could play a great role in improving performance is in computer instructions. Conventional computer-based instructions (for installing a software program for instance) require the trainees to read the manual and then follow the instructions on the computer screen. According to Chandler (1995), this will lead to an excessive amount of cognitive load on working memory, which in turn leads to a poor performance, especially in terms of total time to complete the task. Chandler suggests that Cognitive Load Theory should be applied by having integrated instructions placed on the computer screen and, therefore, being strongly related with the procedures that have to be done.

Cognitive Load Theory, like Dual Coding Theory, originates from cognitive science ideas. However, the two theories examine memory from a different point of view. Although Cognitive Load Theory does not relate directly to Dual Coding Theory, it does use its empirical results to establish the modality effect, which means that it accepts the dual-coding model (to a certain extent). Apart from this, most researchers on Cognitive Load Theory consider visual and auditory memory processes as separate inputs. Thus, a picture and a written text, as parts of a visual input, are assumed to be analysed from the same system within memory, which is not the case in Dual Coding Theory, since it separates verbal from pictorial input when it comes to memory analysis.

The principles of Cognitive Load Theory can offer very useful guidance in instructional design, as studies have demonstrated. However, cognitive load is a factor frequently ignored by instructional designers. Empirical studies have demonstrated that Cognitive Load Theory does offer viable explanations. It is a fact that a human’s working memory cannot receive more than a certain amount of information at a time, and that this amount is approximately the same for most humans. On the other hand, the dual-coding model, although it is supported by many research experiments, is still based on the basic assumption which divides memory into two systems. The strong basis, on which Dual Coding Theory depends on, is the observation that humans can successfully process verbal and nonverbal input and output at the same time. Nonetheless, the two theories can
coexist and produce important techniques for instructional design, such as the modality effect.

3.7 Relevance of the two theories to the research

A number of predictions of both theories will be tested in the experiments on the learning performance of the participants in the two experiments. As far as Dual Coding Theory is concerned, the experimental work will evaluate the superiority of delivering teaching material via the combination of two media (one processed by the nonverbal system, for instance text, and another processed by the imagery system, for instance static diagrams), against one medium (in this case, processed by the nonverbal system), by testing the ability of participants to recall and understand information from the teaching material. In other words, the experimental work will evaluate the predictions of the theory that the verbal and the nonverbal memory systems (whose existence is proposed by this theory), are interconnected, which allows for verbal information elements to be evoked by nonverbal information elements, and vice-versa, and helps learners to recall and comprehend more efficiently.

As far as the Cognitive Load Theory is concerned, the experimental work will check if there are any adverse effects of cognitive load on learning. This will be more appropriately examined in cases where the teaching material is delivered to participants via media that inevitably carry a mass of information details (such as the video material).
Chapter 4  Multimedia

4.1 Introduction

To understand the term ‘multimedia’, it is necessary to analyse and define the term ‘medium’, along with other terminologies that belong to the area of human-computer interaction and which are often used in a confusing way. Most of these terms, like ‘multimedia’, ‘multi-modal’, ‘multi-modality’ and ‘hypermedia’, are widely used even if their meaning is not clear enough. According to Alty (1991), “this is rather unfortunate since a clear terminology would help us to communicate our results more clearly and assess the relevance of other work to our own”.

Human beings communicate information at many levels in order to exchange ideas and messages and to externalise feelings and emotions. Understanding the foundations on which such communication is based will provide a better understanding of how humans and computers should communicate and will clarify the definition of terminologies used.

In order to communicate, human beings follow a basic procedure which, in general, has the following three features (Alty, 1991):

- A property of the world is chosen in which the person who is the transmitter of the information (the one that starts the communication) has some control and therefore is able to change it.

- Any changes caused to this property have to be able to be detected by the people with whom communication is made.

- Some conventions (or syntax and semantics) have to be agreed by the people who take part in the communication for any changes that are likely to take place.

Causing changes to the chosen property requires generation of energy (for instance, if this property is say, speech, then the speaker needs to generate energy for producing the sound of speech). The property change needs to be recognised in one of the five sensory channels of the human receiver (Alty, 1991). The procedure is illustrated in Figure 4.1 (Alty, 1991).
Thus, communication is based upon the triple of (Alty, 1991):

- creation mechanism
- representation system
- recognition system.

Examples that illustrate the above triple include the paper Braille (where impact printing plays the role of the creation mechanism, Braille code plays the role of representation and the touch is the recognition channel); voice output (where the loud speaker plays the role of the creation mechanism, voice plays the role of representation and audio is the recognition channel); and text output (where the pixel light intensity plays the role of the creation mechanism, text plays the role of representation and vision is the recognition channel) (Alty, 1991).

Additionally this triple should involve aspects of semiotics (de Souza, 2005). Semiotics is "the study of signs, both individually and grouped in sign systems. It includes the study of how meaning is made and understood" (Wikipedia, 2006). Semiotics goes beyond linguistics in that it encompasses signs in any medium or sensory modality. Thus, it is very relevant to multimedia design. A fourth item should therefore be added to Alty's triple, that of the semiotics of the interaction.

Recently, a new discipline of Semiotic Engineering applied to Human Computer Interaction has been proposed (de Souza, 2005). This adds the communication of the
designer's vision to the traditional user-centred approach to Human Computer Interaction design.

From the analysis that has been made to demonstrate how communication between human beings is built, the word 'medium' can either refer to the carrier (whatever carries the energy when communication is carried out between people existing in a considerable distance) or the representation system, for instance voice, sound, text or graphics (Alty, 1991). The above are in compliance with the definition given by Frohlich in his framework. Frohlich defines 'medium' as “a representational system for the exchange of information” (Frohlich, 1991).

Frohlich's framework, apart from the medium, is characterised by three more main features, namely 'mode', 'channel' and 'style'. According to Frohlich (1991), a mode is defined as “states across which different user actions can have the same effect”, a channel is defined as “an interface across which there is a transformation of energy” and a style is defined as “a recognised class of methods for supporting interface activity”. Mode consists of language (such as text, speech and gesture) and action (such as events in sound, graphics and motion). Similarly, there are language styles, like command line dialogue, menus, programming languages, natural language and form filling, and action styles, like icons, windows and graphics (Frohlich, 1991). Alty (1991) used the basic framework of Frohlich and slightly modified it, to present a multimedia framework example which is illustrated in Figure 4.2.
Figure 4.2: Alty's multimedia framework (modified from Frohlich)

The semiotic approach adds to this the overall objective of the interface, interest and values involved in this objective, in other words the designer's vision.

4.2 Multimedia

Both Dual Coding Theory and Cognitive Load Theory have resulted in suggestions and predictions about the capabilities of human memory and how information is received and processed. Empirical research carried out on how the principles of these theories are valid in learning tasks (Alty, 2002; Beacham and Alty, 2006; Beacham et al., 2002; Najjar, 1995; Mousavi, Low and Sweller, 1995; Paivio, 1983; Sweller, 1988; Sweller et al., 1990) has examined the presentation of information through a number of media at the same time. The coexistence of more than one channel of presentation is called 'multimedia'.

The word 'multimedia' itself implies the existence of many (multi) media. A medium, as it has already been discussed, refers to the representational system used to carry out the exchange of information that is used to build a communication level. In that sense, the word 'multimedia' is used whenever more that one representational system are used to convey information from one member of the communication group to the other. For
instance, a multimedia presentation occurs in a lecture theatre, where the lecturer explains a diagram illustrated on the wall, through a projector. In this case the voice of the lecturer, the graphics of the diagram and the gestures used are the three media used to transfer information from the lecturer to the students attending the lecture.

However, the most 'popular' use of the word 'multimedia', and the one that is more familiar to people, is the one that refers to media which are generated digitally by computers. These are called computer-based multimedia, which refer to a technology that is constantly evolving to serve many purposes, such as entertainment, education, scientific research or industrial applications. In this case, communication is constructed between human and computer, or human to human via the use of a computer.

Computer-based multimedia involves the use of text, graphics, animation, pictures, video and sound to present information (Najjar, 1996). Any combination of these media can provide a multimedia presentation. Multimedia presentations are now easy to create using modern computer technology. The simultaneous use of the above media in computer environments, in order to establish a communication between humans and computers, is called 'a multimedia interface' (Alty, 1997).

Regarding the term 'multimedia' and 'multimedia presentations' in general, Mayer attempted to define the meaning of the term by viewing 'multimedia' in three different ways (Mayer, 2001). The first view is called 'the delivery media view' and focuses on the devices that are used to deliver information, such as the screen and the speakers in computer-based multimedia or the projector and the lecturer's voice in lecture-based multimedia. According to this view, a textbook cannot form a multimedia presentation, because the only presentation ‘device’ that is used includes the ink printed on paper. Mayer does not accept this view, because it is a technology-centred approach with no respect to the needs of learners. In general, Mayer (2001) suggests that multimedia should be learner-centred, in contrast with technology-centred multimedia which exploits the advantages of the functional capabilities of multimedia but does not respect the learner's capabilities. The goal of learner-centred multimedia is to exploit the capabilities of multimedia to aid human cognition.
The second view is called 'the presentation modes view' and focuses on the way that information is presented (words or pictures), such as on-screen text and narration (verbal) or pictures and animation (pictorial) in computer-based multimedia, or speech (verbal) or projected graphics in lecture-based multimedia. In a textbook, verbal material is represented by text and pictorial material is represented by static images. This view is more learner-centred and is consistent with Paivio's dual-coding model (Paivio, 1986).

The third view, which is called 'the sensory modalities view', focuses on the sensory systems of learners (rather than the verbal and pictorial coding systems which are focused by the second view), which are involved during a multimedia session. For instance, in computer-based multimedia, learners perceive an image via the visual system (eyes) and a narration via the auditory system (ears), in lecture-based multimedia the visual system aids in perceiving the projected graphics and the auditory system aids in perceiving the speaker's voice and in textbooks the visual system is the only one engaged for perceiving both text and pictures (which have a separate internal process afterwards).

Mayer's theory is a compromise between Paivio's two channel 'presentation mode' approach and Baddeley's 'sensory-modality' approach (Baddeley, 1986). The former focuses on verbal and non-verbal stimuli, and the latter on processing through the eyes or ears. Schnottz has developed an integrative model of text and picture comprehension based upon a similar distinction between descriptive and depictive representations (Schnottz and Bannert, 2003).

4.3 The role of multiple media in presentations

There is a belief that multimedia presentations are able to present information more efficiently, especially in complex cognitive tasks. Multimedia designers urgently need to know how to encourage learning through proper presentation of information. For example, Alty (1997; 1999) working in the field of problem solving in process control, has suggested three main advantages that might result from the use of multimedia design techniques. These are:
• Efficiency: multimedia interfaces could help the user to appreciate more rapidly what is happening in a dynamic system.

• Learning: multimedia interfaces could improve the user's ability to learn and assimilate.

• Stimulation: multimedia interfaces could offer a stimulating environment for problem solving that challenges and motivates the user.

In communications, an intermediary is often used to carry communications between the participants (Alty, 1999), which facilitates the transferring of information. In computer-based multimedia presentations, computers play the role of the intermediary establishing a communication between designers and users. Computers impose physical restrictions on multimedia designers when using computers to present information, for example the size of the screen, the quality of the video card, etc. However, continuous improvement in the capabilities of computers has enabled designers to minimise the effect of many of these limitations through the provision of enhanced multimedia presentations. Improvement in multimedia presentations has also been motivated by users' reactions. People seem to enjoy multimedia presentations, often preferring multimedia learning materials. This has led some researchers to suggest that multimedia encourages learning (Bosco, 1986; Bryant et al., 1980; Fletcher, 1989; 1990; Holliday, Brunner and Donais, 1977; Rigney and Lutz, 1976; Samuels, Biesbrock and Terry, 1974; Sewell and Moore, 1980). Najjar (1996) states three reasons why multimedia learning can be more efficient than traditional classroom lectures. First of all, designers can better organise learning materials using instructional methods in multimedia presentations. Secondly, multimedia presentations encourage interactivity more than traditional classroom lectures. Interactivity can be thought as a mutual action between the learner, the learning system and the learning material (Fowler, 1980) and it has positive effects on learning (Bosco, 1986; Fletcher, 1989; 1990; Verano, 1987). Multimedia presentations let learners control the pace of learning to their level, whereas traditional classroom learning often forces learners to move at a specific learning pace. Finally, multimedia material may be more stimulating (a factor that motivates learners in learning) than the material presented through classroom lectures and this has been empirically supported (Clark, 1983; 1985;
Clark and Craig, 1992; Khalili and Shashaani, 1994; Kulik, Bangert and Williams, 1983). However, it is important to realise that some learners perform better in teacher-controlled situations and that guided learning is often very successful.

Improvements in computer technology have enabled modern multimedia presentations to take advantage of developments in computer hardware and software. However, this is not always beneficial for learners. Multimedia designers usually exploit technological facilities to present information, but frequently ignore the real needs of learners. Alty (1993) suggests that designers should bear in mind the question "what might the user be able to do with this new technology?" rather than "what might the user want to do with this new technology?" The two questions frame two perspectives of multimedia design, technology and user perspectives. As has already been discussed, Mayer (2001) refers to these perspectives as technology-centred and learner-centred multimedia. Designers should always ensure that the use of multimedia presentations in learning should respect learners' abilities and limitations.

4.4 Choosing the appropriate media

Based on the learner-centred multimedia approach, designers should make decisions on which combinations of media are the most appropriate to present information. Some media are capable of transmitting specific types of information better than others (Alty, 1993). For example, numerical relations are often better demonstrated through diagrams. The learning style and background of users should also be taken into consideration, together with any known disabilities (e.g. use of the auditory channel for visually impaired users).

Good guidance for choosing the appropriate media is given by Marmollin (1991). Marmollin suggests that the experience of the user should be taken into consideration when choosing the media to present information. According to Marmollin, users with little or no experience in a field may perform well when representations enable explorations. On the other hand, when users have a lot of experience and prior knowledge in a field, then textual representations seem to be best. Between the two extremes, visualisation is preferred. Marmollin suggests that visualisation is very important in
problem solving as it supports creative thinking. What is more, many researchers suggest that visualisation is one of the most important tools in design (Ballay, 1987).

Alty (1997) has suggested three criteria that attempt to measure the ‘appropriateness’ of the chosen media to present information. These are as follows:

- Effectiveness. This can be measured for example through total time needed to solve a problem.
- Information richness. The term has been defined by Daft and Lengel (1984) and describes the ability of information to “change understanding in the recipient within a time interval” (Alty, 1997).
- Expressiveness. Williams and Alty (1998) have used this term to describe “the ability of a medium to support multiple levels of abstraction”.

One technique for measuring the ‘appropriateness’ of a medium for a task is the medium’s signal to noise ratio used by Alty (1997). The ratio measures the amount of relevant information provided by the medium divided by the total information presented (noise).

Multimedia interface design has proceeded slowly, in contrast with the improvements of computer technology. To have positive results in learning, multimedia design should be learner-centred, so that it respects the user’s capabilities and makes the selection of the appropriate combination of media to present information.

### 4.5 Mayer’s Cognitive Theory

Mayer has carried out an extensive research on cognitive multimedia. His studies focus on instructional design within multimedia environments. His research is based on previous theories, such as Dual Coding Theory and Cognitive Load Theory. However, Mayer refines them into his own cognitive theory.

First of all, multimedia learning ought to encourage active learning, instead of the passive receiving of information. Learners are likely to be prompted by multimedia presentations to build mental structures (e.g. schemas) which are probably the basis of Long-Term
Memory (Paivio, 1986). Mayer suggests that the acquisition of information in a passive manner is a major reason why learners cannot use information efficiently in future occasions.

Mayer (2001) also suggests that using multimedia presentations in learning should have two objectives. Firstly, they should present information in such a way that will aid recalling. Secondly, multimedia learning should help learners to understand information, so that they can use this information in future occasions. Depending on whether those objectives are accomplished or not, there are three potential outcomes from multimedia learning. Consider, for instance, a multimedia presentation that gives instructions to inexperienced learners on identifying the CPU chip in a computer's motherboard, along with a description of all of its attributes. One possible outcome from this presentation is no learning, in which the learner neither recalls information on identifying the CPU processor nor is able to reproduce this information in order to solve relevant theoretical or practical problems (for instance how to replace the CPU chip with a new one). Another possible outcome is rote learning, in which the learner can recall information for identifying the CPU processor but he/she cannot use this information for replacing the CPU processor with a new one. The third and most desirable outcome is meaningful learning. This type of learning enables learners to recall information from the presented material and, what is more, reproduce this information so that they can replace the CPU processor as well (Mayer, 2001).

Mayer's Cognitive Theory is based upon three assumptions (Mayer, 2001). The first assumption refers to the existence of a dual channel in memory, meaning that there are two channels in memory for processing different information. There are two versions for this assumption. The first version is based on sensory modalities and regards that the first channel receives, analyses and stores visual information (information received through eyes, such as images or printed text) and the other functions the same way for auditory information (information received through ears, such as sounds or text in auditory form). The second version complies with Dual Coding Theory, considering that the first channel is responsible for nonverbal information (such as pictures or sounds) and the second channel is responsible for verbal information (such as words in printed or auditory
format). Mayer accepts both versions depending on what distinction he wants to make between information materials.

The second assumption relates to the limited capacity of working memory. The two channels, in which the memory is divided, are limited in the amount of information that can process. This means that we cannot remember information when this exceeds the limits of the working memory. As has already been discussed, the amount of information that humans receive over a time interval is called cognitive load and a distinction is made between intrinsic and extraneous cognitive loads (Sweller, 1999; Cooper, 1998; Sweller and Chandler, 1994). According to Mayer, future improvement on multimedia design should focus on reducing as much as possible the extraneous cognitive load, which is a major obstacle for multimedia learning (Mayer, 2001).

The third assumption of Mayer's Cognitive Theory refers to the active learning. Active learning regards learners as active processors who do no just receive information from multimedia presentations, but structure internal knowledge from them (Mayer, 1999; Wittrock, 1989). It is thought that active learning (i.e. applying cognitive processes in order to structure schemas) enhances the learning process.

4.5.1 The model of Mayer's Cognitive Theory

Mayer in his cognitive theory includes both features from the Dual Coding Theory and the Cognitive Load Theory and adds the feature of active learning. Figure 4.3 demonstrates the basic elements of Mayer's Cognitive Theory (Mayer, 2001).

![Figure 4.3: Mayer's Cognitive Theory of multimedia learning](image)
Mayer's cognitive model consists of three memory stores (represented by three boxes), the sensory memory, the working memory and the long-term memory. Pictures and words (originating from the outside world as elements of multimedia presentations and demonstrated at the left part of Figure 4.3) are firstly stored in the sensory memory, for a short period. This type of memory is divided into the visual sensory memory (storing pictures and printed words) and the auditory sensory memory (storing spoken words and sounds).

The main part of the procedure of multimedia learning takes place in the working memory. According to Mayer's cognitive model, working memory is divided into two parts. The first part of the memory (the left part of the box which represents working memory in Figure 4.3) is based on the two sensory modalities (visual and auditory) and therefore stores raw material which consists of pictures and words (in visual or auditory format). In Figure 4.3, in the left part of working memory, the arrows between sounds and images represent the interconnectedness between these sensory modalities. For instance, (similar to the interconnectedness between verbal and non-verbal systems of Paivio's dual-coding model) the auditory format of the spoken word 'cat' (stored in the auditory part of sensory memory) can be mentally converted into the image of a cat and, similarly, the visual format of the image of a cat (stored in the visual part of sensory memory) can be mentally converted into the sound of the spoken word 'cat'. In this first part of working memory, Mayer takes into consideration the limited-capacity assumption (which suggests that working memory stores only limited information), by indicating that selection of images and words is carried out for being stored in the sensory memory (learners choose the most important parts of information to be further processed, since working memory cannot store larger amounts of information).

Finally, knowledge is constructed in the second part of working memory (the right part of the box which represents working memory in Figure 4.3). Words and images are organised into verbal and pictorial models respectively (such as the verbal and non-verbal systems into which Paivio's dual-coding model divides human memory). Knowledge that is created in the second part of working memory is integrated by interconnectedness both
between the two models (verbal and pictorial) and between any of these two models and prior knowledge that has already been created and stored in long-term memory.

4.5.2 Principles of Mayer’s Cognitive Theory

Mayer reports seven principles based on his studies and on the two theories (Dual Coding Theory and Cognitive Load Theory) and provides empirical justification to support each multimedia learning principle. Empirical research includes the presentation of teaching materials, such as instructions on how lightning storms develop, how brakes work and how bicycle tyre pumps work. The seven principles are the following:

- Multimedia Principle
- Spatial Contiguity Principle
- Temporal Contiguity Principle
- Coherence Principle
- Modality Principle
- Redundancy Principle
- Individual Differences Principle

4.5.2.1 Multimedia Principle

The Multimedia Principle suggests that material is learned better if it is presented via words and pictures than words alone (Mayer, 2001). Mayer suggests that when information is presented via words and pictures, learners build both verbal and pictorial models which are likely to interact and aid in learning. If information is presented via words alone, learners are most likely to build only a verbal model, missing the benefit of constructing knowledge through the interaction of two models.

Empirical work was divided into two parts. The first part checked on the multimedia effect using retention tests (which examine the recalling of information). Nine experiments were carried out (Mayer, 1989; Mayer and Anderson, 1991; Mayer and
Anderson, 1992; Mayer et al., 1996; Mayer and Gallini, 1990). The material was presented in three experiments via computer-based multimedia (where narration was used to represent verbal information) and in six experiments via textbook-based multimedia (where text was used to represent verbal information). Overall, in five out of the six experiments which used textbook-based multimedia the multimedia effect was demonstrated by the better performance of students who received information via text and pictures in the retention test, in comparison with the performance of the students who received information via text-only. The three experiments carried out using computer-based multimedia failed to demonstrate a multimedia effect, since in two of them students who watched information via narration only performed better than those who watched information via narration and animated pictures. In the third experiment, the multimedia effect was very small. Mayer argues that the absence of the multimedia effect in these three experiments was due to the richer content of narrated material, compared with the textual material of the other six experiments, which was likely to build a more efficient verbal model.

In the same nine experiments, transfer tests (which examine the comprehension of information) demonstrated a multimedia effect in all nine cases. In other words, students who received information via text (or narration) and pictures understood the material better than the students who received information via text (or narration) only (Mayer, 1989; Mayer and Anderson, 1991; Mayer and Anderson, 1992; Mayer et al., 1996; Mayer and Gallini, 1990).

4.5.2.2 Spatial Contiguity Principle

The Spatial Contiguity Principle suggests that material is learned better when corresponding words and pictures are placed near rather than far from each other in multimedia presentations (Mayer, 2001). According to Mayer, when words are placed close to pictures then it is very likely that learners will use less cognitive resources to analyse information and store both verbal and pictorial information in working memory at the same time. This is less likely to occur when words are presented far away or separately from the corresponding pictures (on screen or on page).
Similarly to the Multimedia Principle, empirical work examined the Spatial Contiguity effect on both computer-based and textbook-based multimedia and carried out both retention and transfer tests. Two experiments were carried out to examine retention and in both cases students who were presented with integrated material (words next to animated pictures in computer-based multimedia or words next to static pictures in textbook-based multimedia) scored higher than those who were presented with separated material (Mayer, 1989; Moreno and Mayer, 1999). Furthermore, the spatial contiguity effect was recorded in all five experiments (one carried out in computer-based multimedia and four carried out in textbook-based multimedia) regarding transfer (Mayer, 1989; Mayer et al., 1995; Moreno and Mayer, 1999).

4.5.2.3 Temporal Contiguity Principle

According to the Temporal Contiguity Principle, material is better learned when words and pictures are presented at the same time rather than successively (Mayer, 2001). Similarly to the Spatial Contiguity Principle, Mayer regards that when words and pictures are presented simultaneously, learners are able to hold both types of information in working memory and make internal connections between them, whereas this is not likely to occur when words and pictures are presented differently in time (especially if verbal and pictorial materials are large).

Obviously, the Temporal Contiguity effect could only be examined in computer-based multimedia. Five experiments were carried out regarding retention (Mayer et al., 1999; Mayer and Anderson, 1991; Mayer and Anderson, 1992). However, only two of them showed a Temporal Contiguity effect, meaning that in these two experiments students who watched the teaching material where words were presented as near to each other as possible in time with animated pictures performed better in the retention test than those who watched the material where words were separated from animated pictures by longer periods of time. On the other hand, the Temporal Contiguity effect was clearly demonstrated in all eight experiments that were carried out regarding transfer (Mayer et al., 1999; Mayer and Sims, 1994; Mayer and Anderson, 1991; Mayer and Anderson, 1992). Interestingly, when Mayer broke down the teaching material in 16 small segments
and repeated the same experiment (students watched each textual and animation segment simultaneously or successively) no Temporal Contiguity effect was recorded in both retention and transfer tests (Moreno and Mayer, 1999; Mayer et al., 1999).

### 4.5.2.4 Coherence Principle

The Coherence Principle suggests that learning is improved when irrelevant information is removed from the teaching material rather than included (Mayer, 2001). The Coherence Principle is broken down to three complementary versions. Firstly, learning is adversely affected when interesting but irrelevant words and pictures are included in a multimedia presentation. Secondly, learning is adversely affected when interesting but irrelevant sounds and music are included in a multimedia presentation. Thirdly, learning is improved when unneeded words are removed from a multimedia presentation (Mayer, 2001). According to Mayer, irrelevant information is likely to engage valuable cognitive resources, affect negatively the organisation of useful material, divert the learner’s attention and cause organising of material around an inappropriate theme.

Six experiments (one in computer-based multimedia and five in textbook-based multimedia) were carried out regarding retention and transfer in the first version of the principle (Harp and Mayer, 1997; Harp and Mayer, 1998; Mayer, Heiser and Lonn, 2001). In all six experiments, students who were presented with the basic teaching material showed through the retention and transfer tests that they recalled and understood the material better than those students who were presented with the expanded material (which included interesting but unneeded words and pictures), yielding a Coherence effect. Furthermore, two experiments were carried out using computer-based multimedia in order to examine the second version of the Coherence Principle (Moreno and Mayer, 2000). In both experiments, students who watched the basic material (via narrated animation) showed better recalling and understanding of the material than those students who were presented with another version of the teaching material, in which background music and environmental sound were embedded. The third version of the Coherence Principle was evaluated by carrying out three experiments (using textbook-based multimedia), which examined the Coherence effect in the case where unneeded words
were removed from the basic teaching material (Mayer et al., 1996). All three experiments yielded the Coherence effect in retention tests, in which students who were presented with a summary of the teaching material showed that they recalled more information than those students who were presented with an expanded teaching material. In addition to this, two out of these three experiments yielded the Coherence effect in transfer tests.

4.5.2.5 Modality Principle

The Modality Principle suggests that learning in computer-based multimedia is better achieved when animation is accompanied by narration than on-screen text (Mayer, 2001). Mayer states that when animation is presented along with on-screen text, then both types of information are processed by the pictorial channel, which is likely to be overloaded. In the case where animation is accompanied by narration then verbal information is processed by the auditory channel (narration), which decreases the cognitive load posed in the pictorial channel. Four experiments were carried out regarding retention and transfer performance of students who watched two versions of the teaching material (Mayer and Moreno, 1998; Moreno and Mayer, 1999). In all four experiments students who observed the presentation of the material via narrated animation performed better in both retention and transfer tests than those students who observed the teaching material via animation and on-screen text, showing a clear Modality effect.

4.5.2.6 Redundancy Principle

The Redundancy Principle suggests that learning in computer-based multimedia is better achieved when animation is accompanied by narration than when it is accompanied by both narration and text (Mayer, 2001). Similarly to the Modality Principle, this effect is based on the cognitive load that is posed in the pictorial channel, due to the processing of pictorial and textual information by this channel (Mayer, 2001). Two experiments were carried out examining the Redundancy effect on students (Mayer, Heiser and Lonn, 2001). The effect was recorded in both retention and transfer tests, in which students who
watched the presentation of the material via narrated animation performed better than those students who watched the presentation of the material via narrated animation with text.

4.5.2.7 Individual Differences Principle

According to the Individual Differences Principle, design effects (which are caused by applying the six previous principles in the construction of multimedia presentations) are stronger for low-knowledge learners than for high-knowledge learners, and for high-spatial learners than for low-spatial learners (Mayer, 2001). Mayer suggests that high-knowledge learners can resort to their prior knowledge whenever a multimedia presentation lacks efficient guidance (by creating mental images based on textual input), whereas this is unlikely to occur in low-knowledge learners due to lack of prior knowledge. Furthermore, Mayer claims that high-spatial learners can mentally connect visual and verbal representations more efficiently using up less memory capacity than low-spatial learners who are more likely to overload their working memory due to holding representations in memory for a long time until integration is achieved.

Empirical studies have examined in which type of students (high-knowledge versus low-knowledge) the Multimedia effect was stronger. High-knowledge students were distinguished from low-knowledge students through the use of a pre-questionnaire, which included general questions related to the teaching material. Two versions of the teaching material were designed using textbook-based multimedia. The well-designed version included information presented via text and pictures, whereas the poorly-designed version included information presented via text-only. Three experiments were carried out regarding retention and in two of them the Multimedia effect was stronger on low-knowledge students (Mayer and Gallini, 1990). In addition to these three experiments, another one was carried out regarding transfer (Mayer et al., 1995; Mayer and Gallini, 1990). In all four cases, the Multimedia effect was stronger on low-knowledge students.

Furthermore, empirical studies examined whether the Temporal Contiguity effect was stronger on high-spatial or low-spatial learners, in computer-based multimedia. High-spatial students were distinguished from low-spatial students through the use of short
versions of two classic tests of spatial ability. Similarly, a well-designed version (simultaneous presentation of animation and narration) and a poorly-designed version of the teaching material (successive presentation of animation and narration) were included in two experiments which used transfer tests (Mayer and Sims, 1994). In both experiments, the Temporal Contiguity effect was stronger on high-spatial students.

4.5.3 Evaluation of Mayer’s Cognitive Theory

Almost all empirical studies supported the seven principles of Mayer’s Cognitive Theory (only a very limited number of studies resulted in different results regarding the Multimedia and the Temporal Contiguity Principles, as far as retention tests were concerned). Concluding from these seven principles, Mayer emphasises the preliminary principle, considering that multimedia presentations (which engage both pictorial and verbal channels) do aid in better recalling and understanding of teaching materials, in contrast to presentations which consist of only verbal messages. In addition to this, efficient multimedia design should make proper use of pictorial and verbal information, with respect to the following five principles. A well-designed multimedia presentation that respects all of the first six principles of Mayer’s Cognitive Theory is more effective with students having low prior knowledge and high spatial ability, in terms of learning. In general, Mayer’s Cognitive Theory is based on both Dual Coding Theory and Cognitive Load Theory, since Mayer accepts the existence of a verbal and a pictorial channel (which is called ‘imagery’ or non-verbal’ system by Paivio) and considers the limited capacity of working memory. Furthermore, all seven principles of Mayer’s theory make partial or whole use of principles which originate from Dual Coding Theory and Cognitive Load Theory.

However, it could be argued that the learning tasks included in Mayer’s experiments were of a limited duration and therefore might not scale up to a realistic task. As will be discussed in the next section, complexity of the learning task is an important factor that could affect the performance and the motivation (to take part in an experiment) of the participants.
4.5.4 Relevance of Mayer’s Cognitive Theory to the research

The principles of Mayer’s Cognitive Theory will be taken into consideration in the design process of the multimedia presentations which will form the core of the empirical work of this research. For instance, the Spatial Contiguity Principle will be taken into account in the design of the multimedia presentation that will combine text and diagrams, and the Temporal Contiguity Principle will be taken into account in the design of the multimedia presentation that will combine sound with diagrams. Mayer’s principles in the design of the multimedia presentations are likely to decrease the cognitive load in the participants’ memory and enable a fair comparison between all media combinations, in terms of learning outcomes. Furthermore, other principles (such as the Multimedia Principle and the Individual Differences Principle) will be supported or criticised based on the results of the empirical work.

4.6 Alty’s empirical work

The scenario of the experimental work of this thesis is strongly based on earlier experimental work that was carried out by Alty (2002) and Alty, Beacham and Al-Sharrah (2003; 2006). During this recent experimental work, they examined the effects of different media combinations on learning, by presenting the same information material to groups of postgraduate students from the Computer Science Department at Loughborough University and comparing their performance based on learning tests that were given to them after the end of the multimedia presentations.

According to Alty (2002), when planning and designing experiments on multimedia learning, it is obvious that choosing the appropriate information material plays an important role for the whole experiment. The learning domain should not be too simple, because learners can easily cope with it, no matter how information is transferred to them. On the other hand, when the learning domain is too complex, then it results in low scores being obtained by most of the participants, which prevents the research from identifying any differentiation caused by different media combinations on the learning performance of participants. In addition to this, motivation of learners is decreased as they are unable to follow the flow of information within the multimedia presentation.
Beacham and Alty (2003; 2006) chose Statistics as the learning domain for the purposes of their multimedia learning experiment. This domain was chosen because it is an important study domain for many postgraduate studies, thereby providing participants with a good motivation to take part seriously in the experiment. It also contrasted with the domains used by Mayer which in general were relatively simple and highly practical in nature.

In all experimental studies carried out by Alty and his colleagues, a basic scenario was followed (Alty, 2002; Alty, Beacham and Al-Sharrah, 2003; 2006). Three types of multimedia presentations were designed as part of the experiment, which presented the teaching material via text-only, text and diagrams, and voice and diagrams. Information was identical in all three multimedia presentations. This means that textual material in the Text-Only presentation was exactly the same in the Text + Diagrams presentation and in the Voice + Diagrams presentation, where the voice was narrating the exact content of the Text-Only presentation. Therefore, textual material was constructed in a way that text could stand alone and also be part of the other two presentations.

In all, four experiments were carried out, each one corresponding to one of the four modules of statistics that were chosen to form the teaching material. Participants were students of a postgraduate Multimedia Interface Design course. The four modules that formed the four experiments were:

1. The Null Hypothesis and the relevance of Statistics
2. The Binomial Distribution
3. Non-parametric distributions – i.e. Ranking (Wilcoxon)
4. The Normal Distribution and the Central Limit Theorem

One important feature of the experiment was the consideration of learning styles, which reflect part of the individual differences of learners. Alty and his colleagues identified the learning styles of the students using the questionnaire designed by Felder and Soloman (1998). Students were divided into three groups (as many as the number of multimedia presentations) and each group was balanced between sensing and intuitive learners. Table
4.1 illustrates how the four experiments were allocated to the three different groups of students (each experiment was carried out on a different day).

Table 4.1: Groups and presentation formats in Alty's four experiments

<table>
<thead>
<tr>
<th>Topic</th>
<th>Text</th>
<th>Text + Diagrams</th>
<th>Voice + Diagrams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Null Hypothesis</td>
<td>Group A</td>
<td>Group B</td>
<td>Group C</td>
</tr>
<tr>
<td>Binomial Distribution</td>
<td>Group B</td>
<td>Group C</td>
<td>Group A</td>
</tr>
<tr>
<td>Ranking</td>
<td>Group C</td>
<td>Group A</td>
<td>Group B</td>
</tr>
<tr>
<td>Normal Distribution</td>
<td>Group A</td>
<td>Group B</td>
<td>Group C</td>
</tr>
</tbody>
</table>

4.6.1 Learning tests

Considering the prior knowledge of participants, which is very likely to affect their performance on the learning test, four methods could be used to enable researchers to assess prior knowledge of participants when using learning tests.

- Use a general pre-test that examines general knowledge of participants on the topics which are covered within learning tasks.
- Ask participants to complete the learning test before and after carrying out the learning task and compare their answers.
- Run a post-test which examines the acquisition of different types of knowledge.
- Ask the participants to evaluate themselves their answer to each question of the learning test, in terms of prior knowledge.

Eventually, Alty (2002) applied the fourth method by placing next to each question of the learning test a ticking box (Table 4.2) that allowed participants to state whether they used any of prior knowledge to answer the question or not.

Table 4.2: Students' assessment of their prior knowledge on each question in Alty's learning test

<table>
<thead>
<tr>
<th>Information recall</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knew it already</td>
<td>Met before and</td>
<td>Vague memory</td>
<td>Never met</td>
<td></td>
</tr>
<tr>
<td></td>
<td>was reminded</td>
<td></td>
<td>before</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In their latest empirical work on dyslexia and media, Beacham and Alty (2006), checked for prior knowledge by requiring the students to fill in the same learning test before and after the presentation of the teaching material.

According to the scenario of each experiment, students of each group watched the corresponding multimedia presentation and afterwards they were asked to fill in a learning test that consisted of questions which tested the recalling and understanding of the teaching material that had just been presented to them. Between all students that took part to the four experiments, only the results of those who attended all four experiments were taken into account.

4.6.2 Results

The performances of the students who took part in Alty’s experiments are illustrated in Figure 4.4, based on the answers they gave in the learning test (Alty, 2002).

![Figure 4.4: The learning test results in Alty's multimedia learning experiments](image)

According to these results, the Sound + Diagrams presentation outperformed the other two presentations in all four experiments. This complies with the Modality effect of Mayer (2001). Furthermore, performance improved from the first to the fourth experiment, as students became more familiar with the multimedia environment of the presentations and managed to devote more time in absorbing information than in coping with the multimedia interface of the presentations. This reveals another important factor that plays an important role in multimedia learning. Design of multimedia interfaces is
very crucial especially when this is required to aid in reaching a solution in a problem solving situation (Alty, 1999). It is therefore of no surprise that multimedia interfaces have to be carefully designed in multimedia learning as well, so that participants spend minimum time in getting familiar with it, and engaging themselves entirely in the material of the presentations.

On the other hand, the Text + Diagrams presentation had barely better results compared with the Text-Only presentation, which does not comply with the suggestions of Dual Coding Theory and the Multimedia Principle of Mayer’s Cognitive Theory. What is more, in the third experiment which presented information on Ranking, the Text-Only presentation is slightly better than Text + Diagrams. These results are likely to be explained if the design of the Text + Diagrams presentations is considered. In this presentation, text was separated from the accompanying diagrams by being presented in the right-side of the screen, as can be seen in Figure 4.5 (Alty et al., 2006).

![Figure 4.5: A screen shot from Alty's Text + Diagrams presentation](image)
This type of design was very likely to cause cognitive load in the memory of participants. Based on Mayer’s cognitive model, participants would have to hold verbal information for a long time within their working memory until integration with pictorial information would be achieved. Due to this procedure, their working memory was very likely to be overloaded, having negative effects in recalling information.

Interestingly, Alty and his colleagues identified differences in the learning performances between sensing and intuitive learners (Alty, 2002; Alty, Al-Sharrah and Beacham, 2003; 2006). The other learning styles yielded no significant differences. In all presentations, intuitive learners performed significantly better than sensing learners (however, not across presentations). It was thought that intuitive learners were likely to perform better due to the theoretical nature of the learning task, but not due to the media combination that was used to present information, since no significant difference was recorded between the two types of learner across presentations.

Another important finding of the studies of Alty and his colleagues is the different types of interaction that were recorded in all three multimedia presentations. In his previous studies (Alty, 2002), interaction was not available and students were passive users who could not interfere with the flow of information. In the latest studies though (Alty, Al-Sharrah and Beacham, 2003; 2006), an interaction mechanism was designed to enable students to interact with the presentation. This mechanism was placed at the top of the screen, as can be seen in Figure 4.5. Depending on the type of interaction that students performed, they were classified into three categories:

- **Fast-forward learners.** They tend to use interaction buttons to move earlier to the next screen pages of the presentation without waiting for the whole information to be presented to them.

- **Passive learners.** They do not use any interaction buttons, allowing the presentation to proceed at its natural pace.

- **Re-learners.** They tend to use interaction buttons to visit again one or more screen pages of the presentation.
This classification of learners into the above categories reflects not only the way that students dealt with novel information in general, but their attitude towards the whole experiment as well. Learners tended to be fast-forward either because information included in that part of the presentation was familiar to them or because they were not fully motivated to participate in the experiment. For both reasons, it would be ideal if the percentage of these learners is quite smaller in multimedia learning experiments than the other two types of learner. On the other hand, re-learning reveals a difficulty to absorb and remember new and complex information, and a true effort to cope with the requirements of the experiment. Passive learners reflected a balanced behaviour of learners who were either not interested in interacting with the presentation or feel comfortable with the pace that the presentation was moving forwards. However, these are not general behaviours, but they are largely affected by the type of presentation. A particular learner might be passive towards the Sound + Diagrams presentation but be a re-learner for the Text-Only presentation. Indeed, the results showed that the Sound + Diagrams presentation included the most passive learners, whereas the Text-Only presentation included the most re-learners, reflecting the difficulty to present novel information in text-only form. In general, the results of Alty’s experimental studies could be summarised as below:

- They supported the suggestions of Dual Coding Theory and Mayer’s Multimedia Principle. In addition to this, the study supported the principles of Cognitive Load Theory through the design of Text + Diagrams presentation.

- The study made use of the Felder-Soloman test in order to identify the learning styles of the students who participated in the experiments, based on the learning model of Felder and Silverman. After balancing each group of participants based on the Dimension of Perception (sensing and intuitive learners), the results of the study showed that learning styles do affect multimedia learning.

- It revealed three types of learning behaviours, based on the interaction of students with multimedia presentations.

These results are very useful in terms of research interest, as they form a basis for comparison of the two experiments which were carried out for the purposes of this thesis.
4.7 Criticism of the usefulness of multimedia in learning

Although research on multimedia learning has shown that the presentation of teaching materials via different media combinations affects learning, there are researchers who have suggested that multimedia do not necessarily play an important part in the learning process. Two striking examples of criticism are those of Clark, and Narayanan and Hegarty.

4.7.1 Clark's criticism

Clark has repeatedly suggested that media do not influence learning (Clark, 1983; 1985; 1994). His most characteristic opinion about media is that they are "mere vehicles that deliver instruction but do not influence student achievement any more than the truck that delivers our groceries causes changes in our nutrition" (Clark, 1983, p.445). Clark (1994) argues that it is the instructional methods that influence learning. Instructional methods are defined as a means to shape information that triggers, replaces or compensates for the cognitive processes necessary for achievement or motivation (Salomon, 1979). A certain instructional method is likely to be effectively delivered to a student using "different types of examples, with many different attributes presented by many different media" (Clark, 1994).

In addition to this, Salomon (1979) argued that it is the media attributes (and not the media themselves) that influence learning, since they are uniquely perceived by learners in order to construct cognitive processes. Clark (1994) went on by suggesting that different media attributes can be appropriately utilised to achieve the same learning goal. Thus, considering that a learning outcome can be reached through the use of different media, instructional design should choose those media which will guarantee the less expensive way to accomplish the desired learning goal (Clark, 1994).

Clark (1994) argued that media do not motivate learners, in terms of studying teaching material. Motivation is based on the personal attributes of learners and the circumstances under which a learning task is being carried out. Furthermore, Clark (1994) replied to those arguments which claimed that each medium (or media combination) is best at
delivering a specific content or method (for instance, television is believed to be ideal in delivering visual, real-time, documentary information and textbooks in constructing encyclopedic knowledge with illustrated examples), by saying that each medium (or media combination) is not limited in the variety of methods and contents that it can present (for instance, computers can be used to present visual, real-time, documentary information). Finally, Clark (1994) disagreed with the suggestion that learning can be enhanced by the use of computer-based instructions (CBI), by presenting evidence which demonstrated that learning through CBI was influenced by the instructional methods that were embedded within CBI and not the computer itself (Kulik, 1985).

It is true that the introduction of new technologies has always led to predictions of massive effects on learning that have often not been borne out in practice, and Clarke claims that information can be represented using any number of different media and that pedagogy is the really important issue. Whilst this thesis supports the importance of pedagogy, it also supports Cobb’s (1997) position that digital media can still affect learning outcomes from the perspective of cognitive efficiency. “Efficient instructional media systems are symbol systems that do some of the learner’s cognitive work for them. It goes without saying, that the most efficient medium would not necessarily be ideal for every stage of learning” (Cobb, 1997, page 11).

4.7.2 Narayanan and Hegarty’s criticism

Narayanan and Hegarty have carried out extensive research on how to construct a cognitive model that could be used to develop an effective computer-based multimedia design, which would aid learners in accomplishing a learning goal. As a result of this research, they have proposed a cognitive model which guides the design of an efficient interface of computer-based multimedia presentations that specifically explains how machines work (Narayanan and Hegarty, 1998). The model is based on the researchers’ suggestion that the design of computer-based multimedia presentations should always consider users’ mental models and strategies first. An appropriate summary of the model is given by the two researchers themselves (Narayanan and Hegarty, 1998):
"The model postulates that people understand text-and-diagram descriptions of machines by first decomposing the diagram of the machine into units that represent its elementary components, then retrieving background knowledge about the machine components and encoding the spatial relations between components to construct a static mental model of the machine. The dynamic behaviours are then mentally simulated using this static model, beginning with information about the behaviour of one component and inferring the behaviours of other components or sub-systems one by one in order of the chain of causality in the machine. This process involves both inference from prior knowledge, and inference based on mental visualisations of spatial behaviours of components".

The comprehension model of Narayanan and Hegarty is a useful one though it became available after the initial design carried out in this thesis. Their important suggestion is that learning is influenced by instructional methods and not by media. Using their model as a basic guide for effective multimedia design, they constructed a computer-based multimedia presentation that explained how a flushing cistern works and compared its efficiency in contributing to learning with the efficiency of three other presentations (Narayanan and Hegarty, 2002). These three presentations included a printed version of the Narayanan’s and Hegarty’s computer-based presentation, a well-known computer-based presentation that described the same type of flushing cistern (designed by Macaulay (1988)) and a printed version of Macaulay’s description.

The hypothesis was that Narayanan and Hegarty’s computer-based presentation would lead to better learning outcomes than the other three presentations. Learning was tested through three types of question, that tested general knowledge of the system, knowledge of how specific components of the system work and knowledge of how to deal with problem-solving situations. The results are summarised as follows (Narayanan and Hegarty, 2002):

- Students who watched Narayanan and Hegarty’s computer-based presentation performed significantly better in all three types of question than those who studied the printed version of Macaulay’s presentation.
• Students who watched Narayanan’s and Hegarty’s computer-based presentation performed significantly better in two types of question (significance in score difference was not recorded in troubleshooting question) than those who watched the Macaulay’s computer-based presentation.

• No significant difference (in all three types of questions) was recorded in the performances of the students who watched Narayanan’s and Hegarty’s computer-based presentation and those who studied its printed version.

In general, students showed that they recalled and understood better the specific teaching material than those who watched the two versions of Macaulay’s presentations (which represented a conventional description of how a machine works, since they were extracted from Macaulay’s award-winning book). In addition to this, students performed similarly in the two versions of Narayanan and Hegarty’s presentations. All four presentations delivered information via verbal and pictorial information (narration and animated diagrams in computer-based multimedia and text with static diagrams in textbook-based multimedia).

Most importantly, the same results were obtained by Narayanan and Hegarty (2002) when they compared a computer-based presentation that was based on their comprehension model that explained algorithms with three other presentations, in terms of learning. The three presentations included a printed version of Narayanan’s and Hegarty’s computer-based presentation, a computer-based presentation that was not designed in accordance with Narayanan and Hegarty’s comprehension model (Narayanan and Hegarty call it conventional computer-based presentation) and a textbook-based presentation, extracted from a textbook by Weiss (1993). Analysis of the learning performance of the students who watched the four different presentations yielded similar results to the former empirical work of the two researchers. Students who watched Narayanan and Hegarty’s computer-based presentation performed better than those who watched the conventional computer-based presentation and those who studied the textbook-based multimedia presentation. In addition to this, they performed similarly to those students who studied the printed version of Narayanan and Hegarty’s computer-based presentation.
Thus, Narayanan and Hegarty (2002) concluded from their empirical research that learning is influenced by the instructional method and not by media. Their instructional method that was based on their comprehension model led to better learning outcomes than the method that was applied by other designers (both using the same media). Furthermore, using the same instructional method, but via different media (textbook-based multimedia versus computer-based multimedia) led to the same learning outcomes.

A key conclusion of Narayanan and Hegarty's work is that animation of itself is not necessarily the best way to get over the operation of complex systems to a learner. They stress the importance of the creation of adequate static models early on in the process, and that animation should only be used after such models are reasonably understood. They also point out that most current animations are run at too high a speed. These conclusions were not relevant because animation did not form a key part in the multimedia presentations in this thesis.

4.8 Conclusion

Much empirical research has already been done and the results do not always lead to similar conclusions, as far as multimedia learning is concerned. The most obvious reason for these differences is that learning itself is a highly complex procedure which involves human memory, whose attributes and functions are still under investigation. Theories have been built describing the way human memory processes information and their suggestions have been used by multimedia learning researchers, in order to support their empirical findings on media combinations and how these affect learning. On the one hand research using media combinations has shown differences in performance (particularly the poor performance of Text-Only presentations). On the other hand much of the work of Narayanan and Hegarty has shown no media difference effects between certain presentation formats (although they did concentrate upon animated presentations and the effects of animation). Interestingly, video has rarely been used in presentations. Furthermore most domains have been limited in scope, or in theoretical domains (e.g. Statistics). This is why the experiments proposed here involve highly practical tasks.
Most researchers have not taken into consideration learning styles when they examine the effects of media combinations on learning (Mayer included in his Individual Differences Principle prior knowledge and spatial ability but not learning style). However, there are already many learning style models and learning style questionnaires available. It was therefore decided to include learning style as a variable.
Chapter 5  The first multimedia learning experiment

5.1 Introduction

Early research on media combinations that could influence the transfer of information in an educational presentation, tended to concentrate on the presentation of information in educational books, lecture presentations and interfaces to special computer applications. The rapid developments in computer technology enabled personal computers to be developed, which supported more advanced auditory and visual technologies. As a result, multimedia presentations became the basic ingredient of many computer applications. Research is now focusing on how such advanced multimedia presentations might contribute to learning, problem solving and effective human-computer interaction.

Experiments are conducted using people as potential learners in learning tasks. Tasks carried out vary in nature and complexity, from simple memory tests to complex learning tasks within specific multimedia environments. The nature of the learning tasks, along with the people that take part in them, depends on the objectives of the research. For instance, carrying out research on how information is best stored and retrieved in children, would involve simple memory tests, such as recalling part of a story that is presented to them in a certain media combination (text-only, text and pictures or voice narration and pictures). Research on the effects of different media combinations on designing efficient interfaces for problem solving situations which might occur in mechanical engineering is likely to involve a problem solving task presented to undergraduate students of a Mechanical Engineering department using various multimedia interfaces. Since one of the key objectives of the work described in this thesis is to examine how choice of media affects students carrying out a practical task, the target task needs to be some form of assembly or diagnostic task, whose instructions on how to fulfil it are delivered by multimedia presentations.

This chapter discusses the design of a preliminary experiment in this type of domain which it was hoped would provide key pointers to the design of a later, more detailed experiment.
5.2 The design of the preliminary experimental task

In choosing an experimental task, the following issues need to be addressed:

- A task should be chosen which sufficiently motivates the participants so that they are interested in the task and feel that they have benefited from performing it. The task should also be sufficiently challenging so that the results can be scaled-up to more realistic situations.

- The target group selected to take part in the experimental research needs to be clearly defined. Of what age should they be? What should be their knowledge background?

- Which media combinations should be tested for their contribution to efficient multimedia presentations and why? Existing design principles involving the co-existence of two or more media within the same presentation should be followed where possible.

- The task should be sufficiently challenging but also of a realistic length (otherwise participants may lose motivation and abandon the task part way through.

5.2.1 The experimental task

As has already been pointed out in Chapter 1, one concern of this research is how information presentation in different media combinations might affect users' performance on a practical task. This contrasts with previous work (Mayer, 2001; Alty, 2002; Alty, Al-Sharrah and Beacham, 2003) where the task has been one involving learning a body of knowledge (e.g. statistical knowledge, development of lightning storms). It was therefore important to carry out a preliminary experiment in order to develop experience in carrying out an experiment in learning, using media to present instructions on how to complete a practical task.

In general, when choosing the kind of task to be presented to participants, an important factor is the complexity of the learning task. It should not be so difficult that participants
become discouraged, nor should it be so simple that participants lose interest. Another important factor is the likely motivation of participants. Concerning the choice of task complexity, Alty (2002) wrote:

"Many experiments that have examined the effects of different media on learning have been constructed over relatively simple subject domains. The material being communicated to learners is often limited in scope and usually not complex in nature. There are, of course, good reasons for this. A complex domain necessarily requires a specialised user base, and an extensive set of learning material will impose serious time requirements on the subjects taking part. Yet it is important to really challenge subjects both with domain complexity and the extent of the material in order to obtain results which will scale-up for real situations."

It is therefore beneficial for the whole experiment to choose a learning task whose complexity will attract the interest of participants but, at the same time, will not discourage them from being able to fulfil it.

A number of potential tasks were considered, for example:

- a car engine maintenance problem,
- the operation of an electrical device,
- a household task,
- a computer hardware assembly task.

Computer assembly tasks are a good example of practical tasks that are reasonably complex and yet interest many people who use computers. They also involve computer hardware, so it is feasible to perform the experiment in a computer laboratory. What is more, their complexity can be easily adjusted to take into account the average experience of the likely participants. Another factor that influenced the choice of task material was that the experimental study would involve participants within the university (students or staff), so the participants were very likely to be computer users. Any participant who demonstrated significant knowledge about computer hardware, was excluded from the experiment. Finally, upgrading computer hardware is a topic that users know it is
important and they may occasionally require it (even if they do not normally do it) so it was felt that motivation would be high.

It was therefore decided to select the computer assembly task for the preliminary experiment, and use the results as a basis for planning and designing a much more detailed experiment. The computer assembly task involved installing and removing the CPU chip and the video card. This task has additional advantages. For example, participants will be able to notice real changes in the speed of specific computer procedures and image quality, which ought to increase motivation and provide a valuable learning experience.

5.2.2 The target subjects

The target group for experimentation were taken from an academic environment, including members of staff, post-graduate students or research students, from various departments in Loughborough University. The task used in the experiments was unsuitable for the general public. More details about the participants of the preliminary experiment are given in Section 5.5.

5.2.3. Media combinations used

Previous experiments have used the media combinations of text, speech and diagrams (including animation). In practical tasks additional media such as real images or video material may be appropriate. It was therefore decided to use these four different media combinations – Text-Only, Text + Diagrams, Sound + Diagrams and Text + Video. Each presentation is described in Section 5.4.

Design guidelines derived from earlier experiments were used in the design of the four presentations. For example, principles such as the Multimedia Principle, the Spatial Contiguity Principle, the Temporal Contiguity Principle, the Coherence Principle, the Modality Principle and the Redundancy Principle were all considered in the design. Additional design approaches were used which are explained during the descriptions of the material created.
5.2.4 The length of the experiment

Another important issue in the choice of a task is the time involved in actually carrying out the experiment. If it is too long it will be difficult to get participants to take part, and even if they do, motivation may still be a problem. From observations and discussions with technical staff in the Computer Science Department of Loughborough University, it was estimated that the experiment (including the presentation of the instructions, the completion of the task and the completion of relevant questionnaires) would take about 1 hour.

5.3 The experimental design

The task can be briefly described as follows:

"You are required to replace both the video card and the central processing unit in a personal computer in order to realise improved graphical performance and improved processing performance"

The core of the proposed task involves assembling common computer components. This requires a standard procedure of installation and removal that can easily be explained. The CPU and the video card are common components. Although the sound card could equally be regarded as a well-known computer component among computer users who have little computer assembly knowledge, it was rejected because there is not an easy way of measuring the performance of two different sound cards. In contrast, the video card and the central processing unit can readily be compared in terms of speed of processing and image quality. Thus, it was decided that the task would involve the replacement of both the CPU chip and the video card and observations of the effects of these replacements.

Since the experimental task is a practical one, the experimental set up will involve a target computer in which the video card and CPU need to be changed, and a computer providing advice and guidance through a multimedia presentation.

The teaching material was divided into two parts. The first part dealt with the installation of the video card, firstly as a concept and secondly as an item of computer hardware.
Learners were informed of its importance within a computer system. Then they were shown information firstly on how to identify a video card within a computer system, and secondly, on how to remove it. Next they were told how to install the new video card and where in the system to place it. A similar procedure was followed in the second part of the presentation, which consisted of information and instructions relating to the installation of the CPU of the system. Instructions were presented to learners on how to identify and remove the CPU chip from the computer system and on how to install the new one.

5.3.1 Design of the teaching material

The teaching material was designed for novices (in terms of knowledge of computer hardware and its physical replacement). In order to determine if a subject satisfied the criterion of being a ‘novice’ it was decided to pose a number of questions to subjects. These questions included:

- Have you ever performed or been involved in a computer assembly task?
- Have you ever seen a video card or a CPU chip?
- Can you identify a video card in the hardware in front of you?

Any participant who demonstrated such knowledge was excluded from the test. The participants responded to a call for experimental subjects and came from a number of departments (respondents included staff, postgraduates and undergraduates).

Advanced computer terminology was avoided where possible and whenever such a term had to be used it was defined before use. In any event, participants were asked at the conclusion of the experiment if there were any terms that they did not understand. This enabled such terms to be clarified in future experiments. Furthermore, the presentation was designed to be a series of small steps so that learners should never lose contact with the flow of new information. The textual content was designed to be understandable and easy to follow. Usage of terms across presentations was made consistent. Text that referred to parts of a diagram was placed near to those parts. Repeated sections of diagrams were made consistent. The amount of text placed on a single screen was
deliberately limited to about 150 words, and obscure phraseology was avoided. As with terminology, subjects were asked at the end of the experiment to identify any screens or sentences that were not understood.

The introduction to the learning task included a description of the workplace where the experiment would take place and a description of the two computers involved, one hosting the multimedia presentations and the other for performing hardware changes. Participants therefore became familiar with the workplace and especially working with the uncovered computer system. Furthermore, watching images and running programs on the target second computer allowed the effect of all the changes on performance caused by substituting the CPU and video card to be observed.

As has been discussed previously, the two assembly tasks were accompanied by additional information concerning the two components and their contribution to the performance of the computer system. As far as the video card is concerned, details were given for ISA slots, PCI slots and the RGB colour system. ISA slots belong to previous technology and since 2002 they have not been included within computer systems. That is why an old computer system was used for the purposes of the assembly tasks, so that both ISA and PCI slots would be present, enabling an ISA video card to be replaced by a PCI video card. ISA and PCI technology differ in two areas, the number of available colours per pixel and the speed of transferring data. ISA cards usually allow the use of up to 256 colours per screen pixel, whereas PCI cards allow the use of true colour, which is translated into millions of colours per pixel. This difference could be observed in practice by learners, by observing the same image, firstly using the ISA card and secondly using the PCI card. Issues concerning data transfer from the two cards to other computer components were not relevant to the practical task, and were only used as background teaching material. Learners were also informed about the RGB system, which generates the colours on the screen.

Additional information concerning CPU chips consisted of appropriate programs which could reflect CPU performance and the computer components that protect the CPU function. To estimate the differences in CPU performance resulting from the CPU change, participants were provided with a definition of prime numbers and how a
sequence would be constructed. They ran a program that calculated prime numbers between 1 and 100000 and displayed all of them on the screen along with the total time of the program's execution. This allowed learners to compare the times of the program's execution with the two different CPU chips and appreciate the improved performance resulting from the CPU change. In addition, participants were taught about the CPU fan and heatsink, which are responsible for preventing the CPU chip from getting overheated. They were taught about how to remove them, before attempting to remove the CPU, and how to replace them, when installing the new CPU in the computer system.

The teaching material used to build the multimedia presentations in the first experiment referred to two teaching sub-domains. The first one dealt with the theoretical background of computer components and the second one provided the instructions on how to perform the step-by-step removal and installation of the video card and the CPU of the computer system. To ease understanding, the presented information was organised into smaller sections. Table 5.1 summarises the six stages of the installation process of the video card and CPU.

Table 5.1: Summary of material used in the first experiment

<table>
<thead>
<tr>
<th>Part 1: Video card</th>
</tr>
</thead>
</table>
| Stage 1 | a) A description of the workplace.  
| b) The role of the video card in a computer system.  
| c) Participants watch an image using the colour option of 256 colours and notice its graphics quality. |
| Stage 2 | a) Instructions on how to identify and remove the old video card, and insert the new video card.  
| b) Participants are taught of RGB system and how to change screen colour settings from 256 colours to High Colour. |
| Stage 3 | Participants watch the same image as before using High Colour option and notice improvement in graphics quality. |

<table>
<thead>
<tr>
<th>Part 2: CPU</th>
</tr>
</thead>
</table>
| Stage 4 | a) The role of a CPU in a computer system.  
| b) Participants are taught about prime numbers and run a prime numbers program recording the time of its execution using the old CPU. |
| Stage 5 | a) Instructions on how to identify and remove the old CPU chip, and install the new one.  
| b) Instructions also include removal and replacement of the CPU fan. |
| Stage 6 | Participants again run the prime numbers program, record the new time of execution and notice the improvement in the processing speed of the new CPU. |
The whole teaching material that was used in the four presentations of the first experiment can be viewed in Appendix B (Section 1)

5.3.2 Common features of the four multimedia presentations

Four computer-based multimedia presentations were created for the purposes of the first experiment. Some attempt was made to not only create useful user-centred designs but, in addition, to communicate to users the design vision inherent in the interaction by using ideas from Semiotics (de Souza, 2005). Each presentation consisted of a different combination of two media (apart from the Text-Only presentation), so that comparisons could be made about the efficiency of these presentations to convey teaching material to participants and enable them to apply the included instructions successfully in order to fulfil practical tasks on computer hardware. All presentations consisted of identical material. The presentation, on which the design of all other presentations was based, was the Text-Only presentation. For example, the written text was the same as the spoken text. The video clips were based on the diagrams.

The four presentations were Text-Only, Text + Diagrams, Sound + Diagrams and Text + Video (which also used sound) and they were all designed using the Flash MX software (Ulrich, 2003). Giving the opportunity to handle efficiently each medium within presentations, Flash software enabled an attractive design to be created for all four presentations (there were many positive comments from subjects about the material).

As it has already been demonstrated in Table 5.1, each of the two main parts was divided into three stages and, in addition to this, each stage was further divided into smaller parts, which were called ‘steps’. Steps were used to organise presentations into groups of information so that learners could further organise teaching material enabling the construction of schemas within their memory, which would facilitate retrieval of information in future (Paivio, 1986; Sweller, 2002). A step was always at least one screen page in size (it could be more than one screen page in length). The number of screen pages in a step varied depending on the amount of information that the step contained. In addition to this, each ‘step’ consisted of smaller chunks of information, which were
called ‘sections’. Each screen page normally contained a reasonable number of ‘sections’, depending on the type of media used in a presentation, so that participants could gradually absorb unfamiliar teaching material before proceeding to the next step. The structure of information in the multimedia presentations into stages and steps is illustrated in Figure 5.1.

![Figure 5.1: Information structure in multimedia presentations of the first experiment](image)

Apart from the information structure, another feature that is common in all presentations is the means of interaction. In this first experiment, it was decided to only allow participants to move forward through the presentation. Participants were not allowed to review any previous sections of the presentation, so they had to be sure that they had fully absorbed information before moving one section forward, using a forward button.

All participants were timed while watching the presentation and fulfilling the practical tasks. The time was measured separately for each section and for the whole presentation. This could lead to indications of how efficiently participants were absorbing information to fulfil the learning tasks of the experiment. The duration of each presentation was not identical. In other studies, (Alty, Al-Sharrah and Beacham, 2003) all three media presentations were of the same duration, because the voice narration was designed to flow at the same pace as the flow of text in the other multimedia presentations. However,
in the experiments described in this thesis, the presentations had their own pace, based on
the natural features of the media that they were built from. The Text-Only presentation
had a faster pace than the Sound + Diagrams presentation, due to the fact that information
can be processed by human beings faster if in a textual form, rather than in an auditory
form.

Thus, the three common features of the four multimedia presentations used in the first
experiment are:

- Information was organised into stages, steps and sections.
- Forward movement (when feeling ready to move on) was the only means of
  interaction used.
- Participants were timed in order to identify how much time they need to absorb
  information.

5.4 The content of the presentations

The following sections deal with each multimedia presentation separately, demonstrating
those features that are common along with those features that differentiate them from
each other. All four presentations of the first experiment are included in the DVD
attached to this thesis.

5.4.1 Text-Only presentation

The Text-Only presentation was the first presentation to be created based on the chosen
teaching domain. Although a Text-Only presentation is the least 'media-rich' presentation, it does not necessarily mean that it will be the least effective. A striking
example has already been mentioned in the case of Beacham and Alty (2006), where the
Text-Only presentation was favoured by dyslexic students.

In the Text-Only presentation all the teaching material had to be converted into pure
textual form. This procedure used two important design principles. Firstly, the text should
be completely identical in all four presentations. The same text is used in the Text +
Diagrams presentation, accompanied by diagrams and pictures, in the Sound + Diagrams presentation in the form of narration over diagrams, and in the Text + Video presentation in the form of auditory narration over the video clips. Secondly, text syntax should be carefully constructed so as to enable the text not only to be able to stand alone, but to be easily applied in the other presentations as well.

In the Text-Only presentation, each screen page could sometimes include more than one section. In this case, according to the design scenario, when users moved on to the next section of information, the previous one would still be on screen, and this would continue until a logical group of sections was concluded. In such instances, the new sections were presented in a different text colour in order to be distinguishable. Figure 5.2 shows one Text-Only screen shot, and illustrates the design principles and the design scenario that were employed in the Text-Only presentation, including features such as the information structure and the interaction button at the bottom of the screen.

![Figure 5.2: Screen shot from the Text-Only presentation](image-url)
The 'go back' button was only there to enable subjects to go back if they accidentally moved to another screen page. Users were asked not to use it except for this purpose, and this was checked by the experimenter.

5.4.2 Text + Diagrams presentation

The design of the Text + Diagrams presentation was based on the textual content in the Text-Only presentation. As has already been discussed, textual information was constructed so that it could be used either alone or with accompanying diagrams. However, some textual information cannot have relevant diagrams or pictures associated with it. Some teaching material was theoretical in nature and the addition of diagrams was unnecessary. For example, the textual section:

"The concept of the first task you are about to fulfil is to find out the importance of the role that the video card plays in displaying the graphics on your monitor".

cannot be suitably added to with a diagram. However, the process of adding diagrams to the text repeatedly caused alterations to the initial Text-Only version, so that diagrams could be better connected to the contents of the text.

Inserting a diagram within the Text-Only presentation was a crucial procedure requiring careful design. Two basic principles were applied in the design of this Text + Diagrams presentation. These were the principles of Cognitive Load Theory and Mayer’s Spatial Contiguity Principle. According to these principles, the text and diagrams should be carefully connected, in terms of their relative placement on the screen. Careful placement of text and diagrams should secure a minimal cognitive load on the learners’ memory. Thus, diagrams were placed close to the part of the text that they were supporting. In addition to this, keywords that were strongly connected to diagrams were coloured in red to stand out from the rest of the text. When a keyword referred to a specific part of a diagram, an arrow connected the keyword with this part of the diagram. Such connection of text and diagrams is shown in Figure 5.3, which shows a screen shot from the Text + Diagrams presentation.
Figure 5.3: Screen shot from the Text + Diagrams presentation

All the diagrams that accompanied the text were also designed using Flash MX software. Real images were not used at all in this presentation, for two basic reasons. Firstly, using both diagrams and real images could hinder proper evaluation of the presentation, because these two types of image although they are both processed and stored in the nonverbal system of memory, they represent information in a different way. This was likely to affect the reliability of final results because real images had already been chosen to be represented in the Text + Video presentation (whenever the use of video clips was not feasible). Secondly, designed diagrams are more flexible than real images and enable designers to emphasise parts of the diagrams that contain important information or even apply animation to represent a part of a process. Animation was applied in some parts of the Text + Diagrams presentation to demonstrate processes such as inserting the video card in a slot or the CPU chip into the socket.
Due to the space occupied by diagrams, screen pages in the Text + Diagrams presentation often contained fewer sections compared with the Text-Only presentations. Thus, when text is accompanied by diagrams, the screen pages usually consist of one or two sections only. Whenever information could not be usefully supported by diagrams, screen pages were identical to the ones in the Text-Only presentation. The processing of information by subjects will usually take more time, due to the addition of diagrams.

5.4.3 Sound + Diagrams presentation

A recorded voice narrated the exact textual content that was included in the presentations of Text-Only and Text + Diagrams. For the purposes of voice recording, standard Windows software was used and the recordings were created at the optimum quality level to minimise background noise.

The Sound + Diagrams presentation was derived from the Text + Diagrams presentation, by replacing the text with voice narration. Therefore, the number of sections per screen page was identical in these two presentations.

Secondly, it is necessary to include a restricted amount of information within auditory sections due to the limited real-time ‘life expectancy’ of sound. Sound by its nature, in contrast with text and pictures, can only be processed sequentially and does not allow online revision, as it is quickly lost through time. The fact that the revision of information was prohibited in all the experimental presentations meant a possible favouring of textual and pictorial form over the auditory form. This is the factor that influenced the separation of textual information into sections, which had to be of reasonable size, so that they could be effectively represented by voice narration. Thus, although the absence of text enabled the presence of more diagrams in one screen page (and therefore more sections per screen page), this was not taken into account in the design of this presentation.

The connection of voice narration with diagrams was influenced by Mayer's Temporal Contiguity Principle by synchronising the sound with the diagrams. Diagrams appeared on screen as soon as the appropriate keyword was uttered by the voice narration, so that participants could best relate the two different forms of information.
Figure 5.3 can also illustrate a screen page in the Sound + Diagrams presentation, by assuming that the textual information is spoken and taking into account that diagrams were presented at the appropriate time to enable connection with the corresponding auditory information. Furthermore, the presentation is longer in time compared to the Text-Only and Text + Diagrams presentations, because sound is normally processed at a slower pace than written material.

5.4.4 Text + Video presentation

The design of the Text + Video presentation followed the other three presentations, since it was the last one to be designed. Like the Sound + Diagrams presentation, the Text + Video presentation had its origins in the Text + Diagrams presentation. Almost all diagrams, both static and animated, were replaced by video clips. The design took advantage of the design principles that had already been followed in the Sound + Diagrams presentation, because information which is conveyed to learners via video clips naturally includes a large amount of detail, some unnecessary, increasing the possibilities of additional cognitive load in human memory. For instance, learners who watch a video clip showing the process of inserting a video card into its slot, inevitably have to watch additional images of the background, which in most cases are not important as instructional information.

The Text + Video presentation had parts presented only in textual form. Furthermore, some static diagrams in the Text + Diagrams presentation either supported information about theoretical material, such as the prime numbers, or represented a procedure which is unsuitable to be included within a video clip. These diagrams were not replaced by video clips in the Text + Video presentation.

In this presentation, although there are two types of medium used to transfer the teaching material to learners, it does not necessarily imply that these media were closely synchronised, as in the other three multimedia presentations. Some text maintained its original form because video clips could not easily represent it (a limited number of screen pages in this presentation contained text-only information). Text was followed by a video clip, whose play was triggered by users as soon as they read and absorbed the textual
information that preceded the information in the video clip. Any connection of different media was carried out within the clips themselves, since video consists in this case of sound over animated real images. The sound in the video clips was represented by the voice narration that was used in the Sound + Diagrams presentation. Thus, voice narration was added over each corresponding video clip and was synchronised so that it could effectively be connected to the sequence of real images in the video clip.

Design of the Text + Video presentation had as its basis the design principles that featured in the other multimedia presentations. However, research on using video clips in a multimedia learning experiment is limited, so there is little information on the use of this sort of video material to transfer information to learners. Thus, design decisions, such as the playing mechanism of the video clips and their position on the screen, were influenced by personal judgement and use of video clips in other presentations, such as those within a web page. Eventually, construction of this multimedia presentation was successfully carried out, as the presentation managed to comply with the basic principle of using identical information in all presentations, due to the use of the same voice narration within video clips. In addition to this, users could only play a video clip once, according to the general principle of not reviewing information.

The total duration of this presentation was independent of the other presentations due to the fact that it contained both text and sound as types of media to present teaching material.

Figure 5.4 shows a screen page extracted from the Text + Video presentation, also demonstrating the playing mechanism of the video clips and the relative size of the window that hosted the clip.
5.5 Participants in the first experiment

In this first prototype experiment, 24 people participated. The experiment took place within Loughborough University, and the participants were either students (undergraduate, postgraduate or research students) or university staff. Selection of participants was based only on their level of background knowledge, aiming for people whose learning experience did not include computer assembly or any detailed knowledge about computer hardware in general. Although some participants were likely to be familiar with computer hardware in terms of computer terminology and vague knowledge of their function, as all of them were computer users, the extent of this knowledge was identified via pre-questionnaires (discussed later in Section 5.6.1).

Participants were recruited in a sequence and they were divided into four groups (as many as the number of multimedia presentations), balanced as far as possible according
to their results from the Felder-Soloman test, so there was an attempt to balance all groups over sensing and intuitive learners.

There was no attempt to provide an even distribution of female and male participants, or English or non-English participants over the four groups. Thirteen participants were male and 11 were female, whereas only 4 participants had English as their first language. However, because all non-English participants were either postgraduate or research students, and the fact that the task was practical in nature with relatively straightforward information material, it was expected that no additional cognitive effort would be required for these students. Participants were informed beforehand of the criteria that would decide upon their suitability for taking part in the experiment, and this resulted in a set of participants whose knowledge background did not include computer assembly.

5.6 Measuring the learning achieved

The usual method of examining the amount of learning that students have gained from teaching materials involves the use of learning tests. Apart from their obvious use in academic fields, where they test learners for the effectiveness of their studying efforts, learning tests also attempt to evaluate the efficiency of a teaching method. In this experiment the learning test was chosen to evaluate the teaching efficiency of each multimedia presentation. Learning tests are usually questionnaires and the type of questions that they consist of strongly depends on the learning domain of the teaching material. Thus, the construction of the learning test for the purposes of the first experiment was chosen to reflect the practical nature of the learning tasks involved in the multimedia presentations.

There are a number of question types that have been included within earlier learning tests. The first type is a recall question. These are questions that examine how well learners have stored information in their memory and are able to retrieve them. The second type is a recognition question. These are multiple choice questions that require learners to compare different pieces of information currently stored in their memory and they have to identify the right answer from the presented set. In Mayer's (2001) research on multimedia learning, 'transfer knowledge' questions were also used. These questions
attempted to examine how well learners absorbed the teaching material and required them to predict the content of additional teaching material (that has not yet been taught but is strongly related to the material already presented to the learners), or to deal with problem solving situations. All these types of question examine how each media combination enables learners to remember (recall or recognise) and understand (learn) the material.

The basic concern of the first experiment was to construct a learning test that would effectively measure how learners remembered and understood the information. Because this first experiment served as a guide for designing and carrying out later experiments, it was decided to construct two types of learning test, so that evaluation of their results would enable the design of a more reliable learning test in the second experiment. The first type consisted exclusively of recall questions, in which learners were required to remember part of the teaching material in order to write down the correct answer. The second type consisted wholly of recognition questions, in which learners were asked to choose the right answer from a selection of answers. In this type, the number of potential answers that accompanied each question varied from three to four possible answers on average, although there were a few particular questions with less (two) or more (five) potential answers. In addition to this, for each group of participants, half of them would complete the first type of questionnaire, whereas the other half would fill in the second type, so that results on both types of questionnaire could be fairly compared in order to provide a pointer to the validity of the learning tests. Both types of questionnaire included a number of questions that tested how efficiently learners were able to transfer their knowledge in order to answer new problems or questions related to the material that they were taught in the multimedia presentations.

There were 32 sections of the material about which participants were tested on recalling or recognising information and on using specific information to solve or answer related problems or questions. These 32 parts covered almost all of the teaching material, either referring to theoretical material (i.e. the RGB system or the prime numbers) or to material related to the computer assembly tasks which had previously been completed by the participants. Creating the two types of questionnaire involved constructing 32 equivalent questions. These equivalent questions were formed, each one corresponding to one of the 32 parts of the teaching material. The recall questions were chosen first and these
determined the construction of the corresponding 32 recognition questions. Transforming a recall question to a recognition question sometimes caused alterations to the original recall question so that both types of questions were as equivalent as possible. The same procedure took place in creating the 'transfer knowledge' questions. An example of two equivalent questions, one belonging to the recall type (1) and the other to the recognition type questionnaire (2), is given below:

1. Where is the CPU fan located in relation to the CPU heatsink?

2. The CPU fan is located:
   a) On the left of the CPU heatsink
   b) On the right of the CPU heatsink
   c) On the top of the CPU heatsink
   d) Under the CPU heatsink

Both recall and recognition learning test can be viewed in Appendices C (Section 3) and C (Section 4).

5.6.1 Effects of prior knowledge in the learning test

In any learning experiment, where participants may have some previous knowledge of the subject matter, it is important to allow for such previous knowledge in assessing the knowledge gained. This is important because research on multimedia learning is attempting to evaluate the learning that has been gained exclusively by watching the teaching material via the multimedia presentations rather than existing previous knowledge.

Mayer has taken prior knowledge into consideration in his own research on multimedia learning (Mayer & Gallini, 1990; Mayer & Sims, 1994; Mayer et al., 1995). In order to identify prior knowledge of the students and examine how this could affect the results, Mayer used a general questionnaire in order to identify the relevant aspects of the background knowledge of each participant. Based on the answers to this questionnaire, Mayer estimated which answers of the learning test were based on prior knowledge of the
participants and which were based on knowledge that had been gained during the multimedia presentations. Alty et al. (2003) on the other hand, applied another method for identifying prior knowledge in their studies. They gave participants the opportunity of assessing the amount of prior knowledge themselves for each question.

To identify participants’ background knowledge for the first experiment, the methods of both Mayer and Alty were used, in order to increase the validity of the procedure. Participants were required to complete an initial pre-questionnaire, whose general questions attempted to clarify which parts of the teaching material they already knew (this questionnaire can be viewed in Appendix C (Section 1)). In addition, in the final learning test, they also assessed their prior knowledge of the presented teaching material. A combination of these two methods identified which questions were answered due to prior knowledge and, therefore, needed to be allowed for in final analysis of results. In fact, the levels of prior knowledge that could affect the completion of the learning test were usually very low, due to the call for participation that clearly excluded people whose learning experience included computer assembly or any relevant knowledge on computer hardware.

5.6.2 Scoring mechanism

The questions that were included in the learning test varied in levels of difficulty. The criteria for defining these levels of difficulty depended upon the complexity of each question, which was characterised either by the amount of thinking or the amount of verbal explanation needed to provide a correct answer. For instance, the question “Where is the CPU fan located in relation to the CPU heatsink?” can be regarded as an easier question compared with the question “Why are the CPU fan and the CPU heatsink necessary for the proper function of the CPU?”. In the case of recognition questions, the complexity of questions can only be defined by the amount of thinking that is necessary to provide an answer. However, it is likely to lead to unreliable results if recognition questions are classified at different levels of complexity, taking into account that answers are always accomplished through a choice of one (or two in some particular cases) correct answers.
The complexity of questions was divided into four levels in both types of questionnaire. Level 1 included the easiest questions and level 4 defined the most difficult. Scoring was based on the level that each question belonged to. In addition, Level-1 questions granted participants with one point, Level-2 questions granted them with two points, Level-3 questions granted them with 3 points and Level-4 questions granted them with 4 points. Classification of each question into the appropriate level was carried out by the two experimenters who endeavoured as far as possible to minimise any effect of their own prior knowledge. In recall questions, the classification of each question into the appropriate level depended on the amount of information required to provide a correct answer and on the complexity of the specific part of the teaching material that the question was addressed to. On the other hand, the recognition questions were classified to the appropriate level of complexity depending on the number of correct answers that had to be selected, the difficulty of recognising the correct answer among the wrong answers and, similarly to the recall questions, on the complexity of the teaching material that they were addressed to.

Most of the corresponding questions in each type of questionnaire belonged to the same level, due to the same part of the teaching material that they examined for learning. However, in a limited number of questions, recall questions and their corresponding recognition questions belonged to different levels of complexity. This difference was caused by the factors that affected the complexity of the two types of question, such as the amount of written information in the recall questions or the number of correct answers that had to be selected, as these have been discussed above. In total, all 32 questions in both types of questionnaire granted the participants an optimum score of 46 points, in the situation that they answered all correctly.

Although the results of comparing the two different questionnaires would be expected to reveal a better performance of those participants who answered the recognition questions, the construction and employment of both questionnaires in the first experiment was necessary, firstly to provide research with useful results and secondly to identify any parts of the teaching material that could be better tested using one or other of the two types of questions.
Results were based on this scoring mechanism to reflect the general performance of participants on watching information presented through a particular media combination and understanding the material. In addition to this, the learning test was separated into two parts. The first part consisted of questions that were addressed to material that was presented in text-only (or sound-only) form in all presentations (as it has already been discussed, the teaching material did not enable the presence of diagrams in all of its parts). The second part included the majority of the questions that referred to material that was accompanied by diagrams (or video clips). This separation allowed research to reach to additional suggestions on multimedia learning, such as the difference in the teaching strength of text-only and sound-only information. Also, results would take into account the time that was spent on watching the relevant information for answering each question, and would search for any connection between time and effective storage of information.

5.7 The scenario for the first experiment

This section summarises the whole procedure of the experiment, describing its main features step by step and their contribution to the final results. Emphasis is given to details that differentiate this experiment from previous similar experimental work and details which supported its validity and its importance for being the basis for the design of the second experiment.

First of all, the experiment was carried out with individual participants, as opposed to the participation in one session by the whole class that was observed in the experimental work of other researchers. This fact made it easy to control the prior knowledge level of participants, because only subjects who met the criteria of participation requiring minimum or no knowledge of the teaching material were accepted. Secondly, the individual experiments enabled the researcher to closely observe each participant and notice his/her reaction to specific parts of the experiment, In this way a number of valuable observations in relation to their motivation, their competence in handling the multimedia design, the way information was presented to them and their performance in the final learning test, were made.
The first stage of the experiment required the participants to complete two questionnaires. The first one was a general questionnaire, which revealed any background knowledge of the participant related to the teaching material contained in the multimedia presentations. The second one was the Felder-Soloman test which identified the participants’ learning styles. Depending on the results regarding the Dimension of Perception (sensing and intuitive learners) each participant was allocated to the appropriate multimedia presentation for watching the information material in order to balance the groups. In addition to this, the participant was given a brief description of what kind of information was going to be presented to him/her and via which media combination. This description also included details about the use of the interaction button that moved participants one section forward and about the restriction of being able to move forwards only.

The second step involved the main part of the experiment that required the participant to watch the corresponding multimedia presentation. If the presentation was either the Sound + Diagrams or the Text + Video presentation, the participant was provided with headphones. The scenario for each presentation allowed learners to experience in real time all the details of the teaching material about the computer system. For instance, every time a computer component was described, along with its position on the motherboard, the participant was asked to move to the other (experiment) computer and identify the component. The experimenter checked that the correct component was identified. When required to remove or replace components, the participant was taught in real time what to do. The step was then carried out before moving to the next one. In this first experiment, participants were not marked for their performance on the practical tasks, such as installing the new CPU, however they were timed, in order to identify any relationship between the time taken to complete the task and the method of presentation. The motivation of the participants was kept high by demonstrating to them differences in the performance of the computer system after carrying out hardware changes. When changing the video card of the computer system, the participants watched the same image before and after replacing the old video card and then wrote down any optical differences in the image. In the case of changing the CPU of the system, the participants ran the prime numbers program before and after changing the CPU and then wrote down the difference in the duration of the program’s execution. Each participant was enabled to
realise the changes in the computer performance (in terms of process speed and image quality) by answering a small questionnaire after watching an image (firstly using the old video card and secondly using the new video card) and after running an appropriate program (firstly using the old CPU and secondly using the new CPU). This questionnaire can be viewed in Appendix C (Section 2).

The final step of the experiment required the participant to complete the learning test (one of the two types of questionnaire), based solely on the material that has just been presented. For each of the 32 questions, the participant stated if he/she had answered the question based on the material that had just been presented or on prior knowledge originating from other sources. This completed the experiment.

Overall, all the research findings of the first experiment are discussed in the next chapter and were used to support the construction and design of the second experiment.
Chapter 6  Results of the first multimedia learning experiment

6.1 Introduction

The main objective of this first experiment was to explore how a second, more substantial, experiment should be designed. The results are divided into three categories.

- General Performance
- Time taken to assimilate information and the performance achieved
- Learning Achieved

The first category refers to the general performance of the participants on the learning test, taking into account factors that were regarded as being of major importance for influencing the results. These factors were:

- Prior knowledge. How did it vary and how did it affect performance?
- The importance of diagrams. For example, the Text-Only presentation could not include diagrams. Even in the Text + Diagrams presentation there were instances where a diagram could not usefully be constructed.
- How effective and relevant were the questions in measuring learning?

The second category refers to the relationship (if any) between time and performance. In other words, is there a connection between the time used by each participant to absorb a specific piece of teaching material and their overall learning achievement? In addition, this category also deals with the time that was spent by each participant to complete subtasks of the practical exercises. For example, can improved absorption of information lead to faster execution of a practical task?

The third category deals with the suitability of the learning test itself. Firstly, the performance of the participants who were tested using recall questions and those who were tested using recognition questions is analysed in order to examine which type of question was more effective in testing the participants' learning of the teaching material. Secondly, all questions were individually examined to determine their ease or difficulty
in being answered by participants, in order to determine if any alterations need to be made to the learning test that was going to be constructed for the second experiment.

Finally, there is a general analysis of the effectiveness of the multimedia design so that improvements can be planned for the material for the second experiment.

6.2 General performance

The first stage of the discussion on the results of the first experiment deals with the performance of the participants on the learning test that followed the multimedia presentations. Comparisons were made between the four groups of participants, each one being presented with the same teaching material in different media combinations. In each group, half of the participants completed the learning test involving recall questions and the other half were assigned to the learning test that involved recognition questions. This would enable an evaluation of the effect of these two types of question.

Initially, overall performance of the participants in answering all 32 questions of the learning test is examined. These results are then progressively refined, as more factors are taken into consideration. In each step, suggestions are made in relation to the original aims and objectives of this experimental work, such as the validity of Dual Coding Theory, and in comparison to the results of previous steps. This procedure enabled the amount of influence that specific factors might have in multimedia learning to be identified.

6.2.1 Overall performance in the learning test

This first analysis of the results examines how the 24 participants performed in the whole learning test, regardless of the type of question that was allocated to them and regardless of their prior knowledge. The performance of each participant is the score obtained using the 32 questions described in the previous chapter (the maximum number of marks was 46). Each question carried a score of between one and four points (depending upon the difficulty of the question). In recall questions, partial answers (and therefore partial scores) were possible. In recognition questions, the answer was obviously restricted to a
finite set (which may contain more than one answer). If the question has more than one correct answer, participants could get a mark between 0 and the maximum score (this occurred in only three questions). Two experimenters independently assigned the marks awarded to each question and where the assignments disagreed, a compromise agreement was eventually reached. Disagreements occurred only in a few questions.

The final score is expressed as a percentage rather than as an absolute score. This allows a comparison to be made between these scores and those obtained after the effects of prior knowledge have been allowed for, because pre-knowledge of a question excludes the mark for that question and hence the maximum score. Based on the above scoring mechanism the Text-Only group scored 62.2% on average, the Text + Diagrams group scored 79.5% the Sound + Diagrams group scored 67.6% and the Text + Video group scored 67.7%.

The overall performance of the four groups of participants in the learning test supports the main principle of Dual Coding Theory – that dual coding processing appears to be superior to single code processing though the number of subjects is too small for significant results to be obtained. The Text-Only group has the worst performance in the 32 questions of the learning test. What is more, learners in two of the three multimedia presentations that presented using multiple media (the Sound + Diagrams and the Text + Video presentations) did achieve a slightly higher score than the Text-Only group, but not significantly so. The scores for the Sound + Diagrams group and the Text + Video group are almost identical. Considering the multimedia design of the corresponding presentations of these two groups, the main difference is the replacement of most diagrams of the Sound + Diagrams presentation with video clips in the Text + Video presentation. Therefore, the addition of video clips did not improve the performance of the Text + Video group. Interestingly, the Text + Diagrams group outperformed all other groups, reaching higher standards of performance. However, no suggestions or conclusions should be made at this stage, because other factors might affect the groups' performance.
6.2.2 The effect of prior knowledge

It is interesting at this stage to examine how knowledge that already existed in the memory of the participants before the experiment might have affected the results. As has already been discussed in Chapter 5, the method for identifying the prior knowledge of learners of the domain in the first experiment, involved a combination of a pre-questionnaire and a self-assessment performed by learners themselves during the test (i.e. their opinion). One way of dealing with this is to exclude the score of questions where the participant has indicated prior knowledge when analysing the performance of the participants. One interesting issue here is to decide whether the score for a question should be excluded if the participant indicates prior knowledge but gets the answer wrong! Since this would mean that the prior knowledge that the participant used did not aid in answering the question, this mark was not excluded.

Excluding prior knowledge in this way, the Text-Only group score changed to 60%, the Text + Diagrams scored 74.9%, the Sound + Diagrams 66.1% and the Text + Video 61.2%. The performance of all groups, taking into account prior knowledge is also illustrated in Figure 6.1.

![Figure 6.1: Results on overall performance of all groups (with and without an allowance for prior knowledge)](image)

Although the performance appears to decrease when prior knowledge is allowed for, the difference is not significant. An SPSS Mann-Whitney non-parametric analysis with
normalised data gave a random probability of \( p<0.358 \), as shown in Table 6.1. Since there is no significant difference because of the effects of prior knowledge, it has been ignored in subsequent analyses of this first experimental data.

<table>
<thead>
<tr>
<th>Score</th>
<th>243.500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mann-Whitney U</td>
<td>543.500</td>
</tr>
<tr>
<td>Wilcoxon W</td>
<td>-918</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td>.358</td>
</tr>
</tbody>
</table>

Interestingly, participants did not appear to benefit from the use of video material. Perhaps this is a natural characteristic of the video material, which presents (possibly irrelevant) information that does not contribute to learning, but requires some space in human memory. The Text + Diagrams group had a tendency to outperform all groups in this stage as well, but again the numbers are too small to give a statistically significant result.

### 6.3 Text-only questions across media

The material that was used in all four multimedia presentations involved media combination. However, some sections of the presentations used a single medium (for example text-only or voice-only) because the other media were not useful in these instances (one example is where the presentation defines an ISA card to stand for Industry Standard Architecture; no diagram would help in this case). Thus, in the Text + Diagrams presentation, there were some sections that were presented in a text-only form. These same sections were also presented in a sound-only form in the Sound + Diagrams presentation and in a text-only form in the Text + Video presentation. In contrast there were sections that used multiple media to advantage.

One could argue that comparing the learning achieved in a Text-Only presentation with that in a Text + Diagrams presentation when some of the questions are text-only in both will weaken the comparison in performance. These were therefore excluded and a re-analysis of the results was performed to see how much participants were adversely
affected by this. This excluded 13 questions making the optimum score in the remaining questions 29.

In this case the Text-Only group scored 64.4% (with prior knowledge excluded, 62.9%), the Text + Diagrams scored 81.3% (78.8%), the Sound + Diagrams 70.7% (69.2%) and the Text + Video 67.7% (63.2%). Interestingly as pointed out earlier, excluding prior knowledge has no appreciable effect. These results are compared with the overall results shown in Figure 6.2.

Figure 6.2: Results when common text-only questions are excluded from the presentations

The changes are small and are certainly not significant. Apart from Text + Video, where there is no change, all other cases show a qualitative increase. With many more subjects in the second experiment it is probably advisable to avoid having questions which are text-only across the presentations even though the effect is small (if any) in this case.

The advantages of diagrams which have been reported in other work (e.g. Mayer, 2001; Alty, 2002; Alty et al., 2003) appear to be present in the results, though of course the results are not significant because of the low numbers of subjects.
6.4 Level of difficulty in questions of the learning test

Another interesting issue is whether different questions in the test were harder than others across all presentations, or whether they were more difficult when presented in one media combination than another. Ideally, the questions should be of an adequate complexity so that they efficiently test the potential of each media combination to convey information that can be successfully stored and retrieved. Questions that are very easy to answer across media combinations will fail to differentiate the ability of remembering and learning information between participants who watched different multimedia presentations. On the other hand, very difficult questions may equally produce scores across all different media presentations. Therefore, each of the 32 questions, that formed both types of the questionnaires, was evaluated to check how participants performed overall.

The importance of identifying questions that are excessively hard or easy has an important objective. This objective is the design of the learning test that is going to be used in the second multimedia learning experiment on the same domain. Any questions that are characterised as too easy or too difficult to be answered overall will be altered (or even excluded) in the new design of the learning test for the second experiment, so that a more reliable learning test can be constructed.

The average score obtained by participants in each question, for each of the media combinations was calculated and is shown in Table 6.2. These scores were calculated by adding up the score for each question and dividing this score by the maximum possible score per presentation. This was then converted to a percentage to enable a comparison to be made. Column 6 shows the average over the four media, and column 7 is a measure of the spread of performance across media (sum of the squared differences from the average). The variability is important and accounts for the differences in overall performance.
Table 6: Average performance on each question across the various media

<table>
<thead>
<tr>
<th>Question</th>
<th>T-Only</th>
<th>T + D</th>
<th>S + D</th>
<th>T + V</th>
<th>Average</th>
<th>Variability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>58.3</td>
<td>100.0</td>
<td>58.3</td>
<td>100.0</td>
<td>79.2</td>
<td>1736.4</td>
</tr>
<tr>
<td>Q2</td>
<td>58.3</td>
<td>75.0</td>
<td>66.7</td>
<td>50.0</td>
<td>62.5</td>
<td>347.3</td>
</tr>
<tr>
<td>Q3</td>
<td>75.0</td>
<td>75.0</td>
<td>75.0</td>
<td>75.0</td>
<td>75.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Q4</td>
<td>50.0</td>
<td>83.3</td>
<td>45.8</td>
<td>41.7</td>
<td>55.2</td>
<td>1089.2</td>
</tr>
<tr>
<td>Q5</td>
<td>75.0</td>
<td>100.0</td>
<td>66.7</td>
<td>33.3</td>
<td>68.8</td>
<td>2274.5</td>
</tr>
<tr>
<td>Q6</td>
<td>33.3</td>
<td>33.3</td>
<td>66.7</td>
<td>41.7</td>
<td>43.8</td>
<td>746.8</td>
</tr>
<tr>
<td>Q7</td>
<td>66.7</td>
<td>83.3</td>
<td>100.0</td>
<td>66.7</td>
<td>79.2</td>
<td>763.7</td>
</tr>
<tr>
<td>Q8</td>
<td>33.3</td>
<td>60.0</td>
<td>0.0</td>
<td>40.0</td>
<td>33.3</td>
<td>1866.7</td>
</tr>
<tr>
<td>Q9</td>
<td>26.7</td>
<td>60.0</td>
<td>40.0</td>
<td>40.0</td>
<td>41.7</td>
<td>566.6</td>
</tr>
<tr>
<td>Q10</td>
<td>33.3</td>
<td>100.0</td>
<td>50.0</td>
<td>50.0</td>
<td>58.3</td>
<td>2500.2</td>
</tr>
<tr>
<td>Q11</td>
<td>88.9</td>
<td>77.8</td>
<td>88.9</td>
<td>100.0</td>
<td>88.9</td>
<td>246.9</td>
</tr>
<tr>
<td>Q12</td>
<td>66.7</td>
<td>100.0</td>
<td>83.3</td>
<td>75.0</td>
<td>81.3</td>
<td>607.5</td>
</tr>
<tr>
<td>Q13</td>
<td>33.3</td>
<td>66.7</td>
<td>66.7</td>
<td>75.0</td>
<td>60.4</td>
<td>1024.6</td>
</tr>
<tr>
<td>Q14</td>
<td>33.3</td>
<td>33.3</td>
<td>16.7</td>
<td>66.7</td>
<td>37.5</td>
<td>1319.5</td>
</tr>
<tr>
<td>Q15</td>
<td>33.3</td>
<td>83.3</td>
<td>16.7</td>
<td>16.7</td>
<td>37.5</td>
<td>2985.6</td>
</tr>
<tr>
<td>Q16</td>
<td>100.0</td>
<td>100.0</td>
<td>83.3</td>
<td>100.0</td>
<td>95.8</td>
<td>208.4</td>
</tr>
<tr>
<td>Q17</td>
<td>83.3</td>
<td>100.0</td>
<td>66.7</td>
<td>79.2</td>
<td>82.3</td>
<td>568.4</td>
</tr>
<tr>
<td>Q18</td>
<td>100.0</td>
<td>83.3</td>
<td>100.0</td>
<td>100.0</td>
<td>95.8</td>
<td>208.4</td>
</tr>
<tr>
<td>Q19</td>
<td>85.8</td>
<td>100.0</td>
<td>83.3</td>
<td>95.8</td>
<td>91.2</td>
<td>189.6</td>
</tr>
<tr>
<td>Q20</td>
<td>100.0</td>
<td>100.0</td>
<td>66.7</td>
<td>100.0</td>
<td>91.7</td>
<td>833.2</td>
</tr>
<tr>
<td>Q21</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Q22</td>
<td>83.3</td>
<td>100.0</td>
<td>66.7</td>
<td>100.0</td>
<td>87.5</td>
<td>763.8</td>
</tr>
<tr>
<td>Q23</td>
<td>73.3</td>
<td>93.3</td>
<td>86.7</td>
<td>93.3</td>
<td>86.7</td>
<td>266.7</td>
</tr>
<tr>
<td>Q24</td>
<td>66.7</td>
<td>83.3</td>
<td>100.0</td>
<td>50.0</td>
<td>75.0</td>
<td>1388.8</td>
</tr>
<tr>
<td>Q25</td>
<td>83.3</td>
<td>66.7</td>
<td>83.3</td>
<td>83.3</td>
<td>79.2</td>
<td>208.2</td>
</tr>
<tr>
<td>Q26</td>
<td>75.0</td>
<td>66.7</td>
<td>83.3</td>
<td>16.7</td>
<td>60.4</td>
<td>2690.6</td>
</tr>
<tr>
<td>Q27</td>
<td>77.8</td>
<td>77.8</td>
<td>100.0</td>
<td>88.9</td>
<td>86.1</td>
<td>339.4</td>
</tr>
<tr>
<td>Q28</td>
<td>100.0</td>
<td>100.0</td>
<td>75.0</td>
<td>100.0</td>
<td>93.8</td>
<td>468.8</td>
</tr>
<tr>
<td>Q29</td>
<td>50.0</td>
<td>83.3</td>
<td>83.3</td>
<td>91.7</td>
<td>77.1</td>
<td>1024.3</td>
</tr>
<tr>
<td>Q30</td>
<td>83.3</td>
<td>91.7</td>
<td>79.2</td>
<td>58.3</td>
<td>78.1</td>
<td>603.5</td>
</tr>
<tr>
<td>Q31</td>
<td>25.0</td>
<td>41.7</td>
<td>33.3</td>
<td>50.0</td>
<td>37.5</td>
<td>347.3</td>
</tr>
<tr>
<td>Q32</td>
<td>58.3</td>
<td>91.7</td>
<td>83.3</td>
<td>66.7</td>
<td>75.0</td>
<td>694.6</td>
</tr>
</tbody>
</table>

A plot of the results for the four media is shown in Figure 6.3.
Figure 6.3: The distributions of percentage of correct answers across the four media

Text + Diagrams has a distinct pattern from the others. Not only are there many more correct answers, additionally, there are very few poor answers (only three answers under 50%). An ANOVA analysis did not reveal a significant difference in the percentage of correct answers across presentations \( (F (3, 124) = 2.518, p<0.061, N=128) \), as displayed in Table 6.3.

Table 6.3: ANOVA results on the correct answers across presentations

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>4447.313</td>
<td>3</td>
<td>1482.438</td>
<td>2.518</td>
<td>.061</td>
</tr>
<tr>
<td>Within Groups</td>
<td>73006.924</td>
<td>124</td>
<td>588.766</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>77454.237</td>
<td>127</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Descriptive Statistics are displayed in Table 6.4.
Table 6.4: The Descriptive Statistics for the correct answers across presentations

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>95% Confidence Interval for Mean</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
<td>Upper Bound</td>
<td></td>
</tr>
<tr>
<td>Text-Only</td>
<td>32</td>
<td>65.95</td>
<td>24.53</td>
<td>4.3373</td>
<td>57.11</td>
<td>74.80</td>
<td>25</td>
</tr>
<tr>
<td>Text + Diagrams</td>
<td>32</td>
<td>81.58</td>
<td>19.72</td>
<td>3.4861</td>
<td>74.47</td>
<td>88.69</td>
<td>33</td>
</tr>
<tr>
<td>Sound + Diagrams</td>
<td>32</td>
<td>69.24</td>
<td>25.73</td>
<td>4.5479</td>
<td>59.96</td>
<td>78.51</td>
<td>.0</td>
</tr>
<tr>
<td>Text + Video</td>
<td>32</td>
<td>70.18</td>
<td>26.50</td>
<td>4.6848</td>
<td>60.62</td>
<td>79.73</td>
<td>17</td>
</tr>
<tr>
<td>Total</td>
<td>128</td>
<td>71.74</td>
<td>24.69</td>
<td>2.1828</td>
<td>67.42</td>
<td>76.06</td>
<td>.0</td>
</tr>
</tbody>
</table>

However a Tukey’s LSD test (which examines the significance levels across two groups), revealed a significant difference in the percentage of correct answers between the Text-Only and Text + Diagrams groups (p<0.01) and between the Text + Diagrams and the Sound + Diagrams groups (p<0.044). In both cases the percentage of correct answers was higher in the Text + Diagrams group. Results of the LSD test are displayed in Table 6.5.

Table 6.5: Difference in the correct answers across any two presentations

<table>
<thead>
<tr>
<th>(A) Presentation</th>
<th>(B) Presentation</th>
<th>Mean Difference (A-B)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td></td>
<td>Sound + Diagrams</td>
<td>-3.28</td>
<td>6.0661</td>
<td>.589</td>
<td>-15.29</td>
</tr>
<tr>
<td></td>
<td>Text + Video</td>
<td>-4.22</td>
<td>6.0661</td>
<td>.487</td>
<td>-16.23</td>
</tr>
<tr>
<td></td>
<td>Text-Only</td>
<td>15.62(*)</td>
<td>6.0661</td>
<td>.011</td>
<td>3.62</td>
</tr>
<tr>
<td></td>
<td>Sound + Diagrams</td>
<td>12.34(*)</td>
<td>6.0661</td>
<td>.044</td>
<td>.33</td>
</tr>
<tr>
<td></td>
<td>Text + Video</td>
<td>11.40</td>
<td>6.0661</td>
<td>.063</td>
<td>-.61</td>
</tr>
<tr>
<td></td>
<td>Text-Only</td>
<td>3.28</td>
<td>6.0661</td>
<td>.589</td>
<td>-8.72</td>
</tr>
<tr>
<td></td>
<td>Text + Diagrams</td>
<td>-12.34(*)</td>
<td>6.0661</td>
<td>.044</td>
<td>-24.35</td>
</tr>
<tr>
<td></td>
<td>Text + Video</td>
<td>-.94</td>
<td>6.0661</td>
<td>.877</td>
<td>-12.95</td>
</tr>
<tr>
<td></td>
<td>Text-Only</td>
<td>4.22</td>
<td>6.0661</td>
<td>.487</td>
<td>-7.78</td>
</tr>
<tr>
<td></td>
<td>Text + Diagrams</td>
<td>-11.40</td>
<td>6.0661</td>
<td>.063</td>
<td>-23.41</td>
</tr>
<tr>
<td></td>
<td>Sound + Diagrams</td>
<td>.94</td>
<td>6.0661</td>
<td>.877</td>
<td>-11.07</td>
</tr>
</tbody>
</table>

* The mean difference is significant at the .05 level.
Some questions were answered similarly across media and this is reflected in a low variability score. Question 21, for example, was correct for every medium (every single participant gave the correct answer) so the variability was zero, though one would normally expect some variation even for an easy question. Questions that were easy to answer across media, have a high average (over 87.5%) and low variability (under say 900). From Table 6.2, questions 11, 16, 18, 19, 20, 21, 22, and 28 fall into this category. Uniformly harder questions obtained much lower percentages correct overall (less than a 50% average). Examples are questions 6, 8, 9, 14, 15 and 31.

In this evaluation, the complexity of the questions was divided into six categories, depending on the total average score for each question and the spread of the answers across media. Three score ranges were defined 0 – <51, 51 – <87.5 and 87.5 - 100. Two variability ranges were used 0 – 900, and 901 – 3000. Table 6.6 shows the distribution of questions over these ranges.

<table>
<thead>
<tr>
<th>Table 6.6: Distribution of scores and variability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Score &lt;51</td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>Variability 0 - 900</td>
</tr>
<tr>
<td>Variability 901 - 3000</td>
</tr>
</tbody>
</table>

The variability is, of course, more limited for low and high averages. The limit for a really hard question was defined as <25% overall, but this did not occur so no question could be regarded as 'too hard'.

6.4.1 Analysis of the easy questions

A question might be easy to answer because of the existence of prior knowledge. For instance, the subject of prime numbers, which was covered by the teaching material in both experiments, is a domain that most of the postgraduate students, who formed the majority of the participants, would know about already. A really hard question might require access to prior knowledge that the participants did not possess.
The problem with questions that are too easy or too complex is that they will not play any significant role in highlighting the differences in performance between media. The questions identified as easy in Table 6.6 are shown in Table 6.7.

<table>
<thead>
<tr>
<th>No.</th>
<th>Question</th>
<th>Average score</th>
<th>Variability</th>
</tr>
</thead>
</table>
| 11  | 1. Where is it best to take hold of the video card? Choose the appropriate diagram from below (a, b, or c)  
    2. Where is it best to take hold of the video card and why? | 88.9 | 246.9 |
| 16  | 1. Which are the three colour channels that determine the colour of a pixel?  
    a) Grey, Red, Blue  
    b) Brown, Green, Red  
    c) Red, Green, Black  
    d) Green, Blue, Red  
    e) Red, Grey, Brown  
    2. Which are the three colour channels that determine the colour of a pixel? | 95.8 | 208.4 |
| 18  | 1. The CPU:  
    a) Processes the colours displayed on a photo  
    b) Processes the calculations made in the program  
    c) Controls the performance of the video card  
    2. What does the CPU do in general? | 95.8 | 208.4 |
| 19  | 1. Which of the numbers below are prime numbers?  
    (4 primes in 7 numbers)  
    2. How is a prime number defined? | 91.2 | 189.6 |
| 20  | 1. The easiest way to define the location of the CPU on the motherboard is to  
    a) Find the CPU card first  
    b) Find the CPU socket first  
    c) Find the ISA slot first  
    d) Find the CPU fan and Heatsink first  
    2. Which computer component helped you to locate the exact place of the CPU on the motherboard? | 91.7 | 833.2 |
| 21  | 1. The efficiency of a CPU chip is generally measured by:  
    a) How fast instructions are carried out  
    b) The number of colours on the screen  
    c) How efficiently instructions are carried out  
    d) The quality of the colours on the screen  
    2. How do we measure the efficiency of a CPU in general? | 100 | 0 |
| 22  | 1. The CPU Fan is located:  
    a) on the left of the CPU Heatsink  
    b) on the right of the CPU Heatsink  
    c) on the top of the CPU Heatsink  
    d) Under the CPU Heatsink  
    2. Where is the CPU fan located in relation to the CPU heatsink? | 87.5 | 763.8 |
1. To insert the CPU chip into its socket, you:
   a) Test and try until the chip is properly inserted
   b) Match the missing pin of the CPU chip with the missing hole of the socket
   c) Align the CPU chip with the CPU socket
2. What should you check before inserting the CPU chip into the CPU socket?

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>1. To insert the CPU chip into its socket, you:</td>
<td>93.8</td>
<td>468.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a) Test and try until the chip is properly inserted</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>b) Match the missing pin of the CPU chip with the missing hole of the socket</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>c) Align the CPU chip with the CPU socket</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. What should you check before inserting the CPU chip into the CPU socket?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It is interesting to check the performance of the four groups of participants in the learning test when the ‘easy’ questions are excluded. When this calculation is carried out, the Text-Only group obtained an average score of 54.7%, the Text + Diagrams group obtained an average score of 76.1%, the Sound + Diagrams group scored 63.9% and the Text + Video scored 60.5%. Figure 6.4 demonstrates this performance compared with the performance of the four groups in all the questions, and shows the effect of low complexity of the questions on the participants’ performance.

![Figure 6.4: Effects of low complexity questions on the performance of the participants](image)

As might be expected, Figure 6.4 shows that excluding the 8 questions that were found to be too easy, has caused a slight decrease to the percentages that represent the learning performance of each group. The difference in the percentages is not significant, but the number of participants is low.
It is interesting to note that the average percentage of correct answers does not differ between recognition and recall questions (as might have been expected). This is probably another indication of the fact that the questions were easy to answer and may have been supported by either prior or general knowledge.

Why should such questions be easy? Firstly, many of the questions involved a combination of reading then doing. For example, during the presentation participants read about the location of the CPU fan and then were asked to locate it. This probably helped them to answer question 22. Questions 11, 20 and 28 are of a similar nature. Questions 16, 18, 19 and 21 could well have been answered from prior knowledge. This indicates that there needs to be more transfer-knowledge questions in the second experiment.

6.4.2 Analysis of the difficult questions

Table 6.8 lists those questions that were categorised as difficult together with the average mark and the variability. The entries in blue are questions with a high variability. The first three questions (6, 8 and 9) are factual questions and the second three (14, 15 and 31) are transfer-knowledge questions. It is reasonably obvious why the last three are difficult. Participants usually find transfer-knowledge more difficult. The first three factual questions are more difficult because the knowledge they cover would not normally be found in prior or general knowledge. This suggests that the redesigned questionnaire should contain more transfer-knowledge and more carefully chosen factual knowledge questions.

<table>
<thead>
<tr>
<th>No.</th>
<th>Question</th>
<th>Average score</th>
<th>Variability</th>
</tr>
</thead>
</table>
| 6   | 1. Mark on the following card diagrams which one would fit into a PCI slot and which one would fit into an ISA slot.  
2. Where are the separators of the ISA and PCI slots located? | 43.8 | 746.8 |
| 8   | 1. What does ISA stand for?  
a) Interconnected System Adapter  
b) Integrated Systems Architecture  
c) Industry Standard Architecture  
d) Industry Systems Adapter  
2. What does ISA stand for? | 33.3 | 1866.7 |
<table>
<thead>
<tr>
<th></th>
<th>Question</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>1. What does PCI stand for?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>a) Personal Computer Interface</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>b) Peripheral Component Interconnect</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>c) Practical Component Inserter</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>d) Protected Communications Interface</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. What does PCI stand for?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>1. What is the difference between “true colour” and “high colour” as far as image quality is concerned?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>a) No difference</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>b) Almost unnoticeable difference</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>c) Small but noticeable difference</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>d) Big difference</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Is there any difference between “true colour” and “high colour” as far as image quality is concerned?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>1. True colour allows a pixel to have about 16.7 million colours. Which number of colours do you think that correspond to high colour?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>a) About 18 million colours</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>b) About 65 thousand colours</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>c) 512 colours</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. In the high colour option, the values that the three colour channels can take are: 32, 32, 64. How would you calculate the total available colour combinations of high colour?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>1. Assuming that you are watching a diagram using the 256 colours as the number of colours displayed on your screen. How much improvement would you expect in colour quality if you went from 256 colours to true colour, and why? (NOTE that a diagram uses palette colours to be displayed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>a) No improvement, because 256 colours are adequate for a proper display of the diagram</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>b) Small improvement due to the addition of some colours</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>c) Big improvement due to the addition of many colours and the proper display of the existing ones.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Assuming that you are watching a diagram using the 256 colours as the number of colours displayed on your screen. How much improvement would you expect in colour quality if you went from 256 colours to true colour and why? (NOTE that a diagram uses palette colours to be displayed)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6.5 How participants interacted with the presentations

In this section, the time that the participants spent while watching the multimedia presentations was examined. This was done in order to identify any relationship between the performance in the learning test and the time spent to absorb the relevant information. Since the multimedia presentations have different durations (apart from the Text-Only and the Text + Diagrams presentations) the analysis was initially restricted to each individual presentation style. However, analysis between presentation styles was also carried out by comparing the time taken by each participant to watch the corresponding
presentation with the average time needed to watch this presentation (which was calculated by the experimenters).

6.5.1 Relationship between time and performance

Firstly, the overall time taken by each participant in each of the four presentations is examined in combination with the corresponding score obtained. The results are presented in Figure 6.5, which shows one diagram for each presentation (and there are six different subjects in each presentation). In the figure, the horizontal axis represents the raw score that was obtained by each participant, and the vertical axis represents the time in seconds that was spent by each participant in watching the corresponding presentation (and fulfilling the practical tasks). The raw scores were used since the factors of prior knowledge and the complexity of the questions did not cause any significant alteration to the percentages that represent the performance of the participants in the learning test.

Figure 6.5: Comparison of time and performance in all four groups of participants
According to these results, there is no obvious pattern to support an analogue relation between time and performance. The performance does not appear to improve or deteriorate when the total observed presentation time increases or decreases. The score obtained is independent of the time participants took in absorbing the information in the corresponding multimedia presentation. It might have been expected that the more time spent in observing a presentation of a novel teaching material, the better the absorbing of the information, and therefore the higher the score in the learning test. However, as can be seen in Figure 6.5, in none of the four groups was this observed.

In the above analysis, the performance of each participant is paired with the time that he/she consumed in watching the whole presentation (including the completion of the practical tasks). A meaningful comparison cannot be made between the four graphs because each multimedia presentation had a different duration. Table 6.9 shows the average duration of the four presentations. The time varies due to the nature of the media that were used to present the teaching material. Since the time taken by users varied across a presentation, a procedure was used to estimate the average optimum duration of a presentation. This was carried out by the experimenters. It involved watching the presentation and fulfilling the practical tasks that were required in the optimum time, before proceeding to the next section. The text of each screen was read at a normal reading pace (auditory presentations necessarily had a fixed time) and an optimum time for each thinking operation was determined.

<table>
<thead>
<tr>
<th>Multimedia presentations</th>
<th>Average duration (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text-Only</td>
<td>2,117</td>
</tr>
<tr>
<td>Text + Diagrams</td>
<td>2,236</td>
</tr>
<tr>
<td>Sound + Diagrams</td>
<td>3,082</td>
</tr>
<tr>
<td>Text + Video</td>
<td>2,454</td>
</tr>
</tbody>
</table>
The estimated times of Table 6.9 enabled the research to compare performance across all 24 participants (instead of carrying out four different studies as shown in Figure 6.5). The time that participants spent in watching the presentation that was allocated to them was compared with the average time of this presentation calculated by the experimenter. For instance, if a participant spent 2,718 seconds in watching the Text-Only presentation (and doing all the required practical tasks), it meant that he/she spent about 28.4% more time than the average duration of that presentation (2,117 seconds). The same calculation was carried out for each participant, and then an average was calculated for the group that they belonged to. These percentages are shown in Table 6.10.

Table 6.10: The times that each participant spent in watching the corresponding presentation

<table>
<thead>
<tr>
<th>Participants</th>
<th>Time (secs)</th>
<th>% difference from average time</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Text-Only</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participant #1</td>
<td>2718</td>
<td>27.7%</td>
<td></td>
</tr>
<tr>
<td>Participant #2</td>
<td>3025</td>
<td>42.1%</td>
<td></td>
</tr>
<tr>
<td>Participant #3</td>
<td>3417</td>
<td>60.5%</td>
<td></td>
</tr>
<tr>
<td>Participant #4</td>
<td>2306</td>
<td>8.4%</td>
<td></td>
</tr>
<tr>
<td>Participant #5</td>
<td>2586</td>
<td>21.5%</td>
<td></td>
</tr>
<tr>
<td>Participant #6</td>
<td>3001</td>
<td>41.0%</td>
<td></td>
</tr>
<tr>
<td><strong>Text + Diagrams</strong></td>
<td></td>
<td></td>
<td>33.6%</td>
</tr>
<tr>
<td>Participant #7</td>
<td>2636</td>
<td>17.3%</td>
<td></td>
</tr>
<tr>
<td>Participant #8</td>
<td>2359</td>
<td>4.9%</td>
<td></td>
</tr>
<tr>
<td>Participant #9</td>
<td>2569</td>
<td>14.3%</td>
<td></td>
</tr>
<tr>
<td>Participant #10</td>
<td>2290</td>
<td>1.9%</td>
<td></td>
</tr>
<tr>
<td>Participant #11</td>
<td>2693</td>
<td>19.8%</td>
<td></td>
</tr>
<tr>
<td>Participant #12</td>
<td>3456</td>
<td>53.8%</td>
<td></td>
</tr>
<tr>
<td><strong>Sound + Diagrams</strong></td>
<td></td>
<td></td>
<td>18.7%</td>
</tr>
<tr>
<td>Participant #13</td>
<td>3584</td>
<td>15.4%</td>
<td></td>
</tr>
<tr>
<td>Participant #14</td>
<td>3439</td>
<td>10.8%</td>
<td></td>
</tr>
<tr>
<td>Participant #15</td>
<td>3223</td>
<td>3.8%</td>
<td></td>
</tr>
<tr>
<td>Participant #16</td>
<td>3124</td>
<td>0.6%</td>
<td></td>
</tr>
<tr>
<td>Participant #17</td>
<td>3503</td>
<td>12.8%</td>
<td></td>
</tr>
<tr>
<td>Participant #18</td>
<td>3333</td>
<td>7.4%</td>
<td></td>
</tr>
<tr>
<td><strong>Text + Video</strong></td>
<td></td>
<td></td>
<td>8.5%</td>
</tr>
<tr>
<td>Participant #19</td>
<td>3451</td>
<td>40.0%</td>
<td></td>
</tr>
<tr>
<td>Participant #20</td>
<td>3120</td>
<td>26.6%</td>
<td></td>
</tr>
<tr>
<td>Participant #21</td>
<td>2903</td>
<td>17.8%</td>
<td></td>
</tr>
<tr>
<td>Participant #22</td>
<td>3065</td>
<td>24.3%</td>
<td></td>
</tr>
</tbody>
</table>
As would be expected, all the participants spent more time than the average calculated duration of the corresponding presentation, since that time represents the optimum learning behaviour from a participant (absorbing information and doing the practical tasks with a minimum delay). Table 6.10 shows that on average, the most time was spent by the participants that were presented with text-only information, which illustrates the extra time to absorb novel information in a text-only format. For example, with presented text, the readers can carry out reflection with the text displayed in front of them (which cannot happen for auditory text, since multimedia design in this first experiment did not enable users to replay auditory information). Not surprisingly, the group of participants who watched the Sound + Diagrams presentation were the closest to the corresponding average time. This is probably because each section of the teaching material could only be received once and is not persistent.

The percentages that represent the time that each participant spent in watching the corresponding presentation can be used to see if there is any relation between time and performance across all participants, instead of the participants of one group only. Figure 6.6 shows the relationship between the percentage of time taken and the performance of all the participants.

Figure 6.6: Relationship between time and performance across all the participants
As can be seen in Figure 6.6, there is no obvious relationship between time and performance across all the participants. As we move from the worst performance to the best performance (moving from the left to the right across the horizontal axis), time is moving randomly across the vertical axis. For example, taking the five longest times (greater than 40%), it is noticed that two of them are related to the two worst performances, one is related to the second best performance, whereas the other two are related to the ninth and tenth best performance. Similarly, if we focus on the participants of the same group, no relation can be identified between time and performance, as it has already been shown in Figure 6.5.

Consequently, it is very likely that the length of the time that learners spent on absorbing a piece of a novel teaching material depended on their individual learning styles or characteristics, such as a global or sequential learning approach or slow reading of text or thorough inspection of diagrams. It is likely that a longer time in processing teaching material does not necessarily guarantee more effective storage and understanding of information.

### 6.5.2 Duration of practical tasks in each group

Another part of the research in this first experiment that deals with time is the one that examines the time that each group of participants consumed on average in:

- receiving and absorbing information on how to identify components within the computer system and on how to fulfil various practical tasks
- actually identifying these components and fulfilling these practical tasks.

In the previous section, the time that was connected to the performance of each participant was represented by the total time that each participant had spent from the moment he/she had started the multimedia presentation until he/she exited from it, having watched the whole teaching material and done all the required practical tasks. One could argue that time should be represented only by the time spent in those sections which contained the necessary information that aided the learners in answering the questions of the learning test (which defined their learning performance). However, it is a complicated
and risky procedure to assign specific sections of the presentations to each question of the learning test because relevant information is spread across the presentations, and are likely to cause referential connections to the memory of a learner contributing to the answer of a specific question.

However, the procedure of identifying computer components and doing practical tasks are specifically described by particular sections of the presentations. Thus, it is feasible to identify all those sections that included information on how to do the tasks of identifying or assembling computer components and calculate the exact time that each participant actually spent in doing these tasks. Afterwards, similarly to the previous research on the relation between time and performance, the time spent on these sections can be compared with the average time (spent by the experimenters) corresponding to the same sections. This comparison provided the research with similar percentages such as in Table 6.10, which enabled the comparison across all four groups of participants. The results are presented in Figure 6.7.

According to Figure 6.7, the Text-Only group spent the longest time in absorbing information in order to identify a computer component or to complete a practical task. They took on average 63.4% more time than the average time in the Text-Only
presentation. A one-way ANOVA analysis yielded a high significant difference in the times spent by the participants across the four groups ($F_{(3, 20)} = 7.021, p<0.002, N=24$) as displayed in Table 6.11.

Table 6.11: ANOVA results on times spent by the participants across presentations

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>6302.907</td>
<td>3</td>
<td>2767.636</td>
<td>7.021</td>
<td>.002</td>
</tr>
<tr>
<td>Within Groups</td>
<td>7883.477</td>
<td>20</td>
<td>394.174</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>16186.384</td>
<td>23</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Descriptive Statistics are displayed in Table 6.12.

Table 6.12: The Descriptive Statistics for times spent by the participants across presentations

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>95% Confidence Interval for Mean</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
<td>Upper Bound</td>
<td></td>
</tr>
<tr>
<td>Text-Only</td>
<td>6</td>
<td>54.98</td>
<td>32.11494</td>
<td>13.11087</td>
<td>21.28</td>
<td>88.68</td>
<td>14</td>
</tr>
<tr>
<td>Text + Diagrams</td>
<td>6</td>
<td>13.16</td>
<td>18.13947</td>
<td>7.40541</td>
<td>-5.87</td>
<td>32.20</td>
<td>-.4</td>
</tr>
<tr>
<td>Sound + Diagrams</td>
<td>6</td>
<td>12.62</td>
<td>7.74489</td>
<td>3.16184</td>
<td>4.49</td>
<td>20.75</td>
<td>-.7</td>
</tr>
<tr>
<td>Text + Video</td>
<td>6</td>
<td>10.48</td>
<td>12.50210</td>
<td>5.10396</td>
<td>-2.63</td>
<td>23.60</td>
<td>-.3</td>
</tr>
<tr>
<td>Total</td>
<td>24</td>
<td>22.81</td>
<td>26.52840</td>
<td>5.41509</td>
<td>11.61</td>
<td>34.01</td>
<td>-.3</td>
</tr>
</tbody>
</table>

In addition to this, a Post-Hoc test (LSD) revealed that the Text-Only participants spent significantly more time than the participants of the Text + Diagrams group ($p<0.002$), the Sound + Diagrams group ($p<0.001$) and the Text + Video group ($p<0.001$). Due to the small number of participants and the fact that the standard deviations were not within a factor of 2, a Kruskal-Wallis test was also carried out in order to produce more valid results. According to this test, the difference in the times taken by the participants across the four presentations was again significant ($p<0.034$), as displayed in Table 6.13.

Table 6.13: Kruskal-Wallis test on times spent by the participants across presentations

<table>
<thead>
<tr>
<th></th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chi-Square</td>
<td>8.673</td>
</tr>
<tr>
<td>df</td>
<td>3</td>
</tr>
<tr>
<td>Asymp. Sig.</td>
<td>.034</td>
</tr>
</tbody>
</table>
Based on the results of both analyses, the Text-Only participants spent significantly more time in identifying computer components and completing the practical tasks than the participants of the other three presentations. The times spent by the participants of these three groups (Text + Diagrams, Sound + Diagrams, Text + Video) were similar.

The learning situation with the Text-Only presentation is unique compared to the other three presentations. In the Text + Diagrams, Sound + Diagrams and Text + Video presentations, text is on the screen with the diagram (or a video) or is being spoken with a diagram present on the screen. In the Text-Only presentation, there is nothing else on the screen to guide the learner, so they have to continuously look at the hardware before them to correctly identify the computer component. This necessarily takes longer than in the other three presentations. This partly explains the results in Table 6.10. Participants who belonged to the Text-Only group needed more time than the other participants for coping with the corresponding presentation because of the lack of image information on the screen.

6.6 Recall questions versus recognition questions

As has been already discussed, one learning test consisted of recall questions, whereas the other consisted of recognition questions (multiple choice). The purpose of using two tests was to evaluate the capability of each type of question (recall or recognition) for testing knowledge, in order to include the most appropriate questions in the learning test of the second experiment.

The method for comparing the two types of question is based on the research on the complexity of questions, which has been included in Section 6.4. Questions in this type of research were examined for the level of successful answers given to each of them across the four groups of participants. In this case, the same method is carried out across the two groups of participants; those who answered the recall test and those who answered the recognition test. The percentage scores for each type of question are shown in Table 6.14.
Comparing the percentage of successful answers for each question (recall and recognition), reveals better performance in recognition questions compared with recall questions. In only 7 out of the 32 questions did the subjects score more in the recall questions than the recognition questions. Furthermore, the average score for the recall questions is 63.7%, whereas the corresponding score for the recognition questions is 80.4%. These results support the expectation that participants would find it easier to...
complete the learning test that included recognition questions than those who completed the learning test that included recall questions.

### 6.7 Use of learning styles

As has already been discussed in Chapter 2, the learning style of a participant may be an important factor that could affect user performance with different media combinations. For this purpose, the ILS test of Felder-Soloman was used in this preliminary experiment in order to gain experience in using the test and to see if there were any preliminary indications from the results that learning styles might be important, though the small number of participants meant that the results would not be significant.

As pointed out in Chapter 2, the Felder technique has four dimensions: Processing, Perception, Input and Understanding. The overall results in the distribution of learning styles are shown in Figure 6.8.

![Distribution of learning styles](image)

**Figure 6.8: Distribution of learning styles across subjects in the first experiment**

The distributions are reasonably well balanced (even with this low number of subjects) except for Visual/Verbal, which commonly is biased towards Visual pole in the general population. If we divide the distribution at the middle point we get:

- 16 (66.7%) were active learners, 8 (33.3%) were reflective learners.
- 12 (50%) were intuitive learners, 12 (50%) were sensing learners.
- 16 (66.7%) were visual learners, 8 (33.3%) were verbal learners.
- 15 (62.5%) were sequential learners, 9 (37.5%) were global learners.

The above results are also in general accordance with those of other studies included in Table 2.2 of Section 2.5.2.

The balance achieved between sensing and intuitive learners in the four groups is shown in Table 6.15.

Table 6.15: The learning styles of the participants in the four groups

<table>
<thead>
<tr>
<th></th>
<th>Sensing learners</th>
<th>Intuitive learners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text-Only</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Text + Diagrams</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Sound + Diagrams</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Text + Video</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

The actual performance of the different types of learners is shown in Figure 6.9. It should be considered when examining the results demonstrated in Figure 6.9 that the small number of participants per group did not enable the existence of an adequate number of both types of learners per dimension. For instance, in the Sound + Diagrams group there is only one reflective learner and in the Text-Only group there is only one global learner. This is why Figure 6.9 does not include the performance of visual and verbal learners, since there were not enough verbal learners to enable analysis to be carried out. In addition, one pole of a learning style may consist mostly of participants who were assigned with the recognition questions test, which is likely to have favoured the performance of this pole over the other, since it has been shown that the participants did better in the recognition questions than the recall questions. It can, however, be noticed that in all three presentations that involved a media combination, the active learners outperformed the reflective learners and the intuitive learners outperformed the sensing learners. Even with a small number of participants the performance difference (whilst not
significant) does follow other results such as those of Alty et al. (2003), as far as the sensing and intuitive learners are concerned.

![Graphs showing performance across media combinations](image)

Figure 6.9: Performance of all types of learners across the media combinations

### 6.8 General discussion on the results of the first experiment

In general, the first experiment had a number of aims. It identified some crucial design issues that needed to be taken into account in the design of the second experiment. For example, it identified some important principles to ensure effective construction of the four multimedia presentations. Furthermore, any flaws in the original multimedia design in this first experiment could be taken into consideration in the design of the second multimedia presentations.

This first experiment also gave indications of the likely performance of learners on different media combinations that deliver teaching material of a practical nature. A crucial aspect of this was the design of the learning test that was provided to them in the last phase of the experiment.
The first experiment has indicated the following points:

1. There are factors that affect the results regarding the measurement of the performance of learners in a learning test and, therefore, they need to be considered in any future design. A common factor in all learning tests was the individual attribute of prior knowledge and how to take it into account. For example, any questions that involve the use of prior knowledge in the answering process should have been excluded. In this experiment, the existence of prior knowledge was examined via a general pre-questionnaire which was used to prevent any participant from taking part if he/she demonstrated high levels of prior knowledge in the examined learning domain. If this is done, the results cannot be dramatically affected by prior knowledge. Another factor is the low or high complexity of the questions in the learning test. Questions of both these types fail to differentiate the quality of learning attained between participants and, furthermore, they were likely to lead to learning performances that might not be valid. Particularly in multimedia learning, questions should be framed so that they discriminate between parts of the teaching material that have been presented via a media combination instead of a single medium. There is a danger when designing presentations (as in the first experiment) where the text-only presentation was designed first, and then the others derived from it. There were occasions when the text was sufficient to convey the required knowledge, so the media combination offered no advantage (or difference). In the second experiment this needs to be avoided. Techniques would need to be used so that the properties of all media are fully exploited in the presentations.

2. The predictions of Dual Coding Theory were verified in three cases. Firstly, all three groups of participants who watched presentations that involved media combinations outperformed the Text-Only group in the learning test. Secondly, lower rates of performance were observed in all groups when the question asked about information that was presented as text-only (or sound-only). Thirdly, the participants of the three media combination groups performed the practical tasks in a significantly shorter time on average compared with the Text-Only group, indicating a tendency to absorb novel information presented via a media combination faster and more effectively.
3. The suggestions of Cognitive Load Theory were also verified by the results of the participants' performance in the learning test. The Text + Video group obtained the lowest score of the three presentations involving a media combination. In addition to this, the average score of this group was only slightly higher than the score of the Text-Only group. This result indicates a likely negative involvement of cognitive load on the participants' memory, due to the huge amount of information included within video clips.

4. The Text + Diagrams group outperformed all the other groups in the learning test. Although previous research has favoured multimedia presentations that presented information material via Sound + Diagrams, an effective design of a Text + Diagrams presentation that respects the design principles of Cognitive Load Theory is likely to achieve a more efficient transfer of information to learners. When diagrams are carefully incorporated within textual information and comply with the Spatial Contiguity Principle, they are likely to optimise the effects of Dual Coding Theory.

5. The learning performance of the participants was based mostly on the nature of media combination, rather than the time that they took to absorb the information. No specific relationship was identified between time and performance.

6. As far as effective evaluation of learning is concerned, learners generally found the recall questions quite complex, whereas the recognition questions were more easily answered. This was demonstrated by comparing the percentage of correct answers in the two types of questionnaire. This caused higher scores to be achieved by the four groups of participants, in terms of their average learning performance, so that the test is less discriminating.

As a result of the first experiment certain aspects needed to be changed. First of all, the total number of participants was necessarily limited due to the preliminary nature of this experiment. Basic features of the experiment, such as the multimedia design of the four presentations, the scenario of the experiment and the method to test learning, had to be evaluated so that they could be appropriately altered in order to have an optimum performance in the second experiment. Since the first experiment involved only one participant at a time, the whole procedure was inevitably time-consuming and therefore
was limited in the number of participants. As a consequence, results were qualitative rather than quantitative. Although in the second experiment the participants would again carry out the experiment individually, there would be more time available so that the number of subjects could be considerably increased.

A second feature of the experiment that was likely to have a negative effect on results was the fact that each information section of the presentations could be watched only once. This provided participants in the Text-Only and the Text + Diagrams groups with an advantage over the other two groups. The information in text and diagrams remained on screen and enabled participants of these two groups to observe information within one section as long as they wanted before deciding to move on to the following section. In contrast, the information in sound or in video clips could only be processed once, due to the nature of these media. This almost certainly affected the performance of the Sound + Diagrams and Text + Video groups, in comparison with the performance of the other two favoured groups.

The third drawback in the first experiment involved the use of recognition questions in one type of the learning test. Although this type of question was necessary to enable a comparison to be made, they were dealt with more easily by learners compared with the recall questions (80.4% of recognition answers were correctly answered in contrast to 63.7% correct answers for recall questions). This was not surprising since users generally find recognition questions easier to answer than recall questions, but the inclusion of this type of question is likely to lead to improved performance and thereby possibly reduce the differences between media combinations.

The amount of information that was included in each multimedia presentation proved to have been more than required based on the average time that each group needed for watching the corresponding presentation. The teaching material that was designed to be used in this first experiment included extended details that described all the necessary features of the two practical tasks. The shortest average time taken belonged to the Text + Diagrams group and was approximately 44 minutes. The longest average time taken was 56 minutes by the Sound + Diagrams group. The presentations were therefore long, due to the amount of information that had to be included in them. The amount of the time
spent on average watching a multimedia presentation, along with the amount of information that was required to be absorbed, was likely to have caused cognitive load in the participants’ memory, and this could have affected their performance in the learning test. In addition to this, a long duration of a multimedia presentation is also likely to cause the participants’ interest in the experiment to fade as more and more information is presented to them.

A fifth feature of this first experiment that may have played a negative role in the final results was the partial addition of diagrams within textual information. The original textual information that was presented was unchanged in all four presentations. All the presentations contained some material of theoretical nature which cannot often be improved by addition of diagrams in the role of supporting information. This resulted in some sections within the presentations that had to be presented via text-only or sound-only. Particularly in the case of the Sound + Diagrams presentation, information that was presented in a sound-only form may well have caused difficulties in information assimilation, because participants could only listen to this particular part of the presentation just once. Furthermore, it is likely that information presented in a single medium may also have caused irritation to the learners.

Based on the results and the drawbacks that were recorded in the preliminary experiment, changes were suggested that would guide the design of the second, major experiment. These alterations are summarised below:

- The experiment should involve a larger number of participants, so that significant results may be obtained.

- The teaching material needs to be altered so that it will enable the addition of diagrams in almost all parts of the presentations.

- The teaching material must be appropriately shortened so that presentations will be of a reasonable duration so that participants do not become tired. In addition to this, the scenario of the experiment should be altered to enable the experiment to be of a reasonable duration.
• Presentations should be revised in order to eliminate the disadvantages of the Sound + Diagrams group and the Text + Video group (the sequential nature of auditory information)

• One learning test should be allocated to all the groups. Based on the comparison results of the two types that were used in the preliminary experiment, the learning test should consist only of recall questions. Similarly to the first experiment, the scoring mechanism should be designed, so that it would take into consideration the different levels of complexity of the questions included in the learning test.

Apart from all these changes, the second experiment should continue to adhere to the same concept of the two practical tasks, so that it will be feasible to make appropriate comparisons with the results of the first experiment. Furthermore, all four multimedia presentations should be included in the second experiment, due to their effective participation in the results of the preliminary experiment. A detailed description of the second experiment’s features and the results obtained will be discussed in the next two chapters.
Chapter 7  The second multimedia learning experiment

7.1 Introduction

The first experiment described in the previous chapter suggested a number of useful design improvements and the second experiment was designed to take account of these improvements.

A number of features remained the same so that the experiments were still broadly comparable:

- The basic criterion for taking part in the experiment required learners not to have any background knowledge on computer hardware assembly.

- There were still four multimedia presentations, which were designed to convey the teaching material to learners. Each presentation consisted of the same media combinations that had been used in the preliminary experiment (text-only, text and diagrams, sound and diagrams, text and video).

- The learning achieved by participants was measured in a similar learning test, where factors such as prior knowledge and question complexity (for creating the scoring mechanism) were taken into account.

- The Felder-Soloman questionnaire was used to identify the learning styles of the participants as before. The participants were then split into four groups and were balanced over the dimensions of Perception so that the ratio of sensing to intuitive learners was similar in each group. As far as the learning performance is concerned, the other dimensions were also taken into account (apart from visual and verbal learners), in order to identify any possible interaction effects between the media combinations and the different learning styles of the participants.

- The participants were timed for the whole of the presentation, so that the research could further evaluate the results obtained in the preliminary experiment on the relationship between time and performance.
Other features were changed, for example:

- Although the core of the material remained the same, there were some additions and deletions.
- The multimedia design was changed to make the experience more interactive.
- More personal attributes were taken into account in terms of balancing groups, for example, gender and mother tongue, in addition to learning style.
- The learning test was exclusively a recall test.
- The scenario of the experiment was altered.

These will be discussed in the following sections.

### 7.2 Changes to the teaching material

The two practical tasks that were chosen to be part of the teaching material in the preliminary experiment proved to be adequately complex and motivating to be included in the second experiment. Therefore, these two tasks formed the core of the teaching material in the second experiment, as well.

However, one of the drawbacks recorded in the preliminary experiment involved the extended duration of the multimedia presentations due to the large amount of information that had to be presented to the learners. It was felt that the duration of approximately 1 hour was too long. As a result, the teaching material was altered in order to contain a more limited amount of detail. This cut the presentation length by approximately half.

The main reason for constructing teaching material of such bulk in the first experiment was the inclusion of many instructional details that would facilitate the assimilation of the novel and complex teaching material. This information included, for instance, a description of the workplace where the experiment took place and an extended description of definitions or assembly procedures that might not have previously been known to the learners. In fact, participants did not find this a problem, so the details could easily be dropped without any loss of clarity. Table 7.1 compares the information content between the two experiments.
Table 7.1: Summary of material used in the second experiment

<table>
<thead>
<tr>
<th>Second experiment material</th>
<th>First experiment material</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Part 1: Video card</strong></td>
<td><strong>Part 1: Video card</strong></td>
</tr>
<tr>
<td>Stage 1</td>
<td>Stage 1</td>
</tr>
<tr>
<td>Information about the role</td>
<td>Description of the</td>
</tr>
<tr>
<td>of the video card in a</td>
<td>workplace. The role of</td>
</tr>
<tr>
<td>computer system. Instructions on how to identify and remove the old video card from the computer system.</td>
<td>the video card in a</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage 2</td>
<td>Stage 2</td>
</tr>
<tr>
<td>Instructions on how to</td>
<td>Instructions on how to</td>
</tr>
<tr>
<td>insert the new video card</td>
<td>identify and remove the</td>
</tr>
<tr>
<td>into the computer system.</td>
<td>old video card, and insert</td>
</tr>
<tr>
<td>Information on the RGB</td>
<td>the new video card.</td>
</tr>
<tr>
<td>system and instructions on</td>
<td>Participants are taught</td>
</tr>
<tr>
<td>how to change the screen</td>
<td>about RGB system and how</td>
</tr>
<tr>
<td>colour settings from 256</td>
<td>to change screen colour</td>
</tr>
<tr>
<td>colours to High Colour.</td>
<td>settings from 256 colours</td>
</tr>
<tr>
<td>Presentation of two images</td>
<td>to High Colour.</td>
</tr>
<tr>
<td>that use these two colour</td>
<td></td>
</tr>
<tr>
<td>combinations respectively,</td>
<td></td>
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<tr>
<td>so that the participants are</td>
<td></td>
</tr>
<tr>
<td>able to identify the</td>
<td></td>
</tr>
<tr>
<td>difference in colour</td>
<td></td>
</tr>
<tr>
<td>quality.</td>
<td></td>
</tr>
<tr>
<td>Stage 3</td>
<td>Stage 3</td>
</tr>
<tr>
<td>Participants watch the same</td>
<td>Participants watch the</td>
</tr>
<tr>
<td>image as before using High</td>
<td>same image as before using</td>
</tr>
<tr>
<td>Colour option and notice</td>
<td>High Colour option and</td>
</tr>
<tr>
<td>improvement in graphics</td>
<td>notice improvement in</td>
</tr>
<tr>
<td>quality.</td>
<td>graphics quality.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Part 2: CPU</strong></th>
<th><strong>Part 2: CPU</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 3</td>
<td>Stage 4</td>
</tr>
<tr>
<td>Information about the role</td>
<td>The role of a CPU in a</td>
</tr>
<tr>
<td>of a CPU in a computer</td>
<td>computer system.</td>
</tr>
<tr>
<td>system. Instructions on</td>
<td>Participants are taught</td>
</tr>
<tr>
<td>how to identify and remove</td>
<td>about prime numbers and</td>
</tr>
<tr>
<td>the old CPU chip. Information about the prime numbers, which are part of a program that tests the speed of the computer system’s CPU.</td>
<td>they run a prime numbers</td>
</tr>
<tr>
<td></td>
<td>program recording the</td>
</tr>
<tr>
<td></td>
<td>time of its execution.</td>
</tr>
<tr>
<td>Stage 4</td>
<td>Stage 5</td>
</tr>
<tr>
<td>Instructions on how to</td>
<td>Instructions on how to</td>
</tr>
<tr>
<td>install the new CPU, the</td>
<td>identify and remove the</td>
</tr>
<tr>
<td>CPU fan and heatsink.</td>
<td>old CPU chip, and install</td>
</tr>
<tr>
<td>Presentation of two outcomes</td>
<td>the new one. Instructions</td>
</tr>
<tr>
<td>of the prime numbers program.</td>
<td>also include removal and</td>
</tr>
<tr>
<td>One is running under the</td>
<td>replacement of the CPU</td>
</tr>
<tr>
<td>old CPU and the other under</td>
<td>fan.</td>
</tr>
<tr>
<td>the new CPU, so that the</td>
<td></td>
</tr>
<tr>
<td>participants are able to</td>
<td></td>
</tr>
<tr>
<td>identify the difference in</td>
<td></td>
</tr>
<tr>
<td>processing speed.</td>
<td></td>
</tr>
<tr>
<td>Stage 6</td>
<td>Stage 6</td>
</tr>
<tr>
<td>Participants run again the</td>
<td>Participants run again the</td>
</tr>
<tr>
<td>prime numbers program,</td>
<td>prime numbers program,</td>
</tr>
<tr>
<td>record the new time of</td>
<td>record the new time of</td>
</tr>
<tr>
<td>execution and notice</td>
<td>execution and notice</td>
</tr>
<tr>
<td>improvement in processing</td>
<td>improvement in processing</td>
</tr>
<tr>
<td>speed of the new CPU.</td>
<td>speed of the new CPU.</td>
</tr>
</tbody>
</table>

The alterations carried out on the teaching material can be clearly seen. First of all, the material is now divided into four stages, instead of six (as was the case in the first experiment) demonstrating how the teaching material has been condensed. In addition to this, the information has been reorganised, which has resulted in the transfer of some information to other stages, thereby creating more compact material. Secondly, some
information has been excluded. Moreover, the user tests for the improvement in graphics quality and in processing speed have been incorporated into the presentations as part of the teaching material, instead of requiring the participants to test this improvement on a different computer, which was a time consuming procedure. Thirdly, the teaching material in the second experiment was presented in a different way. In the first experiment, participants performed a watching-and-doing procedure that required them to carry out a number of subtasks after watching the corresponding instructions within the multimedia presentation. In contrast, in the second experiment, the procedure that was followed required participants simply to watch the multimedia presentation together with all the included instructional information for carrying out any subtasks. The practical tasks were part of the learning test in the second experiment. This is more extensively discussed in the Section 7.6.

The whole teaching material that was used (identical in the four presentations of the second experiment) can be viewed in Appendix B (Section 2).

7.3 Multimedia presentations

The basic structures of the multimedia presentations were changed, though they were still built using Flash MX and consisted of the same media combinations as in the preliminary experiment. What is more, the information material that was embedded in the four presentations was still identical in all of them. This ensured that meaningful comparisons between the various media combinations could be made. All the types of multimedia presentations that were used in the second experiment are included in the DVD attached to this thesis.

7.3.1 Information structure within multimedia presentations

The information was reorganised into four stages. Each stage now consisted of a number of 'scenes' (rather than the term 'steps' used in the preliminary experiment). However, these more compact 'scenes' included less information than the steps, because redundant information had been eliminated. Each scene was provided with a title that informed and
prepared learners for the nature of the information presented to them in the scene. Similarly, each scene was further divided into 'sections' (this is similar to the division of each 'step' into smaller 'sections' in the preliminary experiment). However, whereas in the first experiment each section was presented after the participant had pressed the single interaction button, in the case of the second experiment, sections appeared on the screen one after another at a readable rate until the end of the corresponding scene. Then the participant was notified to interact with the presentation in order to move to another scene. In general, the information material now occupied a more reasonable structure, and presented the information in a more efficient and comprehensive manner. Figure 7.1 illustrates how the information was structured within the four multimedia presentations.

As it can be seen in Figure 7.1, the total number of scenes is 25, in contrast with the 12 steps that formed the similar information structure in the first experiment. This is partly due to the more limited amount of information that is contained in each scene. In addition to this, each scene was designed to spatially occupy one screen page, in contrast with the first experiment where each step could occupy more than one screen page. This was poor design and highly likely to cause additional cognitive load in the participants' memory.
7.3.2 Interaction features

An important added feature of the multimedia design was the addition of an interaction capability. In the presentations of the preliminary experiment, the only interactions allowed were represented by a single button that enabled users to move on to the following section of the presentation. A major innovation that was applied in the second experiment enabled participants to review information as often as they wished. This contrasted with the preliminary experiment, where learners could only view information once.

Two different types of interactive feature were provided in the second experiment. In the first type of interaction (*Across-Scene*), the participants could review any part of the material as many times as they required until they felt confident to complete the learning test. Furthermore, they were able to move within scenes at will so that they could review specific parts of them. This feature was equally applied in all four presentations, but it was mainly intended to contribute to a more efficient reviewing of information in presentations where sound was involved. In the second type of interaction (*Within-Scene*) the participants still had the benefit of reviewing facilities within a scene, but they could not review previous scenes.

Since learners can now review any parts of the information, an interface had to be provided to help participants navigate within the presentation, in case they needed to re-examine a specific part of the teaching material. This was accomplished by providing three interaction features that were embedded in appropriate positions within each multimedia presentation, as can be seen in Figure 7.2. Each number (from 1 to 3) in Figure 7.2 represents the corresponding interaction feature, which performs a distinct function within each scene.
1. The first interaction feature is the navigation bar, placed at the top of the screen. This feature shows participants in which part of the presentation they are currently situated at any time. The bar consists of 25 small boxes, each one representing one multimedia scene. Depending on the colour, each box gives out information on its state. Thus, the dark blue colour shows that the scene has already been visited, the light blue colour identifies the scene currently being watched, and the white colour identifies scenes that have not yet been visited. Each blue-coloured box can function as a button that will transfer the participant directly to the corresponding multimedia scene. In addition to this, when the mouse pointer is placed over a blue-coloured box, learners are shown the title of the corresponding scene, so that they can confirm that they are visiting the appropriate scene. Furthermore, the participants are informed of the corresponding stage that the current scene belongs to. These two functions of the blue-coloured boxes are not available in the *Within-Scene* interaction. In summary, the navigation bar lets
learners know which scenes they have already watched, which scene they are
currently watching and how many scenes separate them from the end of the
presentation, enabling them to move directly to any of the visited scenes. No
facility was provided to allow a learner to jump forward to an unvisited scene, so
that they are 'forced' to read all the information.

2. The second interaction feature is the time-line. This feature consists of a pointer
which slides within a limited area at a rate that depends on the duration of a
multimedia scene. When the pointer reaches the end of this area, the participant is
notified that the scene has reached its end. Most importantly, interaction enables
the participants to place the pointer wherever they require within the area by
either clicking a part of this area or dragging the pointer to the required position.
This feature enables the participants to move freely around the scene, speeding up
or slowing down the flow of information, according to their ability to assimilate
the presented information. In addition to this, they were aware at any time of how
much time is left for the scene to reach its end.

3. The third interaction feature is a set of buttons that enables users to move serially
from one scene to another. Thus, they can move to the next scene or the previous
scene. In the type of the multimedia design that does not enable revision of
information (Within-Scene) the corresponding button is obviously not present.
Furthermore, there are also buttons that enable a learner to play a scene again
from its beginning or pause it, in case they want to assimilate a part of the
information that has already been presented to them before allowing the rest of it
to unfold on the screen.

In addition to these interaction features, each scene was characterised by a title located
below the navigation bar that summarises the content of the information included within
the scene. This was likely to assist learners in identifying scenes when they require re-
examining information in one of the 25 scenes.

The revised multimedia presentations also provided two additional outcomes at the
conclusion of the presentation. The first outcome is one that was produced and analysed
in the first experiment - the time that the participants spent in receiving and assimilating
the information content of each multimedia scene. The second outcome, produced only in the second experiment, identifies the sequence of scenes that each participant followed in watching the whole presentation. This information would allow the identification of the way that users retrieve information, together with the nature of information that is re-examined. Both these two outcomes were previously analysed in the studies of Alty, Al-Sharrah and Beacham (2003) and as a result, three types of learners were identified. The first type of learner was named *passive* and involved all those learners that did not make use of any interaction facilities while watching the presentation. The second type was named *fast-forward* and involved all those learners that frequently made use of the forward button to move on to the next scene before completely assimilating the current scene. The third type was named *re-learner* and included the learners that reviewed information by revisiting multimedia scenes or slowing down the flow of information by making use of the pause button.

These improved multimedia design features were applied in all the presentations to enable the participants of all four groups to access information equally, ensuring the production of more reliable results of the research in this second experiment.

### 7.3.3 Text-Only presentation

In the Text-Only presentation as in all other presentations the sections appeared progressively on the screen as the scene developed. A readable rate was chosen for the appearance of textual information, to ensure that learners could follow the flow of details. If the flow was slower or faster than an individual learner wished, they could appropriately adjust the time-line pointer in order to accelerate or delay the presentation of the following section. If the flow of information was too fast and confusing, participants could pause the scene.

### 7.3.4 Text + Diagrams presentation

The Text + Diagrams presentation also involved sections that were presented consecutively until the end of the corresponding scene. However, the involvement of
diagrams as an information element differed considerably from the corresponding multimedia design in the preliminary experiment.

![Screen shot from the Text + Diagrams presentation](image)

Figure 7.3: Screen shot from the Text + Diagrams presentation

In comparison with the preliminary experiment, more emphasis was placed on the Spatial Contiguity Principle applied between text and diagrams (see Figure 7.3). The arrows that were used in the first experiment to connect keywords with a diagram were removed. Connection between keywords and diagrams was carried out using flashing and red-coloured text. The textual information of a section appeared in the same way as in the Text-Only presentation and afterwards the keyword was coloured in red and flashed for a short time, in order to attract the attention of the participant. Then the corresponding diagram followed the flashing of the keyword so that the participants could relate the keyword to the diagram. The removal of the arrows enabled less visual information to be used, which was expected to decrease the cognitive load on the participant's memory.
Another crucial improvement that was implemented in this version of the Text + Diagrams presentation was the addition of diagrams to all the multimedia scenes. In contrast to the multimedia design in the first experiment, all the textual parts in this Text + Diagrams presentation were accompanied by diagrams. However, this did require some alterations to the textual information itself. This allowed better comparisons to be made between presentations.

7.3.5 Sound + Diagrams presentation

In the first experiment, the Sound + Diagrams presentation included a number of sections that were presented using sound alone, which seemed to be unsettling to learners. The provision of more diagrams in the Text + Diagram presentation enabled these sound-only sections to be removed.

Another disadvantage for the Sound + Diagrams group in the preliminary experiment was the fact that the participants could only listen to auditory information once, due to the nature of the medium. This contrasted with the other groups where textual and diagrammatic information was part of the media combination and so could be read or browsed as often as they wished. The interaction features that were inserted in all the multimedia presentations of this second experiment, such as the 'play the scene again' button, allowed some browsing capability, especially for the subgroup of participants that could only view each multimedia scene once (the Within-Scene group).

The Sound + Diagrams presentation also lacked an effective mechanism for reviewing the auditory information. The time-line interaction feature enabled learners of other presentations to move backwards or forwards within a multimedia scene at will, always being aware of which part of the information they were watching in the visual context. However, this interaction feature does not work for auditory content. Thus, an interaction mechanism needed to be created so that learners in the sound group would be able to scan and identify any specific part of information within a multimedia scene. In the case of the Sound + Diagrams presentation, the interaction mechanism provided can be seen in Figure 7.4, where it is located above the time-line. This feature enabled learners to identify the beginning of each section within a multimedia scene and allowed them to
navigate efficiently within the material so that they could view those parts of information that they needed to re-examine. This interaction mechanism consisted of buttons, like the ones forming the navigation bar, which represented each section of the scene. The state of the buttons provided the participants with useful information:

- Dark blue-coloured buttons informed learners that they had already listened to the auditory information of the corresponding section and by clicking the button they could review this part of the teaching material. Furthermore, by placing the mouse pointer over one of these buttons, the participants were provided with a visual presentation of the first words of the corresponding auditory information, which confirmed which section they were reviewing.

- Light-coloured buttons informed learners of the section that they were currently listening to. The buttons of sections that had not yet been visited were not activated so the box appeared empty. In addition to this, learners were aware of the total number of sections that a scene consisted of, due to the number of boxes. Boxes would progressively become light blue and then dark blue, as can be seen in Figure 7.4.

![Screen shot from the Sound + Diagrams presentation](image-url)
Although learners could also use the time-line pointer to move backwards or forwards within a multimedia scene, it was decided to advise them in the experiment beforehand to take advantage of the sound buttons, because, in the case of auditory information, these were much more effective in identifying a specific part of the teaching material.

To summarise, these improvements in the Sound + Diagrams presentation provided information navigation facilities for learners which were equally efficient as in other presentations (this was not the case in the preliminary experiment):

- All the scenes contained information in diagrams that supported auditory information.
- Learners could play the scene again, which was intended to be especially useful to those who belonged to the subgroup that could not review previous scenes (Within-Scene).
- Learners could efficiently identify and review a particular piece of information material within a multimedia scene.

7.3.6 Text + Video presentation

The Text + Video presentation had a similar design to the Sound + Diagrams presentation in terms of the interaction features. However, it also included an interaction mechanism that enabled participants in this group to identify a particular video clip within a scene. Normally, a video clip was accompanied by text, and this text was shown before the video clip because of space limitations. If learners wanted to review a clip, they would need to specify whether they wished to see the text or the clip. Therefore the button mechanism was re-designed to make this possible. As a result, a button that was related to textual information had a distinct letter ‘T’ on it, in contrast to a video button that (like the sound buttons in the Sound + Diagrams presentation) was labelled with a number which characterised its position in the sequence of the video clips within the scene. The two types of button can be seen above the time-line in Figure 7.5, which shows a screen shot from this type of presentation.
Figure 7.5: Screen shot from the Text + Video presentation

The Text + Video presentation contained a limited number of scenes where visual information was represented by diagrams, instead of video clips, as in the case of the preliminary experiment. This is because some information cannot be usefully presented in the form of a video clip, as discussed earlier. Furthermore, there were no sections that contained only textual material.

To summarise, the Text + Video presentation shared with the Sound + Diagrams presentation the same benefits from the added features, due to the common medium of sound and the interaction mechanism that aided learners in scanning auditory information as efficiently as the participants in the other groups could do with textual information.
7.4 Participation in the second experiment

As in the preliminary experiment, participation in the second experiment required participants not to have any previous background knowledge of computer assembly tasks. In this second experiment, lack of knowledge of this domain was even more important, because the fulfillment of the practical tasks would be part of the learning test (in contrast with the first experiment).

Since students with dyslexia have been found to perform differently with different media (Beacham and Alty, 2006), it was decided to identify dyslexic students in the experiment. Identifying dyslexia in a participant was achieved by including a simple check box in the learning test. In Loughborough University, where dyslexic students or staff are members of the Dyscalculia and Dyslexia Interest Group, most participants were aware of being dyslexic or not.

In order to increase the statistical validity of the experiment, the number of participants was increased from 24 in the first experiment to 80 in this second experiment. This allowed more subgroups of participants to be studied (for example, participants with different learning styles). As in the preliminary experiment, the second study was based on individual participation (rather than carrying out the experiment to the whole group).

The composition of each group depended on more factors, compared with the preliminary experiment. Membership of an experimental group was determined by learning style, gender, and first language (English or non-English) since these additional factors were considered to be likely to affect the learning performance of each group (however, only learning styles were examined for differences in learning performance).

7.5 Learning test

In the second experiment one learning test was used for all the participants, which consisted of 30 recall questions. The test covered most of the teaching material presented in the multimedia presentations. Some questions originated from the learning test of the preliminary experiment, and were either unchanged or appropriately altered.
Alterations to the structure of previously used questions were based on the evaluation that was carried out after the first experiment and involved their level of complexity. Often high levels of complexity resulted from a bad structure of the question, which failed to specify the exact part of the material that was needed to be recalled. For instance, the following question that belonged to the learning test of the first experiment:

"What functions does a video card perform?"

was altered to the following question in the learning test of the second experiment:

"State two basic functions that a video card performs within a computer system."

Similarly, low levels of complexity were usually caused by the structure of the question, which made the question too straightforward. For instance, the following question was evaluated as being of low complexity in the learning test of the first experiment:

"A pixel displays a colour in a dot on the screen. Does the new video card increase the number of colour options in a pixel, or the number of pixels on the screen?"

This question was altered in the learning test of the second experiment to:

"Having installed a better video card, we are enabled to improve image quality. What causes this improvement? (your answer should be related to the pixels on the screen)"

In addition, the learning test of the second experiment also involved testing the completion of the practical tasks within the learning test, unlike the preliminary experiment where the participants were not examined on practical issues.

The whole learning test can be viewed in Appendix D.

7.5.1 Scoring mechanism

Using a single learning test for evaluating the learning achieved by the participants enabled a more efficient scoring mechanism to be applied than the marking scheme that was applied in both types of the learning test in the first experiment. Questions were
marked according to their complexity. The learning test was firstly divided into two main categories, the questions that were addressed to the teaching material and the questions referring to the fulfilment of the practical tasks. The first category was further subdivided into more parts, corresponding to the level of complexity of the questions. Two main criteria were used for evaluating the complexity of a question:

- The relationship between the question and the complexity of the answer required. For instance, answers could involve a simple representation of a part of the teaching material, a combination of more than one part, or require a solution to a problem solving situation.

- The amount of information that was required to be accessed to achieve a correct answer.

Based on the above criteria, questions were divided into three complexity levels. The first level consisted of questions that were expected to be of a low complexity. These questions addressed a limited part of the teaching material. A correct answer to these questions would award the participants 0.5 point. The test contained 8 low complexity questions. An example of this type of question is as follows:

"Which are the three colour channels that determine the colour of a pixel?"

The second level consisted of questions that were defined as being of a moderate complexity. These questions addressed more of the teaching material. In addition to this, questions at this level could involve transfer knowledge to solve simple cases that were related to the presented teaching material. Participants would be awarded 1 point for a correct answer at this level. The learning test included 10 questions that belonged to this level. An example of this type of questions is as follows:

"Which function does the CPU heatsink perform?"

Another example of the type of question that involves a transfer of knowledge is as follows:
"If you had to instruct a user, who had no previous knowledge of the inside of a computer system, on how to find the video card, what would you say?"

The third level consisted of questions that were expected to be of a higher complexity. This type of question required knowledge of a combination of a number of sections of the teaching material. In addition, this level consisted of questions that necessitated the transfer of knowledge to problem solving situations. Four questions of this type were included in the learning test and participants were awarded 2 points for the correct answer. An example of a question that required a combination of information parts is as follows:

"State two basic functions that a video card performs within a computer system."

An example of a problem-solving question is:

"Which number of colours (256, High Colour, True Colour) would you choose in order to achieve a satisfying play of a movie file, especially if your computer system is of a low memory? Go to the computer system and make all the appropriate settings to apply this number of colours to the computer screen."

Only one question was awarded 1.5 points, due to its having a complexity between the second and third level.

The learning test also involved several subtasks that were part of the main practical tasks that formed the core of the teaching material. The same category also included the task of identifying specific computer components in the computer system. In total, 2 questions required identifying particular computer components and 5 questions required the learner to perform a subtask. Depending on the nature and the complexity of the subtask, the participants would be awarded points, ranging from 1.5 to 3 points. To make it feasible to award the participants with the appropriate marks for completing a practical task, each task was broken down into smaller parts, which, added together, provided the total points for each task. An instance is given below:
"Go to the computer system, insert the new CPU chip into the socket and do any additional tasks so that the CPU is ready to function safely."

The participants would obtain 3 marks for fulfilling the above practical task. In particular, they would obtain:

- 1 mark for inserting the CPU chip
- 0.5 mark for locking the CPU chip
- 1.5 marks for replacing the unit of the CPU fan and the CPU heatsink.

### 7.5.2 Prior knowledge

Prior knowledge is a major factor in learning. Learners use prior knowledge to understand new knowledge. It has to be taken into account when assessing how much a learner has actually learned. It is therefore an important and measurable factor which must be taken into account when assessing the performance of a learner in a knowledge test. Two methods were used in the first experiment, to identify prior knowledge and to exclude all the answers that were affected by this factor. The first method required the completion by the participants of a general questionnaire that assessed how much of the teaching material of the presentations was already known. The second method required the participants themselves to perform a self-evaluation on how much their answer was affected by their background knowledge.

Although the combination of these two methods enabled identification of those questions which should be excluded due to prior knowledge, it was a procedure that was based on personal evaluation by the learners. As a consequence, in the second experiment, a different method was used, so that the prior knowledge of the participants could be identified more accurately. A pre-questionnaire was administered before the learning test itself, so the participants completed this questionnaire before watching the presentation that corresponded to their group, unaware that they would take this test as a post-questionnaire at the end of the experiment. Prior knowledge could then be identified by checking the answers to the pre-test questionnaire and comparing them with the final answers to the post-learning test.
7.5.3 Conclusions on the improved learning test

To summarise, the learning test that was designed for the second experiment, was considerably refined, as a result of the findings of the preliminary experiment. Firstly, only recall questions were included in the learning test. Secondly, a number of questions were rephrased, remained unchanged or were excluded, depending on their ability to reveal the variations in the learning performance that the different media combinations were likely to cause to learners. Thirdly, the practical tasks which were the core of the teaching material in both experiments became part of the learning test which examined how successfully the participants of each group could fulfil the various practical subtasks, based on the multimedia instructions that were presented to them. Fourthly, the reliability of the results was strengthened by the improved scoring mechanism that was applied in this learning test, enabling the different contribution of each question to the learning score (i.e. the complexity) to be properly calculated.

7.6 Scenario

This section explains the whole procedure that was followed by participants in the second experiment. The four stages are shown in Table 7.2. The main changes to the procedures of the second experiment resulted from the requirement to reduce the total time of the participants' engagement in the experiment and, to improve the reliability of the results.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1</td>
<td>Completion of the ILS test via email</td>
</tr>
<tr>
<td>Stage 2</td>
<td>Completion of the pre-questionnaire</td>
</tr>
<tr>
<td>Stage 3</td>
<td>Presentation of the teaching material</td>
</tr>
<tr>
<td>Stage 4</td>
<td>Completion of the learning test</td>
</tr>
</tbody>
</table>

As a consequence of the reduction in the total time duration of the experiment, the completion of the ILS test (Felder-Soloman questionnaire), which formed the first stage of the experiment, was carried out on-line via email. Based on the results of the
participant’s learning style test, and together with the other two attributes of gender and mother language, each participant was placed in the appropriate group to watch the corresponding multimedia presentation.

The second stage of the experiment occurred before the presentation of the teaching material. At this stage, participants completed the pre-questionnaire to identify any prior knowledge on the specific topics that were going to be taught through the multimedia presentation. Then participants were given a short tutorial that explained the attributes of the multimedia presentation, such as the interaction mechanisms and how they controlled progress through the experiment, and the specifications of the experiment in general.

The third stage of the experiment consisted of the core of the experiment, which was the presentation of the teaching material via a media combination. The presentation that was allocated to a participant depended on the group to which he or she was allocated, and the participant was informed during the brief tutorial that took place beforehand, of the media that were involved in the presentation. Unlike the first experiment, the process of watching the presentation was never interrupted (as it had been in the first experiment due to the fulfilment of particular subtasks). As soon as the presentation finished, the participants completed the post-learning test, whose completion formed the fourth stage of the experiment.

The basic changes that caused the decrease in the duration of the second experiment compared with the first were located in the first and third stages. The completion of the Felder-Soloman test was dealt with before the experiment itself (it could have been taken a day earlier so the cognitive load was less). The duration of all the presentations was also significantly reduced, firstly due to the alterations that took place in the teaching material and secondly due to the practical tasks being fulfilled in the last stage as part of the learning test. Apart from these crucial changes in the scenario of the second experiment, no other alterations were carried out, and general specifications, such as whether a participant should take part or not, remained the same.

The design of the first experiment was mainly based on the empirical studies of Alty (2002) and Mayer (2001). In contrast, the second experiment was exclusively based on the results of the first experiment. Another important difference in the second experiment
was the addition of the facility for moving backwards and forwards in the presentation. This might provide some interesting information on how participants used this on different media.
Chapter 8  Results of the second multimedia learning experiment

8.1 Experimental procedure

Before the presentation of the results of the second experiment, seven features of the experimental procedure will be discussed, since this experiment was based on them. These features are:

- Call for participation
- Factors that affected the size of participation
- Details of the participants
- The experimental environment
- The procedure
- Duration of the experiment
- Measurements taken in the second experiment

8.1.1 Call for participation

Notices calling for participation in the experiment were distributed around the campus of Loughborough University within all departments. Student Halls and other public areas of the university were also covered. The call included a brief description of the experiment, its approximate duration and the criteria that needed to be satisfied in order to qualify to take part. The main criterion to be met was that all participants should not previously have replaced or installed an internal computer component nor watched it being done. In addition to these notices, all research students, research staff and academic staff of the university departments were emailed a number of times calling for participation (the contents of the email were identical to those of the notice). Both notice and email informed the recipients that each selected participant would receive a £5 reward for their contribution to the results of this research.
Ninety participants who responded met the criteria and were allowed to take part, regardless of their academic background. In all, 18 undergraduate students, 63 postgraduate students and 9 staff were selected. The majority of the participants were postgraduate students (probably because the research student email list was targeted towards them).

8.1.2 Factors that affected the size of participation

All four stages of the experiment were carried out based on the planned scenario (as detailed in Section 7.6). After a participant had agreed to take part in the experiment, he or she completed the Index of Learning Styles test via email (first stage). Four participants who had originally agreed to take part in the experiment, decided to withdraw after completing the ILS test due to lack of spare time.

An appropriate day and time was arranged for each participant to run the following three stages of the experiment. This involved the completion of the pre-questionnaire, the watching of the multimedia presentation and the completion of the post-learning test in the designated experiment workplace.

Because of the problems experienced by dyslexic students as reported in the work of Beacham and Alty (2006), the last question of the post-learning test asked if participants were dyslexic. Three participants identified themselves as being dyslexic and it was clear that they struggled with the presentation. One student declared, for example, that he could not cope with textual information. Since they had volunteered and dyslexia had not been mentioned as a possible exclusion criterion, they were allowed to complete the experiment but their results were excluded from the analysis.

After completing the pre-questionnaire (to determine prior-knowledge) three participants demonstrated very high levels of prior knowledge in their answers to the pre-questionnaire. In these cases, participants had misunderstood the criteria of participation and were asked not to take part in the following stages of the experiment. They therefore withdrew from the experiment.
This left 80 remaining valid participants. These were informed that they could terminate their participation whenever they wanted. However, no participant withdrew during the second, third and fourth stages of the experiment.

### 8.1.3 Details of the participants

A reasonable spread of academic disciplines took part in the experiment. Table 8.1 shows the distribution of participants across departments.

#### Table 8.1: Academic background of participants

<table>
<thead>
<tr>
<th>Department</th>
<th>Undergraduate Students</th>
<th>Postgraduate Students</th>
<th>Staff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business School</td>
<td>1</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Chemical Engineering</td>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Chemistry</td>
<td>2</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Civil and Building Engineering</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Computer Science</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ergonomics and Safety Research Institute</td>
<td>1</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Geography</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Human Sciences</td>
<td>2</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Information Science</td>
<td>0</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Politics, International Relations and European Studies</td>
<td>2</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>School of Sport and Exercise Sciences</td>
<td>2</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Social Sciences</td>
<td>0</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Wolfson School of Mechanical and Manufacturing Engineering</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>17</strong></td>
<td><strong>56</strong></td>
<td><strong>7</strong></td>
</tr>
</tbody>
</table>

In terms of Loughborough Faculties there were 34 participants from Science, 12 from Engineering and 34 from Social and Environmental Studies. The reduced number of Engineers almost certainly reflects the fact that they are more likely to be familiar with the procedures for replacing internal components in computer systems.

The participants were assigned to four groups to take part using the four different presentations. Each group was carefully balanced for gender, learning style and mother
language. Table 8.2, shows the make-up of each of the four 20-learner groups. Among the 80 participants, 25 were male and 55 of them were female. Since the number of female participants was greater than the number of male participants, the same proportion of female to male participants was achieved in each group. In addition to this, approximately 1/3 (27 out of the 80 participants) had English as their first language so each group contained the same proportion of participants whose mother language was English compared with those who had a different mother language.

<table>
<thead>
<tr>
<th>Table 8.2: Attributes of the four groups of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning styles</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td><strong>Text-Only</strong></td>
</tr>
<tr>
<td><strong>Text + Diagrams</strong></td>
</tr>
<tr>
<td><strong>Sound + Diagrams</strong></td>
</tr>
<tr>
<td><strong>Text + Video</strong></td>
</tr>
</tbody>
</table>

As shown in Figure 8.1, the distribution of any two learning styles within a dimension is well-balanced, apart from the dimension of Input (Visual/Verbal), which commonly consists of more visual learners in the general population. If we divide the distribution at the middle point (considering balanced learners to belong to one of the two poles), we get the following numbers of learners that participated in the second experiment:

- 49 (61.25%) were active learners, 31 (38.75%) were reflective learners.
- 43 (53.75%) were intuitive learners, 37 (46.25%) were sensing learners.
- 63 (78.75%) were visual learners, 17 (21.25%) were verbal learners.
- 49 (61.25%) were sequential learners, 31 (38.75%) were global learners.
The above results are consistent with the overall results that have been recorded by previous research which made use of the Felder-Soloman test (Table 2.2, Section 2.5.2) and with the distribution results of the preliminary experiment.

Studies that used the ILS to examine the learning styles of people taking part in learning tasks have produced results that show a general tendency of learners towards specific poles. Tendencies are likely to vary in size based on the knowledge background of learners. For instance, people tend to balance between sensing and intuitive learners when taking into account all academic backgrounds, whereas in engineering courses there are usually more sensing learners than intuitive learners. What is more, most people are visual learners, as it has been shown by research on learning styles. Most studies have used the learning model within engineering environments, which, however, does not prevent the model from being applied in other environments as well.

The groups were adjusted to include about the same relative numbers of sensing and intuitive learners. The four groups were then assigned to one of the four presentation styles, namely, Text-Only, Text + Diagrams, Sound + Diagrams, and Text + Video.
8.1.4 The experimental environment

The experiment was carried out between February and July 2005. It took place in a computer laboratory located in the department of Computer Science in Loughborough University, which offered all the necessary facilities for carrying out an experiment on multimedia learning. A workplace was constructed within the laboratory, consisting of a computer machine that presented the appropriate multimedia presentation, and a computer system, in which the appropriate physical changes took place during the experiment. Experiments were arranged to take place during the afternoon hours to ensure an empty room so that participants could watch the presentations without being disturbed by external factors.

8.1.5 The procedure

Interaction with the experiment supervisor was allowed during the duration of the experiment but only either to clear up trivial misunderstandings with respect to the interaction mechanisms of the presentations, or if a participant whose first language was not English had difficulty with a word in the teaching material (whenever this was a reasonable request). Particularly in the presentations of the Sound + Diagrams and the Text + Video, participants were assisted in adjusting the volume of the incoming sound via the headphones, to their own preferences.

At the end of the experiment the supervisor held an informal discussion with the participants about the whole procedure. Participants were asked to express their opinion about the usefulness of the experiment in terms of learning, and how much they had been motivated. All participants commented that they were satisfied with the contents of the teaching material and the procedure of the experiment in general. Additionally, they expressed pleasure and satisfaction from gaining knowledge in this particular domain (this was the main reason why replacement and installation of computer components were chosen to be the core of the teaching material — it was pleasing to note that this was a good choice).
Interestingly, some of the learners who belonged to the Text-Only group said they found it quite difficult to deal with the practical tasks included in the learning test, in particular, attempting to apply the presented textual instructions in the practical tasks. However, no participant complained about the clarity of the textual instructions. This factor will be examined in the results analysis.

### 8.1.6 Duration of the experiment

The whole experiment (excluding the first stage of completing the Felder-Soloman test, as this was carried out via email) was shorter than the first experiment. The total time involved watching the presentation and then doing the post-test, which included practical tasks. As expected, the presentation time in this second experiment was almost half the length of the first experiment, as shown in Table 8.3. Moving the practical tasks from the third stage to the fourth stage mainly caused this reduction.

<table>
<thead>
<tr>
<th>Multimedia presentations</th>
<th>First Experiment (seconds)</th>
<th>Second Experiment (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>Within-Scene</strong></td>
</tr>
<tr>
<td>Text-Only</td>
<td>2,117</td>
<td>1,307 (62.0% difference)</td>
</tr>
<tr>
<td>Text + Diagrams</td>
<td>2,236</td>
<td>1,717 (30.3% difference)</td>
</tr>
<tr>
<td>Sound + Diagrams</td>
<td>3,082</td>
<td>1,840 (67.5% difference)</td>
</tr>
<tr>
<td>Text + Video</td>
<td>2,454</td>
<td>1,559 (57.4% difference)</td>
</tr>
</tbody>
</table>

There are two time values in the second experiment because half the participants were allowed to move backwards and forwards between scenes (Across-Scene), whereas the other half could only replay the current scene but were not allowed to visit earlier scenes (Within-Scene). Interestingly, only the Text-Only presentation showed an increased time for the Across-Scene participants. It may be that since the Within-Scene participants knew they could not revisit a scene after leaving it, they spent more time in each scene to make
sure they had understood it. In contrast, in the Text-Only case, perhaps the increased difficulty in comprehending (or remembering) the material in text form, made them carry out more re-examination of material when possible. More will be said about this when the detailed navigation data is examined. In Table 8.3 it can be seen that the largest reductions in time were recorded in the presentations where sound was involved (Sound + Diagrams, Text + Video).

On completion of the presentations, participants spent approximately a further 15 to 25 minutes answering the required questions and fulfilling the practical tasks of the learning post-test. The time taken to complete the learning test varied across individuals as might be expected. For example, 6 non-English participants spent more than 20 minutes in this stage of the experiment, which is likely to imply that additional time was needed to translate and comprehend the contents of each question. The whole experiment lasted less than an hour, whereas the first experiment lasted approximately one hour and a half.

8.1.7 Measurements taken in the second experiment

First of all, the scores for each group participant in the post-learning test were recorded. The scores obtained by both the Within-Scene and Across-Scene group participants within each of the four main groups were calculated. Additionally, the scores of the group participants in both the written answers and in the practical tasks were determined.

In the second experiment, the time taken by the participants to watch the various presentations was recorded and how participants moved through the sequence of scenes was also recorded automatically by the system. This enabled participants to be classified into one of the three types of learners (fast-forward, passive, re-learners) and identify any special attributes in their learning performance.

Finally, the learning scores obtained by participants with different learning styles was compared within each group, in order to examine the influence of each media combination on learners of different learning styles.
8.2 The results of the learning test

The 30 questions of the learning test provided the participants with a maximum score of 36 points. Different questions had different marks as discussed in Section 7.5.1.

8.2.1 Overall scores in the test

The spread of scores for the learning test (over all four presentations) obtained in the second test are shown in Figure 8.2 (taken from SPSS output). A small group performed very poorly but most performed reasonably well, indicating that the test was found to be neither too hard nor too easy by most participants.

![Figure 8.2: The overall performance on the test](image)

The cluster of students at the low end of the distribution were analysed to see if there was a reason for their poor performance. Seven out of the eight poor performers were in groups experiencing text (either by itself (4 participants) or with video (3 participants)). This represented 7 out of 40 participants in these groups. In the other groups only 1 out of 40 participants had a low score (in the Sound + Diagrams group).
It is also interesting to see how students performed in the second experiment compared with the first. This is shown in Figure 8.3 where the percentage of correct scores is compared (since the actual maximum score was different in the two cases). Overall the scores were higher on the first experiment, but this was to be expected since some easy questions were removed. Interestingly, performance is similar across the four presentation styles although the reduction for sound-based presentations (Sound + Diagrams and Text + Video) is less. A likely reason for this better relative performance in the sound-based presentations is the addition of the capability of participants to replay either the current scene or previous scenes (or part of them). In text-based presentations, replaying the current scene (although possible) is not useful because all the text is displayed and remains on the screen until the participant wishes to move on. In contrast, scenes in the sound-based presentations in the first experiment were highly sequential and could not be replayed. In the second experiment both the current scene and previous scenes could be revisited and this reduced the problems associated with the sequential nature of sound. As a result an improved performance would be expected.

![Figure 8.3 Comparison of scores obtained between the first and second experiments](image-url)
8.2.2 Comparison of the overall performance of the four groups

The Text-Only group obtained a mean score (and standard deviation) of 17.31 (6.18), the Text + Diagrams group obtained a score of 23.62 (3.99), the Sound + Diagrams scored 21.58 (5.66) and the Text + Video group scored 20.57 (6.68). The Descriptive Statistics are shown in Table 8.4.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Std. Dev</th>
<th>Std. Error</th>
<th>95% Confidence Interval for Mean</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bnd</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Upper Bnd</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Text-Only</td>
<td>20</td>
<td>17.31</td>
<td>6.18</td>
<td>1.381231</td>
<td>14.41</td>
<td>20.10</td>
<td>5.37</td>
</tr>
<tr>
<td>Sound + Diagrams</td>
<td>20</td>
<td>21.58</td>
<td>5.66</td>
<td>1.265310</td>
<td>18.93</td>
<td>24.23</td>
<td>5.00</td>
</tr>
<tr>
<td>Text + Video</td>
<td>20</td>
<td>20.57</td>
<td>6.68</td>
<td>1.494713</td>
<td>17.44</td>
<td>23.60</td>
<td>7.12</td>
</tr>
<tr>
<td>Total</td>
<td>80</td>
<td>20.77</td>
<td>6.06</td>
<td>.677577</td>
<td>19.42</td>
<td>22.12</td>
<td>5.00</td>
</tr>
</tbody>
</table>

Our initial hypothesis is that there is a difference in the performance between the four groups. There are 20 data points in each distribution. The Null Hypothesis is that any difference between the distributions is due to chance. The data has been examined using a one-way ANOVA analysis (the standard deviations are within a factor of 2 and the Levene Test has a significance factor of 0.475). This shows a highly significant result with (F 4.243, p<0.008, N=80). Thus the Null Hypothesis can be rejected. There is a significant difference between the four results. A summary of the ANOVA result is given in Table 8.5.

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>416.231</td>
<td>3</td>
<td>138.744</td>
<td>4.243</td>
<td>.008</td>
</tr>
<tr>
<td>Within Groups</td>
<td>2485.346</td>
<td>76</td>
<td>32.702</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2901.577</td>
<td>79</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 8.4 demonstrates the distribution of the results across the four presentations.
Figure 8.4: Distribution of scores over the four presentations

The Text-Only distribution has an overall lower score distribution than the others. The low score distribution of the Text-Only group is also reflected in a post-hoc LSD test, in which the significance levels across the four presentations are examined. The LSD Test results for significance are shown in Table 8.6.

Table 8.6: The differences in performance between the presentations

<table>
<thead>
<tr>
<th>(A) Presentation</th>
<th>(B) Presentation</th>
<th>Mean Difference (A-B)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>Text-Only</td>
<td>Text + Diagrams</td>
<td>-6.31(*)</td>
<td>1.808367</td>
<td>.001</td>
<td>-9.91</td>
</tr>
<tr>
<td></td>
<td>Sound + Diagrams</td>
<td>-4.27(*)</td>
<td>1.808367</td>
<td>.021</td>
<td>-7.88</td>
</tr>
<tr>
<td></td>
<td>Text + Video</td>
<td>-3.26</td>
<td>1.808367</td>
<td>.075</td>
<td>-6.63</td>
</tr>
<tr>
<td>Text + Diagrams</td>
<td>Text-Only</td>
<td>6.31(*)</td>
<td>1.808367</td>
<td>.001</td>
<td>2.71</td>
</tr>
<tr>
<td></td>
<td>Sound + Diagrams</td>
<td>2.04</td>
<td>1.808367</td>
<td>.263</td>
<td>-1.56</td>
</tr>
<tr>
<td></td>
<td>Text + Video</td>
<td>3.05</td>
<td>1.808367</td>
<td>.096</td>
<td>-.55</td>
</tr>
<tr>
<td>Sound + Diagrams</td>
<td>Text-Only</td>
<td>4.27(*)</td>
<td>1.808367</td>
<td>.021</td>
<td>.67</td>
</tr>
<tr>
<td></td>
<td>Text + Diagrams</td>
<td>-2.04</td>
<td>1.808367</td>
<td>.263</td>
<td>-5.64</td>
</tr>
<tr>
<td></td>
<td>Text + Video</td>
<td>1.01</td>
<td>1.808367</td>
<td>.577</td>
<td>-2.59</td>
</tr>
<tr>
<td>Text + Video</td>
<td>Text-Only</td>
<td>3.26</td>
<td>1.808367</td>
<td>.075</td>
<td>-.34</td>
</tr>
<tr>
<td></td>
<td>Text + Diagrams</td>
<td>-3.05</td>
<td>1.808367</td>
<td>.096</td>
<td>-6.65</td>
</tr>
<tr>
<td></td>
<td>Sound + Diagrams</td>
<td>-1.01</td>
<td>1.808367</td>
<td>.577</td>
<td>-4.61</td>
</tr>
</tbody>
</table>

* The mean difference is significant at the .05 level.

Adding diagrams to the Text-Only and to the voice narration presentations, results in a significant improvement in the performance score. Surprisingly, adding video footage to
the text or replacing diagrams with video footage does not give a significantly improved performance. This will be further discussed later.

8.2.3 Comparison of the overall performance of the interaction subgroups

Each presentation had two different interaction mechanisms – Within-Scene and Across-Scene. The Within-Scene subgroups could only replay the current scene but could not re-examine the information in previous scenes. The Across-Scene subgroups could do both. Figure 8.5 demonstrates the performance of each subgroup across the four groups of the experiment.

![Graph showing performance of subgroups](image)

**Figure 8.5: Results on the overall performance of all the subgroups**

The overall scores of participants are analysed to see if the two interaction mechanisms have a significantly different effect. The hypothesis is that the two interaction mechanisms result in a significant difference in scores attained. A 2x4 ANOVA analysis was carried out across the four presentations for the subgroups.

The standard deviations are again within a factor of 2 (Table 8.7) and the Levene Test gives a significance level of p< 0.226. Thus the ANOVA approach is justifiable.
Table 8.7: The Descriptive Statistics for the performance of the subgroups

<table>
<thead>
<tr>
<th>Presentation</th>
<th>Subgroup</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text-Only</td>
<td>Across-Scene</td>
<td>19.97</td>
<td>4.45</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Within-Scene</td>
<td>14.64</td>
<td>6.60</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>17.31</td>
<td>6.18</td>
<td>20</td>
</tr>
<tr>
<td>Text + Diagrams</td>
<td>Across-Scene</td>
<td>23.74</td>
<td>4.32</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Within-Scene</td>
<td>23.50</td>
<td>3.87</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>23.62</td>
<td>3.99</td>
<td>20</td>
</tr>
<tr>
<td>Sound + Diagrams</td>
<td>Across-Scene</td>
<td>20.86</td>
<td>7.43</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Within-Scene</td>
<td>22.30</td>
<td>3.35</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>21.58</td>
<td>5.66</td>
<td>20</td>
</tr>
<tr>
<td>Text + Video</td>
<td>Across-Scene</td>
<td>19.34</td>
<td>7.66</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Within-Scene</td>
<td>21.80</td>
<td>5.69</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>20.57</td>
<td>6.68</td>
<td>20</td>
</tr>
<tr>
<td>Total</td>
<td>Across-Scene</td>
<td>20.98</td>
<td>6.17</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Within-Scene</td>
<td>20.56</td>
<td>6.02</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>20.77</td>
<td>6.06</td>
<td>80</td>
</tr>
</tbody>
</table>

The results of the ANOVA analysis are shown in Table 8.8.

Table 8.8: ANOVA results for the significance of Presentation and Subgroup on score

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>599.609 (a)</td>
<td>7</td>
<td>85.658</td>
<td>2.679</td>
<td>.016</td>
</tr>
<tr>
<td>Intercept</td>
<td>34507.278</td>
<td>1</td>
<td>34507.278</td>
<td>1079.305</td>
<td>.000</td>
</tr>
<tr>
<td>Subgroup</td>
<td>3.507</td>
<td>1</td>
<td>3.507</td>
<td>.110</td>
<td>.741</td>
</tr>
<tr>
<td>Presentation</td>
<td>418.231</td>
<td>3</td>
<td>138.744</td>
<td>4.340</td>
<td>.007</td>
</tr>
<tr>
<td>Subgroup * Presentation</td>
<td>179.871</td>
<td>3</td>
<td>59.957</td>
<td>1.875</td>
<td>.141</td>
</tr>
<tr>
<td>Error</td>
<td>2301.967</td>
<td>72</td>
<td>31.972</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>37408.855</td>
<td>80</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>2901.577</td>
<td>79</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a R Squared = .207 (Adjusted R Squared = .130)

The ANOVA analysis on the scores of the subgroups yielded \( F (1, 72) = 0.110, p<0.741, N=80 \) showing that the Null Hypothesis cannot be rejected. The nature of the interaction does not affect the score. The presentation result is the same as previously presented. There is also no interaction effect between Presentation and Subgroup type \( F (3, 72) = 1.875, p<0.141, N=80 \). This is not surprising from Figure 8.5 since for three of the presentations the differences are slight. However, the difference in the Text-Only case looks quite large in Figure 8.5. It is therefore interesting to look in more detail at the data and carry out two more analyses on the performance of the subgroups.
The first analysis compares the overall performance of each subgroup within a presentation (for instance, comparison of the performance of the Across-Scene and Within-Scene subgroup in the Text-Only group). The second analysis compares the performance of the corresponding subgroups across the four presentations (for instance, comparison of all the Within-Scene subgroups across the four groups).

The means and standard deviations (in parentheses) for the eight subgroups from Table 8.7 are the following:

- Text-Only: Across-Scene 19.97 (4.45), Within-Scene 14.64 (6.60)
- Text + Diagrams: Across-Scene 23.74 (4.32), Within-Scene 23.50 (3.87)
- Sound + Diagrams: Across-Scene 20.86 (7.43), Within-Scene 22.30 (3.35)
- Text + Video: Across-Scene 19.34 (7.66), Within-Scene 21.80 (5.69)

The effect of the two interaction mechanisms (the Across-Scene and Within-Scene mechanisms) on the performance of the participants in each presentation can now be examined. A one-way ANOVA analysis yields the following significance levels for each presentation:

- Text-Only: $F_{(1,19)} = 4.402, p<0.05, N=20$
- Text + Diagrams: $F_{(1,19)} = 0.017, p<0.898, N=20$
- Sound + Diagrams: $F_{(1,19)} = 0.311, p<0.584, N=20$
- Text + Video: $F_{(1,19)} = 0.667, p<0.445, N=20$

The Text-Only result is as we expected just significant. It is possible that with a much larger number of participants an even more significant result might have been achieved. It is unlikely that any of the other presentations would yield a significant result even with a large number of participants.

It is possible that participants of the Across-Scene subgroups may not have taken advantage of the interaction mechanisms that enabled them to review previous scenes. This may explain the lack of any significant difference between the performances of the
two subgroups within each presentation. Table 8.9 shows how much participants re-examined the information in previous scenes for the Across-Scene subgroups.

<table>
<thead>
<tr>
<th></th>
<th>Number of participants</th>
<th>Number of revised scenes visited</th>
<th>Scenes revisited per participant</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Text-Only</strong></td>
<td>9 out of 10 (90%)</td>
<td>113 scenes</td>
<td>11.3</td>
</tr>
<tr>
<td><strong>Text + Diagrams</strong></td>
<td>6 out of 10 (60%)</td>
<td>53 scenes</td>
<td>5.3</td>
</tr>
<tr>
<td><strong>Sound + Diagrams</strong></td>
<td>9 out of 10 (90%)</td>
<td>75 scenes</td>
<td>7.5</td>
</tr>
<tr>
<td><strong>Text + Video</strong></td>
<td>5 out of 10 (50%)</td>
<td>41 scenes</td>
<td>4.1</td>
</tr>
</tbody>
</table>

Table 8.9 lists in the second column the number of participants who actually took advantage of the interaction mechanism. For example in the Text-Only group (consisting of ten persons) only one participant did not use the facility (similarly with the Sound + Diagrams group). In contrast nearly half the participants in the other two groups used the facility.

In the third column the total number of scenes revisited is given and this is restated as the number of scenes revisited per participant in the fourth column. This partially explains the lack of difference between the Across-Scene and Within-Scene interaction mechanisms. The potential for revising scenes was mostly taken advantage of in the Text-only case (which produced a significant result).

Let us now examine if there is a significant difference in performance within particular subgroups (Across-Scene subgroups or Within-Scene subgroups) across presentations. The hypothesis is that there is a significant difference between the performances between the four Across-Scene subgroups. A one-way ANOVA analysis shows that there is no significance in the difference between the four Across-Scene subgroups. The F value is \( F_{(0, 36)} = 0.991, p<0.408, N=40 \). An LSD post-hoc analysis yields the results displayed in Table 8.10.
Table 8.10: Performance differences between presentations in Across-Scene

<table>
<thead>
<tr>
<th>(A) Presentation</th>
<th>(B) Presentation</th>
<th>Mean Difference (A-B)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>95% Confidence Interval</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text-Only</td>
<td>Text + Diagrams</td>
<td>-3.76</td>
<td>2.759677</td>
<td>.181</td>
<td>-9.36</td>
<td>-1.83</td>
<td>1.83</td>
</tr>
<tr>
<td></td>
<td>Sound + Diagrams</td>
<td>-.89</td>
<td>2.759677</td>
<td>.750</td>
<td>-6.48</td>
<td>-4.96</td>
<td>4.71</td>
</tr>
<tr>
<td></td>
<td>Text + Video</td>
<td>.64</td>
<td>2.759677</td>
<td>.819</td>
<td>-4.96</td>
<td>-6.23</td>
<td>6.23</td>
</tr>
<tr>
<td>Text + Diagrams</td>
<td>Text-Only</td>
<td>3.76</td>
<td>2.759677</td>
<td>.181</td>
<td>-1.83</td>
<td>9.36</td>
<td>9.36</td>
</tr>
<tr>
<td></td>
<td>Sound + Diagrams</td>
<td>2.87</td>
<td>2.759677</td>
<td>.304</td>
<td>-2.72</td>
<td>8.47</td>
<td>8.47</td>
</tr>
<tr>
<td>Sound + Diagrams</td>
<td>Text + Video</td>
<td>4.40</td>
<td>2.759677</td>
<td>.120</td>
<td>-1.20</td>
<td>10.00</td>
<td>10.00</td>
</tr>
<tr>
<td></td>
<td>Text-Only</td>
<td>.89</td>
<td>2.759677</td>
<td>.750</td>
<td>-4.71</td>
<td>6.48</td>
<td>6.48</td>
</tr>
<tr>
<td>Text + Video</td>
<td>Text + Diagrams</td>
<td>-2.87</td>
<td>2.759677</td>
<td>.304</td>
<td>-8.47</td>
<td>2.72</td>
<td>2.72</td>
</tr>
<tr>
<td></td>
<td>Text + Video</td>
<td>1.52</td>
<td>2.759677</td>
<td>.584</td>
<td>-4.07</td>
<td>7.12</td>
<td>7.12</td>
</tr>
<tr>
<td></td>
<td>Text-Only</td>
<td>-.64</td>
<td>2.759677</td>
<td>.819</td>
<td>-6.23</td>
<td>4.96</td>
<td>4.96</td>
</tr>
<tr>
<td></td>
<td>Sound + Diagrams</td>
<td>-4.40</td>
<td>2.759677</td>
<td>.120</td>
<td>-10.00</td>
<td>1.20</td>
<td>1.20</td>
</tr>
<tr>
<td></td>
<td>Text + Diagrams</td>
<td>-1.52</td>
<td>2.759677</td>
<td>.584</td>
<td>-7.12</td>
<td>4.07</td>
<td>4.07</td>
</tr>
</tbody>
</table>

As expected, there are no significant differences between any two Across-Scene subgroups across two presentations.

As far as the Within-Scene subgroups are concerned, there is a significant difference between their performances across the four presentations, as shown by a one-way ANOVA analysis ($F_{(3,36)} = 6.223$, $p<0.002$, $N=40$). Similar to the overall performances of the participants across the four presentations, it is the Text-Only group that causes the significance in the difference between the performances. Table 8.11 shows the significance levels on the differences between the performances of two Within-Scene subgroups clearly illustrating the different performance in the Text-Only group.

In comparison with the significance levels referring to the difference between the performances of all the participants across the four presentations (Table 8.6), the Within-Scene subgroups present an additional significant difference between the performance of the Text-Only and the Text + Video Within-Scene subgroups. It is therefore suggested that the performance of the participants who watched the Text-Only presentation, and could not re-examine information of previous scenes, accounts to a great extent for the poor learning performance of the whole Text-Only group, combining the results of the statistical analysis that has been carried out on both Across-Scene and Within-Scene subgroups.
Table 8.11: Performance differences between presentations in *Within-Scene*

<table>
<thead>
<tr>
<th>(A) Presentation</th>
<th>(B) Presentation</th>
<th>Mean Difference (A-B)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>Text-Only</td>
<td>Text + Diagrams</td>
<td>-8.86(*)</td>
<td>2.274399</td>
<td>.000</td>
<td>-13.47</td>
</tr>
<tr>
<td></td>
<td>Sound + Diagrams</td>
<td>-7.66(*)</td>
<td>2.274399</td>
<td>.002</td>
<td>-12.27</td>
</tr>
<tr>
<td></td>
<td>Text + Video</td>
<td>-7.16(*)</td>
<td>2.274399</td>
<td>.003</td>
<td>-11.77</td>
</tr>
<tr>
<td>Text + Diagrams</td>
<td>Text-Only</td>
<td>8.86(*)</td>
<td>2.274399</td>
<td>.000</td>
<td>4.25</td>
</tr>
<tr>
<td></td>
<td>Sound + Diagrams</td>
<td>1.20</td>
<td>2.274399</td>
<td>.601</td>
<td>-3.41</td>
</tr>
<tr>
<td></td>
<td>Text + Video</td>
<td>1.70</td>
<td>2.274399</td>
<td>.460</td>
<td>-2.91</td>
</tr>
<tr>
<td>Sound + Diagrams</td>
<td>Text-Only</td>
<td>7.66(*)</td>
<td>2.274399</td>
<td>.002</td>
<td>3.05</td>
</tr>
<tr>
<td></td>
<td>Text + Diagrams</td>
<td>-1.20</td>
<td>2.274399</td>
<td>.601</td>
<td>-5.81</td>
</tr>
<tr>
<td></td>
<td>Text + Video</td>
<td>.50</td>
<td>2.274399</td>
<td>.827</td>
<td>-4.11</td>
</tr>
<tr>
<td>Text + Video</td>
<td>Text-Only</td>
<td>7.16(*)</td>
<td>2.274399</td>
<td>.003</td>
<td>2.55</td>
</tr>
<tr>
<td></td>
<td>Sound + Diagrams</td>
<td>-1.70</td>
<td>2.274399</td>
<td>.460</td>
<td>-6.31</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-.50</td>
<td>2.274399</td>
<td>.827</td>
<td>-5.11</td>
</tr>
</tbody>
</table>

* The mean difference is significant at the .05 level.

A graph of the distribution of scores for the four presentations clearly shows the poor performance of the Text-Only *Within-Scene* subgroup (Figure 8.6).

![Figure 8.6: The score distribution over the four presentations for the *Within-Scene* subgroups](image)

In contrast, the distribution for the *Across-Scene* subgroups shows no obvious difference between the Text-Only group and the other three groups as shown by the earlier statistical analysis (Figure 8.7).
8.2.4 Comparison of the overall performance in the written and practical part of the learning test

The learning test consisted of the written part (questions that needed to be answered using information that was previously presented) and the fulfilment of a set of computer-based practical tasks based upon the knowledge learned in the presentation. Figure 8.8 compares the overall performance of the participants across the four presentations in the Written and Practical parts. Score is represented by percentages, in order to make it feasible to compare the performance of the participants in the two parts of the learning test (since the maximum score in the written part was 23.5 and in the practical tasks was 12.5).
Except for the Text-Only presentation, the participants appear to have performed considerably better in the fulfilment of the practical tasks, than in the written part of the learning test. The hypothesis is that there is a significant difference in the performance of participants in the written part of the learning test compared with the practical tasks, across all four presentations. A 2x4 ANOVA test yields a high level of significance. The means and standard deviations of the performance of each group in the two parts of the post-learning test are given in Table 8.12.

Table 8.12 The Descriptive Statistics for score in the two parts of the learning test across the four presentations

<table>
<thead>
<tr>
<th>Part</th>
<th>Presentation</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Written</td>
<td>Text-Only</td>
<td>48.70</td>
<td>18.49</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Text + Diagrams</td>
<td>55.93</td>
<td>13.23</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Sound + Diagrams</td>
<td>52.39</td>
<td>14.93</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Text + Video</td>
<td>50.40</td>
<td>16.30</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>51.86</td>
<td>15.78</td>
<td>80</td>
</tr>
<tr>
<td>Practical</td>
<td>Text-Only</td>
<td>46.80</td>
<td>19.09</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Text + Diagrams</td>
<td>83.80</td>
<td>14.50</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Sound + Diagrams</td>
<td>74.15</td>
<td>23.34</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Text + Video</td>
<td>69.80</td>
<td>27.07</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>68.64</td>
<td>25.15</td>
<td>80</td>
</tr>
<tr>
<td>Total</td>
<td>Text-Only</td>
<td>47.75</td>
<td>18.58</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Text + Diagrams</td>
<td>69.86</td>
<td>19.67</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Sound + Diagrams</td>
<td>63.27</td>
<td>22.26</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Text + Video</td>
<td>60.10</td>
<td>24.14</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>60.25</td>
<td>22.56</td>
<td>160</td>
</tr>
</tbody>
</table>

The ANOVA results are given in Table 8.13.
There is a highly significant difference in performance between the written and the practical parts ($F(1, 152) = 31.533, p<0.0001, N=160$). Also there is a highly significant difference in performance across presentations ($F(3, 152) = 9.624, p<0.0001, N=160$). Finally there is an interaction between Presentation and Part ($F(3, 152) = 4.699, p<0.004, N=160$). This interaction can be seen in Figure 8.7 where the performance in the Text-Only presentation is quite different from that in the other three.

### 8.2.4.1 Performance in the written part

It is hypothesised that there will be a difference in performance of participants in the written part of the test across presentations. A one-way ANOVA test was carried out on the performance of the participants across all presentations and showed there was no significance in the difference between their percentage scores in the written part of the learning test ($F(3, 76) = 0.768, p<0.515, N=80$). Thus, the Null Hypothesis cannot be rejected. In addition to this, no significance is recorded in the difference between the performances of the participants across any two presentations (in the written part of the learning test). The result of a post-hoc LSD analysis is shown in Table 8.14.
Table 8.14: Performance differences in the written part of the learning test

<table>
<thead>
<tr>
<th>(A) Presentation</th>
<th>(B) Presentation</th>
<th>Mean Difference (A-B)</th>
<th>Std. Error</th>
<th>Sig. I</th>
<th>95% Confidence Interval Lower Bound</th>
<th>95% Confidence Interval Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text-Only</td>
<td>Text + Diagrams</td>
<td>-7.23</td>
<td>5.01362</td>
<td>.153</td>
<td>-17.22</td>
<td>2.75</td>
</tr>
<tr>
<td></td>
<td>Sound + Diagrams</td>
<td>-3.69</td>
<td>5.01362</td>
<td>.464</td>
<td>-13.68</td>
<td>6.29</td>
</tr>
<tr>
<td></td>
<td>Text + Video</td>
<td>-1.70</td>
<td>5.01362</td>
<td>.736</td>
<td>-11.68</td>
<td>8.29</td>
</tr>
<tr>
<td>Text + Diagrams</td>
<td>Text-Only</td>
<td>7.23</td>
<td>5.01362</td>
<td>.153</td>
<td>-2.75</td>
<td>17.22</td>
</tr>
<tr>
<td></td>
<td>Sound + Diagrams</td>
<td>3.54</td>
<td>5.01362</td>
<td>.483</td>
<td>-6.45</td>
<td>13.52</td>
</tr>
<tr>
<td></td>
<td>Text + Video</td>
<td>5.53</td>
<td>5.01362</td>
<td>.273</td>
<td>-4.45</td>
<td>15.52</td>
</tr>
<tr>
<td>Sound + Diagrams</td>
<td>Text-Only</td>
<td>3.69</td>
<td>5.01362</td>
<td>.464</td>
<td>-6.29</td>
<td>13.68</td>
</tr>
<tr>
<td></td>
<td>Text + Diagrams</td>
<td>-3.54</td>
<td>5.01362</td>
<td>.483</td>
<td>-13.52</td>
<td>6.45</td>
</tr>
<tr>
<td></td>
<td>Text + Video</td>
<td>1.99</td>
<td>5.01362</td>
<td>.692</td>
<td>-7.99</td>
<td>11.98</td>
</tr>
<tr>
<td>Text + Video</td>
<td>Text-Only</td>
<td>1.70</td>
<td>5.01362</td>
<td>.736</td>
<td>-8.29</td>
<td>11.68</td>
</tr>
<tr>
<td></td>
<td>Text + Diagrams</td>
<td>-5.53</td>
<td>5.01362</td>
<td>.273</td>
<td>-15.52</td>
<td>4.45</td>
</tr>
<tr>
<td></td>
<td>Sound + Diagrams</td>
<td>-1.89</td>
<td>5.01362</td>
<td>.692</td>
<td>-11.98</td>
<td>7.99</td>
</tr>
</tbody>
</table>

8.2.4.2 Performance in the practical part

The performance of the participants on the completion of the practical tasks is characterised by what appears to be more significant differences across the four presentations, as shown in Figure 8.8 above. The hypothesis is that there is a significant difference between the performances of the participants across the presentations. Interestingly, a one-way ANOVA analysis shows that there is a highly significant difference in the scores that were obtained by the participants in the completion of the practical tasks ($F_{(3,76)} = 10.631$, $p<0.0001$, $N=80$). Thus, the Null Hypothesis can be rejected.

Similarly to the overall performance of the participants in the whole learning test, the significance in the difference between their learning performances in the completion of the practical tasks is mainly due to the low scores that were obtained by the Text-Only group. This is shown in Table 8.15 which displays the significance levels in the difference between the performances of the participants in this part of the learning test across any two presentations (LSD analysis).
Table 8.15: Performance differences in the practical part of the learning test

<table>
<thead>
<tr>
<th>(A) Presentation</th>
<th>(B) Presentation</th>
<th>Mean Difference (A-B)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>Text-Only</td>
<td>Text + Diagrams</td>
<td>-37.00(*)</td>
<td>6.80519</td>
<td>.000</td>
<td>-50.55</td>
</tr>
<tr>
<td></td>
<td>Sound + Diagrams</td>
<td>-27.35(*)</td>
<td>6.80519</td>
<td>.000</td>
<td>-40.90</td>
</tr>
<tr>
<td></td>
<td>Text + Video</td>
<td>-23.00(*)</td>
<td>6.80519</td>
<td>.001</td>
<td>-36.55</td>
</tr>
<tr>
<td>Text + Diagrams</td>
<td>Text-Only</td>
<td>37.00(*)</td>
<td>6.80519</td>
<td>.000</td>
<td>23.45</td>
</tr>
<tr>
<td></td>
<td>Sound + Diagrams</td>
<td>9.65</td>
<td>6.80519</td>
<td>.160</td>
<td>-3.90</td>
</tr>
<tr>
<td></td>
<td>Text + Video</td>
<td>14.00(*)</td>
<td>6.80519</td>
<td>.043</td>
<td>.45</td>
</tr>
<tr>
<td>Sound + Diagrams</td>
<td>Text-Only</td>
<td>27.35(*)</td>
<td>6.80519</td>
<td>.000</td>
<td>13.80</td>
</tr>
<tr>
<td></td>
<td>Text + Diagrams</td>
<td>-9.65</td>
<td>6.80519</td>
<td>.160</td>
<td>-23.20</td>
</tr>
<tr>
<td></td>
<td>Text + Video</td>
<td>4.35</td>
<td>6.80519</td>
<td>.525</td>
<td>-9.20</td>
</tr>
<tr>
<td>Text + Video</td>
<td>Text-Only</td>
<td>23.00(*)</td>
<td>6.80519</td>
<td>.001</td>
<td>9.45</td>
</tr>
<tr>
<td></td>
<td>Text + Diagrams</td>
<td>-14.00(*)</td>
<td>6.80519</td>
<td>.043</td>
<td>-27.55</td>
</tr>
<tr>
<td></td>
<td>Sound + Diagrams</td>
<td>-4.35</td>
<td>6.80519</td>
<td>.525</td>
<td>-17.90</td>
</tr>
</tbody>
</table>

* The mean difference is significant at the .05 level.

The difference in the performance between the participants of the Text-Only group and any of the other three groups is highly significant, which, combined with Figure 8.8, demonstrates a poor performance of this group in the completion of the practical tasks. As far as the other three groups of participants are concerned, the only significant difference is recorded between Text + Video and Text + Diagrams groups. Surprisingly, the Text + Video group achieved a worse performance than the Text + Diagrams group. We might have expected that video material would help in the completion of the practical tasks.

8.2.4.3 Comparison of performance in the two parts within each presentation

As far as each presentation itself is concerned, the percentage scores that were separately obtained in the two parts of the learning test are significantly different, apart from the Text-Only presentation, which is expected, since the performances of the Text-Only participants in the two parts of the learning test appear to be very similar in Figure 8.8. A one-way ANOVA analysis was carried out for each one presentation and yielded the following significance levels for the difference between the performances in the two parts of the learning test:
Based on the above results, in all the presentations apart from the Text-Only presentation, the participants have significantly performed better in the completion of the practical tasks than in answering correctly the questions included in the learning test. In the Text-Only presentation, the participants obtained a similarly low percentage score in both parts of the learning test. This suggests that they found it equally difficult to cope with the complexity of the questions and the completion of the practical tasks.

8.2.5 Comparison of the overall performance of the interaction subgroups in the two parts of the learning test

This section examines if there is any significant difference in performance in the written and practical parts between participants within the Within-Scene and Across-Scene subgroups.

8.2.5.1 Performance of the interaction subgroups in the written part of the learning test

Figure 8.9 shows the scores of the two subgroups in the written part of the learning test across the presentations.
The Text-Only presentation is the only presentation that appears to have an obvious difference between the performances of the Across-Scene and the Within-Scene subgroups in the written part of the learning test. However, a one-way ANOVA analysis shows that this difference does not quite reach significance ($F_{(1, 18)} = 4.067$, $p<0.059$, $N=20$).

The results of a 2x4 ANOVA analysis on the performance of the eight subgroups in the written part of the learning test are shown in Table 8.16. The results show that there is no significance in the difference between the performances of the participants in the written part of the learning test across the four presentations ($F_{(3, 72)} = 0.782$, $p<0.508$, $N=80$), which has already been analysed and shown in the Section 8.2.4.1. In addition to this, there is no significant difference between the performances of the eight subgroups in this part of the test ($F_{(1, 72)} = 1.843$, $p<0.179$, $N=80$). Finally, there is no interaction effect between the performances of the eight subgroups in this part of the test and the type of presentation ($F_{(3, 72)} = 1.154$, $p<0.333$, $N=80$).
Table 8.16: Results of 2x4 ANOVA analysis on the performance of the subgroups in the written part

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>1890.478(a)</td>
<td>7</td>
<td>270.068</td>
<td>1.093</td>
<td>.377</td>
</tr>
<tr>
<td>Intercept</td>
<td>215123.579</td>
<td>1</td>
<td>215123.579</td>
<td>870.522</td>
<td>.000</td>
</tr>
<tr>
<td>Presentation</td>
<td>579.491</td>
<td>3</td>
<td>193.164</td>
<td>.782</td>
<td>.508</td>
</tr>
<tr>
<td>Subgroup</td>
<td>455.440</td>
<td>1</td>
<td>455.440</td>
<td>1.843</td>
<td>.179</td>
</tr>
<tr>
<td>Presentation * Subgroup</td>
<td>855.547</td>
<td>3</td>
<td>285.182</td>
<td>1.154</td>
<td>.333</td>
</tr>
<tr>
<td>Error</td>
<td>17792.656</td>
<td>72</td>
<td>247.120</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>234808.713</td>
<td>80</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Corrected Total 19683.135 79

*a R² = .096 (Adjusted R² = .008)

If the performance of the two types of subgroups is considered separately, then a one-way ANOVA analysis also shows no significant difference between the performances of the Across-Scene subgroups (F (3, 36) = 0.573, p<0.636, N=40) and between the performances of the Within-Scene subgroups (F (3,36) = 1.383, p<0.264, N=40) across the four presentations. Additionally, a post-hoc LSD Analysis shows that there are no significant differences between the performances of any two Across-Scene subgroups (i.e. between the Text-Only Across-Scene subgroup and the Text + Diagrams Across-Scene subgroup) or any two Within-Scene subgroups, in the written part of the learning test.

8.2.5.2 Performance of the interaction subgroups in the practical part of the learning test

Figure 8.10 shows the average scores obtained by the two subgroups in the completion of the practical tasks. Similarly to the overall performance of the participants across the four presentations (regarding the completion of the practical tasks), it is the Text-Only subgroups that demonstrate a lower performance in this part of the learning test. Furthermore, the differences between the performances of the two subgroups within each presentation appear to be obvious in all cases. However, one-way ANOVA analyses show that these differences are not significant.
As far as the performances of the eight subgroups in the practical tasks are concerned, a 2x4 ANOVA analysis was carried out and the results are shown in Table 8.17.

According to these results, there is a highly significant difference between the performances of the participants in the completion of the practical tasks across the four presentations ($F_{(3, 72)} = 11.149$, $p<0.0001$, $N=80$), which has already been analysed and shown in the Section 8.2.4.2. There is no significant difference between the performances of the eight subgroups in the completion of the practical tasks ($F_{(1, 72)} = 1.408$, $p<0.239$, $N=80$) and, additionally, there is no interaction effect between the performances of the
eight subgroups in this part of the test, and the type of media combination 
\( F(3.71) = 2.098, p<0.108, N=80 \).

The performances of the Across-Scene subgroups in the completion of the practical tasks, 
across presentations, did not show any significant differences, according to a one-way 
ANOVA analysis \( F(3, 36) = 2.245, p<0.1, N=40 \). The difference between the 
performances of the Text-Only and the Text + Diagrams Across-Scene subgroups is the 
only significant result between any two Across-Scene subgroups \( p<0.017, N=20 \), 
according to the results of a post-hoc LSD Analysis.

On the other hand, the difference between the performances of the Within-Scene 
subgroups in the completion of the practical tasks is very significant, as shown by a one-
way ANOVA analysis \( F(0, 36) = 14.872, p<0.0001 \). In addition to this, the standard 
deviations are within a factor of 2 (Table 8.18) and the Levene Test gave a significance 
level of \( p<0.394 \), which both support the validity of the results.

<table>
<thead>
<tr>
<th>Text-Only</th>
<th>10</th>
<th>39.90</th>
<th>18.66935</th>
<th>5.90377</th>
<th>26.54</th>
<th>53.25</th>
<th>5.00</th>
<th>66.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text + Diagrams</td>
<td>10</td>
<td>66.90</td>
<td>12.61789</td>
<td>3.99013</td>
<td>77.87</td>
<td>95.93</td>
<td>59.0</td>
<td>100</td>
</tr>
<tr>
<td>Sound + Diagrams</td>
<td>10</td>
<td>80.90</td>
<td>14.43337</td>
<td>4.56423</td>
<td>70.57</td>
<td>91.22</td>
<td>51.0</td>
<td>100</td>
</tr>
<tr>
<td>Text + Video</td>
<td>10</td>
<td>78.00</td>
<td>22.55857</td>
<td>7.13384</td>
<td>61.86</td>
<td>94.14</td>
<td>29.0</td>
<td>100</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>71.42</td>
<td>25.15989</td>
<td>3.97813</td>
<td>63.38</td>
<td>79.47</td>
<td>5.00</td>
<td>100</td>
</tr>
</tbody>
</table>

This high level of significance is once again due to the poor performance of the Within-Scene subgroup who watched the Text-Only presentation. The Text-Only Within-Scene subgroup shows a significant difference between their performance in the completion of the practical tasks and the performance of the Text + Diagrams Within-Scene subgroup \( p<0.0001, N=20 \), the performance of the Sound + Diagrams Within-Scene subgroup \( p<0.0001, N=20 \) and the performance of the Text + Video Within-Scene subgroup \( p<0.0001, N=20 \), as shown by the results of a post-hoc LSD Analysis.
8.3 Learning styles

As has already been discussed, the Felder-Soloman ILS (Index of Learning Styles) test was used to identify the learning styles of the participants in the second experiment as well. The formation of each group was based on the answers of the learners to the 44 questions of the test, so that each group of participants could include a balanced number of sensing and intuitive learners. Formation of the groups was based on these two types of learners, since previous research (Table 2.2, Section 2.5.2) has shown that among other learning styles, these two are half distributed across learners. In addition to this, similar multimedia learning research carried out by Alty et al. (2003) has suggested that the learning performance of these two types of learner is differentiated.

Figure 8.11 displays the learning performance of the 80 participants across the four presentations, depending on their learning style within the three dimensions. The dimension of Input was not included in the analysis, since the verbal learners were greatly outnumbered by the visual learners, which prevented a valid analysis to take place among this type of learning style.

As shown in Figure 8.11, there appear to be performance differences between participants with different learning styles, across all the presentations, except for the Text-Only presentation (only the sequential and global learners seem to perform differently in this presentation). The differentiation in performance looks more obvious between the sensing and intuitive learners (excluding the Text-Only presentation), which is consistent with the research of Alty et al (2003).
8.3.1 Performance of active and reflective learners

First of all we examine if there is a significant difference in the performance of active/reflective participants across presentations and across learning style. A 2x4 ANOVA was carried out on the scores. The means and standard deviations are shown in Table 8.19.

Table 8.19: The Descriptive Statistics for the active/reflective learners

<table>
<thead>
<tr>
<th>Presentation</th>
<th>Act_Ref</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text-Only</td>
<td>Active</td>
<td>17.12</td>
<td>6.12</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Reflective</td>
<td>17.54</td>
<td>6.61</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>17.31</td>
<td>6.18</td>
<td>20</td>
</tr>
<tr>
<td>Text + Diagrams</td>
<td>Active</td>
<td>23.01</td>
<td>3.70</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Reflective</td>
<td>24.22</td>
<td>4.37</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>23.62</td>
<td>4.00</td>
<td>20</td>
</tr>
<tr>
<td>Sound + Diagrams</td>
<td>Active</td>
<td>20.57</td>
<td>5.95</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Reflective</td>
<td>23.46</td>
<td>4.92</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>21.58</td>
<td>5.66</td>
<td>20</td>
</tr>
<tr>
<td>Text + Video</td>
<td>Active</td>
<td>20.13</td>
<td>7.62</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Reflective</td>
<td>21.87</td>
<td>2.43</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>20.57</td>
<td>6.68</td>
<td>20</td>
</tr>
<tr>
<td>Total</td>
<td>Active</td>
<td>20.16</td>
<td>6.33</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>Reflective</td>
<td>21.73</td>
<td>5.57</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>20.77</td>
<td>6.06</td>
<td>80</td>
</tr>
</tbody>
</table>
The standard deviations are within a factor of 2 and the Levene Test for Homogeneity gave a significance of 0.399, so the assumptions of the ANOVA are justified. The results of the statistical analysis are given in Table 8.20.

Table 8.20: Results of 2x4 ANOVA analysis on the performance of the active and reflective learners

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>474.008(a)</td>
<td>7</td>
<td>67.715</td>
<td>2.008</td>
<td>.066</td>
</tr>
<tr>
<td>Intercept</td>
<td>31741.257</td>
<td>1</td>
<td>31741.257</td>
<td>941.423</td>
<td>.000</td>
</tr>
<tr>
<td>Presentation</td>
<td>422.992</td>
<td>3</td>
<td>140.997</td>
<td>4.182</td>
<td>.009</td>
</tr>
<tr>
<td>Act_Ref</td>
<td>44.235</td>
<td>1</td>
<td>44.235</td>
<td>1.312</td>
<td>.256</td>
</tr>
<tr>
<td>Presentation * Act_Ref</td>
<td>15.296</td>
<td>3</td>
<td>5.099</td>
<td>.151</td>
<td>.929</td>
</tr>
<tr>
<td>Error</td>
<td>2427.569</td>
<td>72</td>
<td>33.716</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>37408.855</td>
<td>80</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>2901.577</td>
<td>79</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a R²= .163 (Adjusted R²= .082)

There is clearly an effect between presentations (F (3, 72) = 4.182, p<0.009, N=80) independent of whether students are active or reflective learners which was already established earlier. No significant effect is observed between active and reflective learners (F (1, 72) =1.312, p<0.256, N=80) and there is also no significant interaction effect between active and reflective learners and the presentation type (F (3, 72) = 0.151, p<0.929, N=80).

8.3.2 Performance of sensing and intuitive learners

For sensing/intuitive learners the corresponding analyses are given in Table 8.21 and Table 8.22.
Table 8.21: The Descriptive Statistics for the sensing/intuitive learners

<table>
<thead>
<tr>
<th>Presentation</th>
<th>Sen. Int</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text-Only Sensing</td>
<td>17.26</td>
<td>6.58</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Intuitive</td>
<td>17.36</td>
<td>6.04</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>17.31</td>
<td>6.18</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Text + Diagrams</td>
<td>21.71</td>
<td>3.08</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Intuitive</td>
<td>25.18</td>
<td>4.09</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>23.82</td>
<td>3.99</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Sound + Diagrams</td>
<td>20.17</td>
<td>6.39</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Intuitive</td>
<td>23.70</td>
<td>3.77</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>21.58</td>
<td>5.66</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Text + Video Sensing</td>
<td>17.02</td>
<td>6.22</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Intuitive</td>
<td>24.90</td>
<td>4.39</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>20.57</td>
<td>6.68</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Total Sensing</td>
<td>18.94</td>
<td>5.98</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>Intuitive</td>
<td>22.89</td>
<td>5.50</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>20.77</td>
<td>6.06</td>
<td>80</td>
<td></td>
</tr>
</tbody>
</table>

The standard deviations are within a factor of 2 and the Levene Test for Homogeneity gave a significance of 0.295, so the assumptions of the ANOVA are justified.

Table 8.22: Results of 2x4 ANOVA analysis on the performance of the sensing/intuitive learners

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>843.405 (a)</td>
<td>7</td>
<td>120.486</td>
<td>4.215</td>
<td>.001</td>
</tr>
<tr>
<td>Intercept</td>
<td>34371.500</td>
<td>1</td>
<td>34371.500</td>
<td>1202.401</td>
<td>.000</td>
</tr>
<tr>
<td>Presentation</td>
<td>403.900</td>
<td>3</td>
<td>134.633</td>
<td>4.710</td>
<td>.005</td>
</tr>
<tr>
<td>Sen_Int</td>
<td>275.901</td>
<td>1</td>
<td>275.901</td>
<td>9.652</td>
<td>.003</td>
</tr>
<tr>
<td>Presentation * Sen_Int</td>
<td>150.987</td>
<td>3</td>
<td>50.329</td>
<td>1.761</td>
<td>.162</td>
</tr>
<tr>
<td>Error</td>
<td>2058.172</td>
<td>72</td>
<td>28.586</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>37408.855</td>
<td>80</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>2901.577</td>
<td>79</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\( R^2 = .291 \) (Adjusted \( R^2 = .222 \))

There is clearly an effect between presentations \( F (1, 72) = 4.71, p<0.005, N=80 \) independent of whether students are sensing or intuitive learners which was already established earlier. In contrast to the active/reflective learners there is a highly significant effect between sensing and intuitive learners \( F (1, 72) = 9.652, p<0.003, N=80 \). There is
again no significant interaction effect between sensing and intuitive learners and the presentation type (F (3,72) = 1.761, p<0.162, N=80).

By inspection, it appears that the main presentation effect is due to the different scoring in the Text-Only presentation (i.e. the presentation with only one medium). Therefore a 2x3 ANOVA was carried out on the performance of the sensing and the intuitive learners across the presentations excluding the Text-Only presentation. The results are shown in Table 8.23.

Table 8.23: Results of 2x3 ANOVA analysis on the performance of the sensing/intuitive learners excluding the Text-Only presentation

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>523.652(a)</td>
<td>5</td>
<td>104.730</td>
<td>4.242</td>
<td>.003</td>
</tr>
<tr>
<td>Intercept</td>
<td>28749.483</td>
<td>1</td>
<td>28749.483</td>
<td>1164.421</td>
<td>.000</td>
</tr>
<tr>
<td>Presentation</td>
<td>61.939</td>
<td>2</td>
<td>30.969</td>
<td>1.254</td>
<td>.293</td>
</tr>
<tr>
<td>Sen_Int</td>
<td>362.053</td>
<td>1</td>
<td>362.053</td>
<td></td>
<td>.000</td>
</tr>
<tr>
<td>Presentation * Sen_Int</td>
<td>62.868</td>
<td>2</td>
<td>31.434</td>
<td>1.273</td>
<td>.288</td>
</tr>
<tr>
<td>Error</td>
<td>1333.257</td>
<td>54</td>
<td>24.690</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>30693.766</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>1856.909</td>
<td>59</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a R² = .282 (Adjusted R² = .216)

The presentation effect indeed disappears (F (2,54) = 1.254, p<0.293, N=60), which has already been shown by the first analyses on the overall performance of the participants across the presentations. However, the significant difference between sensing and intuitive learners is even higher (F (1,54) = 14.664, p<0.0001, N=60).

It is interesting to examine if these two types of learner differ between their performances in the two parts of the test (Written versus Practical). Firstly, a one-way ANOVA analysis was carried out on the performances of the two types of learners in the written part of the test (not considering the distribution of their performances across the four presentations). The means and standard deviations are displayed in Table 8.24.
Table 8.24: Descriptive Statistics for the sensing/intuitive learners in the written part of the test

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>95% Confidence Interval for Mean</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Upper Bound</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensing</td>
<td>43</td>
<td>46.70</td>
<td>15.30</td>
<td>2.33395</td>
<td>41.99</td>
<td>15.40</td>
<td>77.70</td>
</tr>
<tr>
<td>Intuitive</td>
<td>37</td>
<td>57.85</td>
<td>14.31</td>
<td>2.35243</td>
<td>53.08</td>
<td>20.20</td>
<td>86.70</td>
</tr>
<tr>
<td>Total</td>
<td>80</td>
<td>51.86</td>
<td>15.78</td>
<td>1.76477</td>
<td>48.34</td>
<td>15.40</td>
<td>86.70</td>
</tr>
</tbody>
</table>

As shown in Table 8.24, the standard deviations are within a factor of 2 and, additionally, the Levene Test for Homogeneity gave a significance of 0.526, so the assumptions of the ANOVA are justified (the results are displayed in Table 8.25).

Table 8: 25: ANOVA results on the performance of the sensing/intuitive learners in the written part

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>2474.078</td>
<td>1</td>
<td>2474.078</td>
<td>11.214</td>
<td>.001</td>
</tr>
<tr>
<td>Within Groups</td>
<td>17209.057</td>
<td>78</td>
<td>220.629</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>19683.135</td>
<td>79</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Interestingly, there is a highly significant difference between the performances of the sensing and intuitive learners in the written part of the test ($F_{(1,78)} = 11.214$, $p<0.001$, $N=80$).

A one-way ANOVA analysis was also carried out on the scores obtained by the sensing and intuitive learners in the practical part of the learning test (again, not considering the distribution of their performances across the four presentations), however the results showed that there is no significance in the difference between their performances ($F_{(1,78)} = 3.637$, $p<0.06$, $N=80$).

Furthermore, 2x4 ANOVA analyses were carried out on the scores obtained by sensing and intuitive learners first in the written, and then in the practical parts of the test - this time across presentations. No significant difference was found between the performances of these two types of learners in the two parts of the test (Written part: $F_{(1,72)} = 1.843$, $p<0.179$, $N=80$; Practical part: $F_{(1,72)} = 1.408$, $p<0.239$, $N=80$). There was also no
interaction effect between their performances in the two parts of the test and the presentation type (Written part: \( F_{(3,72)} = 1.154, p<0.333, N=80; \) Practical part: \( F_{(3,72)}=2.098, p<0.108, N=80).\)

### 8.3.3 Performance of sequential and global learners

Since the proportion of visual learners was so high, no analysis on the performance of the visual and verbal learners was carried out.

For sequential and global learners the corresponding analyses are given in Table 8.26 and Table 8.27.

**Table 8.26: The Descriptive Statistics for the sequential/global learners**

<table>
<thead>
<tr>
<th>Presentation</th>
<th>Seq</th>
<th>Glo</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text-Only</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sequential</td>
<td>18.81</td>
<td>6.94</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global</td>
<td>15.05</td>
<td>4.26</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>17.31</td>
<td>6.18</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Text + Diagrams</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sequential</td>
<td>22.28</td>
<td>3.44</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global</td>
<td>24.71</td>
<td>4.23</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>23.62</td>
<td>3.99</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sound + Diagrams</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sequential</td>
<td>21.29</td>
<td>6.21</td>
<td>14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global</td>
<td>22.25</td>
<td>4.56</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>21.58</td>
<td>5.66</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Text + Video</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sequential</td>
<td>19.70</td>
<td>5.87</td>
<td>14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global</td>
<td>22.60</td>
<td>8.54</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>20.57</td>
<td>6.68</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>20.41</td>
<td>5.87</td>
<td>49</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>21.33</td>
<td>6.41</td>
<td>31</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>20.77</td>
<td>6.06</td>
<td>80</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The standard deviations are just within a factor of 2 and the Levene Test for Homogeneity gave a significance of 0.593, so the assumptions of the ANOVA are justified.
Table 8.27: Results of 2x4 ANOVA analysis on the performance of the sequential/global learners

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>553.064(a)</td>
<td>7</td>
<td>79.009</td>
<td>2.422</td>
<td>.028</td>
</tr>
<tr>
<td>Intercept</td>
<td>31344.550</td>
<td>1</td>
<td>31344.550</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td>Presentation</td>
<td>449.528</td>
<td>3</td>
<td>149.843</td>
<td>4.594</td>
<td>.005</td>
</tr>
<tr>
<td>Seq_Glo</td>
<td>7.252</td>
<td>1</td>
<td>7.252</td>
<td>.222</td>
<td>.639</td>
</tr>
<tr>
<td>Presentation * Seq_Glo</td>
<td>131.080</td>
<td>3</td>
<td>43.693</td>
<td>1.340</td>
<td>.268</td>
</tr>
<tr>
<td>Error</td>
<td>2348.513</td>
<td>72</td>
<td>32.618</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>37408.855</td>
<td>80</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>2901.577</td>
<td>79</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) R^2 = .191 (Adjusted R^2 = .112)

There is clearly an effect between presentations (F (3, 72) = 4.594, p<0.005, N=80) independent of whether students are sequential or global learners which was already established earlier. There is no significant effect between sequential and global learners (F (1, 72) = 0.222, p<0.639, N=80). There is again no significant interaction effect between sequential and global learners and the presentation type (F (3, 72) = 1.34, p<0.268, N=80).

8.3.4 Performance of learning styles within each presentation

Finally, Table 8.28 displays the significance levels in the differences between the performance of active/reflective learners, sensing/intuitive learners, and sequential/global learners within each presentation (significance levels are the outcome of a one-way ANOVA in each case).

Table 8.28: Significance levels on the differences between learning styles within each presentation

<table>
<thead>
<tr>
<th></th>
<th>Active/Reflective</th>
<th>Sensing/Intuitive</th>
<th>Sequential/Global</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text-Only</td>
<td>F=0.021, 1, 18, p&lt;0.885, N=20</td>
<td>F=0.001, 1, 18, p&lt;0.972, N=20</td>
<td>F=1.865, 1, 18, p&lt;0.189, N=20</td>
</tr>
<tr>
<td>Text + Diagrams</td>
<td>F=0.448, 1, 18, p&lt;0.512, N=20</td>
<td>F=4.419, 1, 18, p&lt;0.050, N=20</td>
<td>F=1.936, 1, 18, p&lt;0.181, N=20</td>
</tr>
<tr>
<td>Sound + Diagrams</td>
<td>F=1.205, 1, 18, p&lt;0.287, N=20</td>
<td>F=1.971, 1, 18, p&lt;0.177, N=20</td>
<td>F=0.114, 1, 18, p&lt;0.739, N=20</td>
</tr>
<tr>
<td>Text + Video</td>
<td>F=0.244, 1, 18, p&lt;0.627, N=20</td>
<td>F=10.215, 1, 18, p&lt;0.005, N=20</td>
<td>F=0.786, 1, 18, p&lt;0.387, N=20</td>
</tr>
<tr>
<td>All Participants</td>
<td>F=1.312, 1, 72, p&lt;0.256, N=80</td>
<td>F=9.652, 1, 72, p&lt;0.003, N=80</td>
<td>F=0.222, 1, 72, p&lt;0.639, N=80</td>
</tr>
<tr>
<td>Across Presentations</td>
<td>F=0.151, 3, 72, p&lt;0.929, N=80</td>
<td>F=1.761, 3, 72, p&lt;0.162, N=80</td>
<td>F=1.340, 3, 72, p&lt;0.268, N=80</td>
</tr>
</tbody>
</table>
The interesting results which come out of these analyses is that the sensing learners perform significantly worse than the intuitive learners in the presentations of Text + Diagrams and Text + Video.

8.4 Times to complete watching the presentation

Participants firstly watched the presentation until they were confident that they were ready to take the test. The time taken to complete watching the presentations varied across the presentation type. Figure 8.12 (SPSS output) shows the distribution of times for all presentation types (time is measured in seconds).

Figure 8.12: The distribution of time taken to complete the test

The data in the above histogram can be broken down into the four distributions for the presentations as shown in Figure 8.13.
As shown in Figure 8.13, the Text-Only group overall appears to have spent the least time in watching the corresponding presentation (whether they belonged to the Across-Scene or to the Within-Scene subgroup). This is also verified by the average times displayed in Table 8.3, Section 8.1.6.

### 8.4.1 Statistical analysis of times spent by the participants

A one-way ANOVA analysis was carried out on the times spent by all the participants in watching the corresponding presentations. The Descriptive Statistics are displayed in Table 8.29.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>95% Confidence Interval for Mean</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Upper Bound</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Text-Only</td>
<td>20</td>
<td>1363.60</td>
<td>631.58</td>
<td>141.226</td>
<td>1068.01</td>
<td>622</td>
<td>2586</td>
</tr>
<tr>
<td>Text + Diagrams</td>
<td>20</td>
<td>1684.30</td>
<td>385.80</td>
<td>86.269</td>
<td>1503.74</td>
<td>799</td>
<td>2603</td>
</tr>
<tr>
<td>Sound + Diagrams</td>
<td>20</td>
<td>1825.70</td>
<td>451.16</td>
<td>100.883</td>
<td>1614.55</td>
<td>1292</td>
<td>2803</td>
</tr>
<tr>
<td>Text + Video</td>
<td>20</td>
<td>1495.75</td>
<td>240.98</td>
<td>53.885</td>
<td>1382.97</td>
<td>1095</td>
<td>2025</td>
</tr>
<tr>
<td>Total</td>
<td>80</td>
<td>1592.34</td>
<td>475.60</td>
<td>53.173</td>
<td>1486.50</td>
<td>622</td>
<td>2803</td>
</tr>
</tbody>
</table>

The standard deviations have a factor greater than 2. In addition to this, the Levene test gives a high significance level (p<0.002), which does not support the validity of the
ANOVA results. Therefore, a non-parametric analysis was carried out instead (Kruskal-Wallis test) which yielded a high significance level on the differences between the times spent in watching the four presentations ($p<0.004$, $N=80$).

Checking on the standard deviations, it is obvious that it is the Text-Only presentation that is likely to have caused the ANOVA test to fail, since the times of this group result in a large standard deviation, in comparison with the other three. The size of the standard deviation in the Text-Only presentation would be expected, since the Text-Only Across-Scene subgroup made extensive use of the interaction mechanisms (Table 8.9, Section 8.2.3) which enabled the participants to re-examine previous scenes, and therefore spend considerably more time than the Text-Only Within-Scene subgroup. Indeed, excluding the Text-Only group and running again an one-way ANOVA analysis on the times spent for watching the other three multimedia presentations gives an acceptable significance level for the Levene test ($p<0.087$). This analysis yields a high significance level for the differences between the times spent by the participants in watching the three presentations ($F(2, s, )= 4.005$, $p<0.024$, $N=60$). An examination of the mean times taken in Table 8.3, Section 8.15, indicates that the Sound + Diagrams group spent the most time in watching the presentation out of these three groups, whereas the Text + Video group spent the least. Furthermore, the results of a post-hoc LSD analysis are shown in Table 8.30.

**Table 8.30: Difference in times between any two presentations except for the Text-Only presentation**

<table>
<thead>
<tr>
<th>(A) Presentation</th>
<th>(B) Presentation</th>
<th>Mean Difference (A-B)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>95% Confidence Interval</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text + Diagrams</td>
<td>Sound + Diagrams</td>
<td>-141.40</td>
<td>116.971</td>
<td>.232</td>
<td>-375.63</td>
<td>92.83</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Text + Video</td>
<td>-188.55</td>
<td>116.971</td>
<td>.112</td>
<td>-45.68</td>
<td>422.78</td>
<td></td>
</tr>
<tr>
<td>Sound + Diagrams</td>
<td>Text + Diagrams</td>
<td>141.40</td>
<td>116.971</td>
<td>.232</td>
<td>-92.63</td>
<td>375.63</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Text + Video</td>
<td>329.95(*)</td>
<td>116.971</td>
<td>.007</td>
<td>95.72</td>
<td>564.18</td>
<td></td>
</tr>
<tr>
<td>Text + Video</td>
<td>Text + Diagrams</td>
<td>-188.55</td>
<td>116.971</td>
<td>.112</td>
<td>-422.78</td>
<td>45.68</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sound + Diagrams</td>
<td>-329.95(*)</td>
<td>116.971</td>
<td>.007</td>
<td>-564.18</td>
<td>-95.72</td>
<td></td>
</tr>
</tbody>
</table>

* The mean difference is significant at the .05 level.

As shown in Table 8.30, there is a significant difference between the times spent by the participants in watching the Sound + Diagrams and the Text + Video presentations.
It seems likely that the separation of each group into Across-Scene and Within-Scene subgroups has affected the time taken to watch the presentations, as shown, for instance, by the standard deviation of the times spent for watching the Text-Only presentation (Table 8.29). The whole data was therefore analysed to see if there was a significant difference between the times of the Across-Scene subgroups and the Within-Scene subgroups. The hypothesis is that there is a difference in time taken between the two types of subgroup. An analysis of the data indicated that there was no statistical significance between the times taken for the two types of subgroup (Kruskall-Wallis, p<0.587, N=80) (A non-parametric test was also used here because the standard deviations vary by more than a factor of two and the Levene Test gave a highly significant result (p<0.012), which did not support the validity of the results of a 2x4 ANOVA analysis on the data). The Null Hypothesis therefore cannot be rejected.

Since it is the Across-Scene subgroups that caused a big difference between the standard deviations concerning the times spent in watching the corresponding presentations, analysis could be carried out only on the times spent by the Within-Scene subgroups (since there was not found any significant difference between the times spent by the Across-Scene and the Within-Scene subgroups, as well). A one-way ANOVA analysis shows that there is no significant difference between the times spent by the Within-Scene subgroups for watching the four presentations (F (3,36) = 2.637, p<0.064, N=40). In addition to this, a post-hoc LSD Analysis yields a significance result for the differences between the times spent by the Text-Only Within-Scene subgroup and the Text + Diagrams Within-Scene subgroup (p<0.048, N=20), and between the times spent by the Text-Only Within-Scene subgroup and the Sound + Diagrams Within-Scene subgroup (p<0.012, N=20).

Interestingly, the Text-Only participants took the shortest time to complete this watching phase but also had the worst overall scores.

8.4.2 Relationship between time and performance

In the preliminary experiment (Chapter 6) no relationship was identified between time and performance. It was therefore decided to see if this was true in the main experiment.
Diagrams were therefore constructed that connected a participant’s performance with the corresponding time taken. The resultant graph was then examined to see if there were any patterns that could suggest a potential relationship between time and performance. Figure 8.14 includes four diagrams that display for each presentation group, the distribution of the participants’ scores in relation to the time that they spent in watching the corresponding presentation.

Figure 8.14: Relationship between time and performance in each presentation

As shown in Figure 8.14, no obvious pattern is created by the points that connect performance and time for the participants of each group. Performance does not appear to improve or get worse when more time is spent by participants in assimilating the teaching instructions included in the corresponding presentation. It has already been determined that performance has been influenced by other factors, such as the learning styles of the participants, or the media combination being used. Another factor might be prior knowledge.
8.5 Performance considering prior knowledge

A final check on the results considers the possible effects of prior knowledge. All results presented in the previous sections of this chapter are ‘raw’ results and although three participants who declared at the outset that they had a significant amount of prior knowledge were excluded, the rest of the participants often showed some fragmentary prior knowledge in the pre-test. Such knowledge was usually low and unlikely to have any effect, but needs to be checked. Figure 8.15 shows the difference in learning performance of the participants when prior knowledge was considered. In this case percentages have to be used, since the optimum score is different in the two types of score.

![Figure 8.15: Prior Knowledge vs. Raw Results](image)

As can be seen in Figure 8.15, prior knowledge appears to be limited among all the participants. A 2x4 ANOVA analysis was carried out on the differences between the percentage scores obtained by the participants with and without considering the effects of their prior knowledge. The Descriptive Statistics are displayed in Table 8.31.
Table 8.31: Descriptive Statistics for raw scores and prior knowledge scores

<table>
<thead>
<tr>
<th>Presentation</th>
<th>PriorKnow</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text-Only</td>
<td>Not Considered</td>
<td>48.07</td>
<td>17.16</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Considered</td>
<td>43.90</td>
<td>16.38</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>45.99</td>
<td>16.69</td>
<td>40</td>
</tr>
<tr>
<td>Text + Diagrams</td>
<td>Not Considered</td>
<td>65.61</td>
<td>11.09</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Considered</td>
<td>62.43</td>
<td>11.03</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>64.02</td>
<td>11.04</td>
<td>40</td>
</tr>
<tr>
<td>Sound + Diagrams</td>
<td>Not Considered</td>
<td>59.95</td>
<td>15.72</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Considered</td>
<td>58.54</td>
<td>15.56</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>59.24</td>
<td>15.46</td>
<td>40</td>
</tr>
<tr>
<td>Text + Video</td>
<td>Not Considered</td>
<td>57.13</td>
<td>18.57</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Considered</td>
<td>55.20</td>
<td>18.16</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>56.17</td>
<td>18.15</td>
<td>40</td>
</tr>
<tr>
<td>Total</td>
<td>Not Considered</td>
<td>57.69</td>
<td>16.83</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>Considered</td>
<td>55.02</td>
<td>16.72</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>56.35</td>
<td>16.78</td>
<td>160</td>
</tr>
</tbody>
</table>

As shown in Table 8.31, the factor is within 2, concerning the standard deviations. In addition to this, the Levene test gave a significance level of $p<0.709$, which allows for using the results of the ANOVA analysis. These are shown in Table 8.32.

Table 8.32: ANOVA results on the difference between raw scores and prior knowledge scores

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>7315.789 (a)</td>
<td>7</td>
<td>1045.113</td>
<td>4.241</td>
<td>.000</td>
</tr>
<tr>
<td>Intercept</td>
<td>508124.858</td>
<td>1</td>
<td>508124.858</td>
<td>2061.957</td>
<td>.000</td>
</tr>
<tr>
<td>Presentation</td>
<td>6983.334</td>
<td>3</td>
<td>2327.778</td>
<td>9.446</td>
<td>.000</td>
</tr>
<tr>
<td>PriorKnow</td>
<td>285.877</td>
<td>1</td>
<td>285.877</td>
<td>1.160</td>
<td>.283</td>
</tr>
<tr>
<td>Presentation * PriorKnow</td>
<td>46.578</td>
<td>3</td>
<td>15.528</td>
<td>.063</td>
<td>.979</td>
</tr>
<tr>
<td>Error</td>
<td>37457.122</td>
<td>152</td>
<td>246.428</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>552897.769</td>
<td>160</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>44772.912</td>
<td>159</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(a) $R^2 = .163$ (Adjusted $R^2 = .125$)

The results show that there is no significant difference between the two types of percentage score ($F_{(1,152)} = 1.16$, $p<0.283$, $N=160$). In addition to this, there is no interaction effect between percentage scores with and without prior knowledge considered and the type of presentation ($F_{(0,152)} = 0.063$, $p<0.979$, $N=160$).
Since the background knowledge of the participants did not play a major role in forming the results of their overall performance, all the analyses that were carried out using the raw scores as data can be regarded as valid.

8.6 Types of learner based on scene-sequence

As has already been discussed, Alty et al. (2006) have identified three types of learner, based on the observing behaviour of the participants during their multimedia learning experiment – passive learners, re-learners and fast-forward learners. These three types are now specified in terms of the attributes of the multimedia presentations that were designed as part of the second experiment.

- **Passive learners** tend not to interact with the presentation (in order to re-examine information included in a previous scene, re-play the current scene or parts of it, delay or speed-up the flow of information) and they wait for each scene to end before clicking on the button that moves them to the following scene.

- **Re-learners** tend to use interaction mechanisms to visit previous scenes and re-examine the teaching material included in them. In the Within-Scene subgroups, **Re-learners** often re-play the current scene or re-examine parts of it.

- **Fast-forward learners** tend to use interaction mechanisms to speed-up the flow of information or move to the following scene before the current scene reaches its end.

Some participants may use all three types of interaction in a presentation. For instance, they may use interaction mechanisms either to re-examine previous scenes or to speed-up the flow of information. Whilst learners could use all three mechanisms, normally one would predominate. Learners were therefore defined by the most frequently recorded observed behaviour. For instance, a participant who showed features of a passive learner, but used once the interaction mechanism in order to move earlier to the following scene, would be still defined as passive learner.

In total, there were 47 re-learners (58.7%), 25 passive learners (31.3%) and 8 fast-forward learners (10.0%). They were distributed across presentations as follows:
• Text-Only: 14 re-learners, 4 passive learners, 2 fast-forward learners
• Text + Diagrams: 7 re-learners, 8 passive learners, 5 fast-forward learners
• Sound + Diagrams: 14 re-learners, 6 passive learners
• Text + Video: 12 re-learners, 7 passive learners, 1 fast-forward learner

As expected the number of fast-forward learners was low. In fact, only one fast-forward learner was recorded in the two presentations where sound was involved (Sound + Diagrams, Text + Video), since the sequential nature of auditory information prevents participants from speeding-up the flow of information (this would only be useful when information was re-examined) or moving earlier to the following scene.

Figure 8.16 demonstrates the average performances of the two types of learner (re-learners and passive learners) across presentations. The performance of the fast-forward learners was not taken into consideration due to the limited number of this type of learner.

As shown in Figure 8.16, except for the Sound + Diagrams presentation, the average performance of the two types of learner is similar across the presentations. In addition to this, a 2x4 ANOVA analysis yielded no significant differences between the performances of re-learners and passive learners ($F_{(1, 64)} = 0.475$, $p<0.493$, N=72) nor an interaction effect between the performances of these two types of learner and the presentation type.
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\(F(1, 64) = 0.682, p<0.566, N=72\). The results of this analysis were expected, since the basic difference between re-learners and passive learners included the time that was spent in observing the teaching material (obviously re-learners spent more time than passive learners), which was already found not to have any relationship with performance.

8.7 Summary of the results

Let us first summarise the analyses that took place on the second experiment and the results that originated from them.

1. An analysis was carried out on the raw scores of the participants across presentations.
   - The difference between the performances of the participants across the presentations was found to be significant.
   - The performances of the participants who watched the Text-Only presentation were significantly lower than those of the participants who watched the Text + Diagrams presentation and the Sound + Diagrams presentation. No other significant difference was found between the performances of the participants of any two presentations (for example no significant difference was found between the Text-Only and Text + Video presentations).

2. An analysis was carried out on the raw scores of the participants of the Across-Scene and the Within-Scene subgroups across presentations.
   - There was no significant difference between the performances of the Across-Scene participants and the Within-Scene participants. In addition to this, no interaction effect was found between the performances of the Across-Scene and Within-Scene subgroups and the type of presentation.
   - The Text-Only presentation was the only one in which the participants of the Within-Scene subgroup scored significantly lower than those of the Across-
Scene subgroup. No other significant difference was found within the other three presentations.

- No significant difference was found between the performances of the four Across-Scene subgroups across the four presentations. Furthermore, the Across-Scene subgroups did not present any significant difference between their participants’ performance across any two presentations.

- The difference between the performances of the four Within-Scene subgroups across the four presentations was significant. Furthermore, the Text-Only Within-Scene subgroup scored significantly lower than the Within-Scene subgroups of the Text + Diagrams presentation, the Sound + Diagrams presentation and the Text + Video presentation, respectively. No other significant difference was found between the performances of two Within-Scene subgroups across any two presentations.

3. An analysis was carried out on the percentage scores of the participants in the written and practical parts of the learning test.

- The difference between the performances of the participants in the two parts of the test was found to be significant. Also, there was a significant interaction effect between the performances of the participants in the two parts of the test and the type of presentation.

- Concerning the performances of the participants in the written part, no significant difference was found across the four presentations. As expected, no significant difference was found between the performances of any two presentations in the written part.

- Concerning the performances of the participants in the practical part, the difference between them was found to be significant across the four presentations. Furthermore, the performances of the Text-Only group was found to be significantly lower than those of any of the other three groups (Text + Diagrams, Sound + Diagrams, Text + Video), as far as the practical part is still concerned. For the same part of the test, the Text + Diagrams
group was found to have performed significantly better than the Text + Video group.

- Participants were found to have performed significantly better in the practical part of the test than in the written part within each presentation, except for the Text-Only presentation.

4. An analysis was carried out on the performances of the subgroups in the written and practical part of the learning test.

- No significant difference was found between the performances of the eight subgroups in the written part of the test. Also, the participants of the eight subgroups presented no interaction effect between their performances and the presentation type.

- The difference between the performances of the Across-Scene subgroups in the written part of the test, across the four presentations, was found to be non-significant. For the same part of the test, no significant difference was found between the performances of any two Across-Scene subgroups. The same results were obtained for the Within-Scene subgroups, as well.

- No significant difference was found between the performances of the eight subgroups in the practical part of the test. In addition to this, the eight subgroups presented no interaction effect between their performances in the practical part and the presentation type.

- There was no significant difference between the performances of the Across-Scene subgroups in the practical part of the test, across the four presentations. However, the Text + Diagrams Across-Scene subgroup performed significantly better in this part of the test than the Text-Only Across-Scene subgroup. The difference between the performances of the Within-Scene subgroups in the practical part, across the four presentations, was found to be significant. The Text-Only Within-Scene subgroup performed significantly worse in the practical part of the test than the other three Within-Scene subgroups.
5. An analysis was carried out on the raw scores of the participants with different learning styles across presentations.

- No significant difference was found between the performances of the active and reflective learners. Furthermore, these learners did not present any interaction effect between their performances and the presentation type.

- Intuitive learners performed significantly better than sensing learners. Significance in difference became even higher when analysis excluded the Text-Only group. In addition to this, intuitive learners performed significantly better than sensing learners within the Text + Diagrams presentation and within the Text + Video presentation. There were no interaction effects between the performances of sensing and intuitive learners and the presentation type. Furthermore, intuitive learners performed significantly better than the intuitive learners in the written part of the test, but there was no significant difference between their performances in the practical part. No significant difference was found between the performances of these two types of learner across presentations in both parts of the test and there was no interaction effect between their performances in the two parts of the test and the presentation type.

- No significant difference was found between the performances of the sequential and global learners. There was also no interaction effect between the performances of these two types of learner and the presentation type.

6. An analysis was carried out on the times spent by the participants in watching the presentations.

- A significant difference was found between the times spent by the participants in watching the corresponding presentations.

- In order to validate the ANOVA analysis, the Text-Only participants were excluded, and the corresponding analysis yielded a significant difference between the times spent by the participants in watching the other three presentations. In addition to this, the Sound + Diagrams participants spent
significantly more time in watching the corresponding presentation than the Text + Video participants.

- No significant difference was found between the times spent by the Across-Scene and the Within-Scene participants in watching the corresponding presentations.

- No significant difference was found between the times spent by the Within-Scene participants in watching the corresponding presentations. However, the Text-Only Within-Scene subgroup spent significantly less time than the Text + Diagrams Within-Scene subgroup and the Sound + Diagrams Within-Scene subgroup in watching the corresponding presentation.

- No relationship was identified between time and performance. The various performances of the participants within each presentation appeared to improve or get worse irrelevant to the time that they spent in watching the corresponding presentation.

7. An analysis was carried out on the performances of the participants with and without considering prior knowledge.

- No significant difference was found between the performances of the participants across presentations with or without considering prior knowledge. In addition to this, there was no interaction effect between the two types of performance and the presentation type.

8. An analysis was carried out on the performances of re-learners and passive learners across presentations.

The performances of the two types of learner yielded no significance across presentations. There was also no significant interaction effect between these performances and the presentation type.
8.8 Discussion of the results and conclusions

The first striking result is the poor performance of the Text-Only group compared with the rest, as has been seen qualitatively in Figure 8.4.

Firstly, the spread of the results is very different. The performance in Text + Diagrams and Sound + Diagrams is very close (all scores are between 15 and 25 apart from one outlier, and the difference in performance is not significant p<0.263 (from Table 8.6)). In contrast, both presentations which do not include diagrams have high standard deviations (6.18 and 6.68, and this is not caused by an outlier). Performance in the Text-Only presentation was very different than the other three. There was a highly significant difference between Text-Only and both Text + Diagrams (p<0.001) and Sound + Diagrams (p<0.021), and whilst the difference between Text-Only and Text + Video failed to reach a <0.05% significance it was approaching significance (p<0.075). The lack of the second visual medium (diagrams) has clearly adversely affected overall performance and the addition of video material was not equivalent to diagrammatic material. The other interesting result is the failure of the Sound + Diagrams presentation to stand out from the rest in contrast to the results of the experimental work of Alty and his colleagues (Alty, Al-Sharrah and Beacham, 2003; 2006) where Sound + Diagrams performance was significantly better. The difference is the improved performance of the Text + Diagrams group which has now reached a performance similar (and slightly higher) to that of Sound + Diagrams. This may be because the text in this experiment was placed very close to the relevant parts of the diagrams, in keeping with Mayer’s Spatial Contiguity Principle (Mayer, 2001), whereas in the Beacham and Alty experiment, the text was separated from the diagrams and they commented that the poor performance of Text + Diagrams might be accounted for by this text positioning. The Text + Video results are new and it was surprising that the addition of video material did not improve performance enough to compensate for the lack of diagrams. The practical nature of the experimental tasks was thought before the experiment to favour the presentation of the teaching material (at least a major part) through the use of video material, since participants could see exactly what they had to do without attempting to make any additional internal connections between verbal and non-verbal information (as occurred in the other three presentations).
Results were then analysed using a different approach, in order to identify the origins of the performance differences of the four groups of participants. Each presentation was subdivided into separate performances in the Across-Scene subgroup (they could visit previous scenes and re-examine parts of the teaching material) and in the Within-Scene subgroup (they could only re-play the current scene but not visit previous scenes). The Text-Only presentation was again the one that differed from the other presentations, in participants' performance in these two subgroups. Among the four Across-Scene subgroups, only the Text-Only subgroup took advantage of the interaction mechanisms that enabled them to re-examine information in previous scenes, which presumably aided them in comprehending the teaching material more efficiently. This was also reflected by the fact that the Across-Scene subgroup performed significantly better than the Within-Scene subgroup, within the Text-Only presentation. Therefore, the overall poor performance of the Text-Only group is partially due to the low scores of the Within-Scene subgroup who watched this presentation. This suggestion is also supported by the significantly lower performance of the Text-Only Within-Scene subgroup in comparison with the performance of the other three Within-Scene subgroups (there was even a significant difference between Text-Only and Text + Video Within-Scene subgroups, which was absent from the overall performances concerning these two presentations), and by the fact that no significant difference was found between the performances of the four Across-Scene subgroups, which indicates that the Text-Only participants managed to overcome the disadvantage of having only one medium by extensively re-examining information in the teaching material, thereby obtaining similar scores. This suggests that interactivity is an important factor in improving understanding in text-only based material.

A second analysis of the performance of the participants was achieved by separating out each participant's performance into percentage scores obtained in the written and the practical parts of the test. Analysis of the two types of score showed that participants performed significantly better in the practical part of the test than in the written part. Presumably, their attention was more attracted by the instructions on how to complete the practical tasks (whose presentation was more likely to involve a diagrammatic animation or a video clip in those presentations that involved a media combination) than by
peripheral information on the role of specific computer components. Interestingly, the various media combinations did not differentiate between the performance of the participants in the written part of the test, whereas there was a significant difference between the performance of the participants in the practical part of the test. Again, it was the Text-Only group who performed poorly in this part of the test, obtaining a significantly lower percentage score than all the other three groups. Thus, another factor that caused the overall poor performance of the Text-Only group was the low scores obtained by these participants in the completion of practical tasks. The absence of an additional medium (diagrams?) therefore really affected the performance of the participants.

An interesting result from the analysis of performance was the inability of the video material to enable learners to perform better than those who observed the teaching material via other media combinations. Before the experiment, it was expected that the video material would be useful in conveying instructions on how to carry out practical tasks, because such material shows exactly how a practical task is carried out. However, the performance of the Text + Video participants could not be significantly differentiated from the performances of the other three groups and, what is more, they performed significantly worse than the Text + Diagrams group which is surprising. Diagrammatic material once again proved to be more helpful to learners than video material, suggesting that information presented via diagrams is more efficiently stored and accessed in human memory than information presented via video. Further analysis of the performance of the subgroups in the two parts of the test did not yield any additional information on the differences between performances.

As expected, the practical part of the test included significant differences in performance, especially among the Within-Scene subgroups (the Text-Only Within-Scene accounted for the poor performance of the Text-Only group in the practical part of the test, since it performed significantly worse than the other three Within-Scene subgroups). Across-Scene subgroups who had previously showed that they had a similar performance in the whole test, demonstrated the same learning behaviour in the practical part of the test, as well. The only exception was recorded between the presentations of Text-Only and Text
+ Diagrams (the Text-Only *Across-Scene* subgroup scored significantly lower than the Text + Diagrams *Across-Scene* subgroup in the practical part of the test).

In general, the Text-Only group stood out from the rest of the groups, in terms of the performance in the learning test. The participants who watched this presentation showed that they faced great difficulties in recalling information presented only via text and, additionally, in using it efficiently in order to cope with the requirements of the learning test. These difficulties became even more obvious when earlier information could not be re-examined and when such information referred to the completion of the practical tasks. In particular, the ability to re-examine information proved to be essential for the Text-Only participants, since this improved performance to the level achieved by other groups even in the practical part of the test. This poor performance of the Text-Only group was also accompanied by results which showed that this group (in particular the *Within-Scene* subgroup) spent less time watching the corresponding presentation than the rest of the groups. Therefore, less time in watching the presentation did not suggest a positive effect of the media combination in understanding the material. The time taken was related to the nature of the media and the way learners interacted with them. In addition to this, time taken did not show any relationship with the performance level achieved by participants, which meant that spending longer times (or shorter times) in observing the teaching material did not necessarily imply a good learning performance or effective comprehension of information.

When information is presented via diagrams, the verbal information can either be in an auditory or textual format, and both connect effectively with diagrams and provide a learning benefit of the participants. Sound, due to its nature, is easier to connect with diagrams, in terms of synchronisation. However, a careful design of the Text + Diagrams presentation, respecting the relevant design principles, can compensate for the drawback of synchronisation in this presentation (in relation to the Sound + Diagrams presentation), providing learners with an effective connection of text and diagrams.

The addition of video material is evaluated in two ways. Firstly, compared with the Text-Only presentation (in terms of comparing a single medium with media combination), video material enabled participants to perform significantly better than those who
watched information only via text, considering the performance of the *Within-Scene* subgroups (both overall performance and performance in the written and practical parts of the learning test). Secondly, the video material did not improve performance compared with the other presentations which included a media combination. Considering overall performance in the learning test and the performance in the written part of the test, this was not surprising, since all the presentations (especially in the *Across-Scene* subgroup) did not cause any differentiation in the learning performance of the participants. However, the low performance in the practical part of the test for Text + Video (which was established by the significant difference in the performance between this presentation and the Text + Diagrams presentation) suggested that the features of this media combination were not likely to favour an effective storage of information in human memory. A key characteristic feature of video material is the great bulk of information details which are included within a video section, much of which is redundant compared with the core of the teaching material. This high volume of information could (particularly by the results on the practical part of the learning test) cause an inefficient storage of such information in the low-capacity human memory.

The results on learning styles analysis were consistent with other research both in terms of distribution of different learning styles among participants and the performance of different types of learner in the learning test. This consistency supported the use of the Felder-Soloman test as a means of identifying the learning styles of the participants. Most importantly, analysis of the scores obtained by the participants in the learning test showed significant differentiation in performance only between sensing and intuitive learners, similar to the Alty, Al-Sharrah and Beacham (2003; 2006) research. In addition to this, intuitive learners performed better than sensing learners in the theoretical part of the test (the difference in performance in the practical part between these learners was close to, but not significant), which again is similar to the results of the Alty et al. research who used only theoretical teaching material within multimedia presentations and therefore were unable to check the relevance of the practical nature of the material. Another similarity with this research was the fact that significance was not found across presentations. It is therefore suggested that the learning performance of these two types of learner is affected by the type of material rather than the type of media which are used to
present the material. It is also possible that performance of sensing and intuitive learners is affected by the type of learning test that is used to evaluate the knowledge that they obtained through a teaching procedure. The learning test that was used in the second experiment included a number of questions (all in the theoretical part) that required learners to apply their obtained knowledge to a problem-solving situation (that was not directly covered by the teaching material). In addition to this, Felder (1996) has pointed out that sensing learners dislike being tested on material that has not been covered in the teaching procedure (in our case the multimedia presentation) and, presumably, they are therefore more likely to perform inadequately in problem-solving situations. In general, intuitive learners are more innovative than sensing learners and are likely to adjust more efficiently when faced with novel teaching methods, such as the computer-based lectures that were represented by multimedia presentations.

These experiments compare student learning across different presentation media combinations and different interactive styles. They do not inform us of how such learning might differ in equivalent one-to-one, or one-to-many, face-to face teaching situations. This is a separate area of research not covered in the thesis.
Chapter 9  Conclusions and future recommendations

9.1 Introduction

This chapter presents the conclusions that have been drawn from the results of the experimental work and highlights any limitations in the work done. It also suggests future work that might be done to further extend the research. The work done is first summarised, before the conclusions are presented.

9.1.1 Literature review

A review was carried out on previous research whose work was related to this research. The review covered three major fields (which were part of multimedia learning): learning, memory theories and multimedia presentations.

The review on learning was divided into two parts. The first part examined how learning is achieved through the learning cycles (the three learning cycle models of Lewin, Dewey and Piaget were described). Out of this work, learning models have been proposed by various researchers and the inventories have been developed that have been based on these models. Their use has led to the identification of what are termed 'learning styles'. A number of candidate learning models were examined and the Felder-Silverman learning model was chosen to be used in the empirical work for the following reasons:

- It is a model which has been extensively used, particularly in engineering domains
- Its validity is supported by experimental work (Kovacic, 2004) and it has been used in other work on multimedia learning (Alty, 2002; Alty et al., 2003; 2006)
- It falls within the classes of model supported by Coffield (Coffield et al., 2004) who have given the most comprehensive analysis of learning models to date
- It is easy to administer and pleasant to use.

The Felder-Soloman test measures learners on four axes with extreme poles of Active/Reflective, Sensing/Intuitive, Verbal/Visual, and Sequential/Global learning
styles. There has been a limited amount of work on the effect of learning styles on learning and significant differences have been observed between the performance of sensing and intuitive learners, but as yet the reasons for this are not understood (Alty et al., 2006).

A review of the research that has been carried out on memory and its functions examined the predictions of Dual Coding Theory and Cognitive Load Theory on how information is stored, organised and accessed in human memory. Each theory gives insights into how learned information might be stored and retrieved and both theories have a considerable body of empirical support.

Media were then defined and described in terms of their use and role in human-to-human and human-to-computer communication. Empirical work which measured the effects of different media combinations on learning was identified. In particular, the empirical work of Mayer (and his cognitive theory) and Alty were reported. In addition, criticism regarding media and their contribution to learning was examined and this will be discussed further in the conclusions.

It was therefore decided to examine learning achieved in the same task in four different multimedia presentation environments – Text-Only, Text + Diagrams, Sound + Diagrams and Text + Video. The first three have already been used extensively in previous research but the fourth (Text + Video) has not been fully examined before. The task was deliberately chosen to be of a highly practical nature because most previous work has been on either theoretical material (e.g. Statistics, the Weather), the behaviour of Dynamic Systems (e.g. the cistern of Narayanan and Hegarty, (2002)) or explaining the operation of simple devices (e.g. pumps and brakes Mayer, (2001)). Thus, the actual task used in this research was the removal and installation of components in a computer system. It was thought that the practical nature of the task might favour sensing learners. In addition the use of video material might be important in a highly practical task.

Two experiments were planned – a preliminary pilot experiment to test out the design and suggest improvements – and a second full experiment with the improved design.
9.1.2 First experiment

The initial multimedia design considered all major design principles (based on other theories) and attempted to provide well-designed teaching material that would be understandable by a wide mix of learners.

Four presentations were constructed, each one including identical textual (or auditory where sound was involved) information. The construction of all presentations was based on the content of the Text-Only material, since this had to be able to stand alone. The addition of diagrams led to the constructions of the Text + Diagrams presentation and the replacement of text by voice narration led to the construction of the Sound + Diagrams presentation. The replacement of most diagrams by video material led to the construction of the Text + Video presentation.

The first experiment had the character of a pilot experiment and its results were used to aid in the design of the second major experiment. Twenty-four people took part in the pilot. The participants were divided into four groups; each group was presented with a different multimedia presentation. In addition to this, the participants answered the Felder-Soloman test to determine their learning styles and they were assigned to a group such that each group would contain a balanced number of sensing and intuitive learners. Before watching the multimedia presentation, the participants filled in a general questionnaire that assessed the amount of prior knowledge on the teaching domain.

Interaction was very limited in the pilot experiment. Participants could only move forward to the next section of the presentation (previous sections could not be re-examined). Learners first observed the corresponding presentation, and carried out all the practical tasks that were part of the teaching material (for instance, installation of the video card and CPU). At the end of the presentation, they were given a learning test which evaluated the knowledge they had acquired during the presentation.

A scoring mechanism was created, based on the complexity of each question in order to measure the learning achieved. There were both recall and recognition (multiple choice) questions. Although useful lessons were learned from the pilot, the number of participants was too low to enable statistically significant results to be obtained. The time that the participants spent on watching the corresponding presentations and the time
that they spent on identifying computer components and doing the various practical tasks were also recorded. Two other effects were examined. The effects of prior knowledge on the learning achievement reached was calculated and, additionally, the effect of question complexity was examined.

9.1.3 Second experiment

The second experiment was based on the results of the preliminary experiment, which led to a number of improvements in the teaching material, the multimedia design, the construction of the learning test and its scoring mechanism, and the scenario of the experiment. First of all, the teaching material was altered and shortened to make it more readable and reduce the time to be needed for its delivery. The multimedia design of the Text + Diagrams presentation was improved in order to create a more efficient connection of text and diagrams. A number of interaction mechanisms were added to all presentations that enabled some participants to move between previous, current or following scenes (only half of the participants in each group could visit previous scenes, whereas the other half could not). The learning test was modified so that it consisted only of recall questions. Most of them belonged to the learning test that was used in the preliminary experiment, having undergone slight alterations, so that they would be more or less complex, in terms of effectively testing knowledge. In addition to this, the scoring mechanism was altered to take into account the changes that took place in the learning test. The scenario of the experiment included one major change in relation to the preliminary experiment. The completion of the practical tasks was now carried out after watching the corresponding multimedia presentation, and was included as part of the learning test (a scoring mechanism was created so that the participants would obtain the appropriate score for fulfilling each practical task).

Eighty participants took part in the second experiment. Like in the first experiment, they were divided into four groups, depending on their learning styles, so that each group would contain a balanced number of sensing and intuitive learners (learning styles were still identified through the use of the Felder-Soloman test). Analysis on the results of the second experiment included the performance of the participants in the learning test,
order to identify any differentiation in learning caused by the various media combinations. This was further divided into the performance in the written part of the learning test (questions that referred to the teaching material) and the practical part of the learning test (performance on the completion of specific practical tasks).

Learning performance was yet again divided into the subgroups that could re-examine information of previous scenes of the presentation (Across-Scene subgroups) and those who could not (Within-Scene subgroups). Analysis was also carried out on the performance of the participants with different learning styles and different interaction behaviour, in order to identify the effects of learning styles and interaction mechanisms on learning. Finally, analysis was carried out on the times that were spent by the participants of each group in watching the corresponding presentations, so that any relationship between time and performance could be identified.

9.2 Conclusions based on the results of the research

The results will be examined in relation to the initial four hypotheses (stated in section 1.6).

9.2.1 First hypothesis examined

As far as the overall scores (in the whole learning test) are concerned, there was a significant difference in the performance of the participants across the four media combinations. However, this significant difference was proved to be due to the poor performance of the Text-Only participants which differed from the performance of the rest of the participants (as illustrated in Figure 9.1); when the analysis focused on the scores of the participants across any two presentations, it was demonstrated that the Text-Only group performed significantly lower than the Text + Diagrams and the Sound + Diagrams groups (interestingly there was no significant difference in performance between Text-Only and the Text + Video group).
However, the performance of the Text-Only participants was improved in relation to the other participants, when information could be re-examined (Across-Scene subgroups). The Text-Only participants managed to achieve a similar performance to the participants of the other three groups (as illustrated in Figure 9.2) by extensively re-examining information in previous scenes (in contrast with the other groups who made limited use of the interaction mechanism that enabled them to visit previous scenes and re-examine information).

![Figure 9.1: Overall performance across the four presentations](image1)

![Figure 9.2: Overall performance across the four Across-Scene subgroups](image2)

Dividing the learning test into the written part and the practical part provided the research with more interesting results concerning the learning performance of the Text-Only
participants. In the written part, no significant difference was recorded in the performance across the four presentations. This result was maintained regardless of whether participants could re-examine information of previous scenes (Across-Scene subgroups) or not (Within-Scene subgroups). This has been demonstrated in Figure 8.9.

Although there appears to be a difference in the Text-Only Within-Scene case, this was not significant. On the other hand, the Text-Only participants performed poorly in the completion of the practical tasks (practical part of the test), as they obtained significantly lower scores than all the other three groups. Similarly to the overall results in the whole learning test, the Text-Only participants improved their performance in the practical part of the test by extensively re-examining information of previous scenes (Across-Scene subgroups). As a result, they performed similarly to the Sound + Diagrams and Text + Video Across-Scene subgroups in the practical part of the test, but not to the Text + Diagrams Across-Scene subgroup, who still outperformed the Text-Only participants. The difference in the performance of Text-Only and Text + Diagrams participants in the practical part of the test (both in Across-Scene and Within-Scene subgroups) has been demonstrated in Figure 8.10.

The difference in the performance of the Text-Only participants in comparison with the participants who were presented the teaching material via a media combination was also recorded in the preliminary experiment. The Text-Only participants spent significantly more time in identifying computer components within the computer system and in carrying out the various practical tasks. Therefore, it was more complicated for them to comprehend information in text-only format and use it to fulfil tasks of a practical nature.

In general, in the cases where information in previous scenes could not be re-examined the Text-Only material lacked in efficiency, as far as recalling and comprehension is concerned. This result was even more striking in the practical part of the test, which was considered to be more complex than the written part. The performance of the Text-Only participants in this case (no re-examination of information) is in accordance with the basic prediction of the Dual Coding Theory (human memory consists of the verbal and nonverbal systems, whose interconnectedness aids in recalling and comprehending information) and the Multimedia Principle of Mayer’s Cognitive Theory (multimedia
learning is better achieved via the combination of media that support each other, than the use of a single medium).

However, the similar performance of the Text-Only participants (in relation to the performance of the other three groups) in the cases where they extensively re-examined previous information supports the criticisms of Clark (1983; 1985; 1994) and Narayanan and Hegarty (2002), who stressed the importance of teaching strategies in contrast with the effects of media on learning. In addition to this, this extensive re-examination of information occurred in a reasonable time. Although the performance of the Text-Only participants was improved by re-examining information, they were still outperformed by the Text + Diagrams participants in the practical part of the test, which shows that in complex learning tasks (such as those of a practical nature), information in text-only format cannot deliver instructions as efficiently as in text-and-diagrams format. The latter result also suggests that in complex learning tasks text-only information is likely to less effective unless supported by other media.

As far as the different performances in the two parts of the test are concerned, it is likely that participants were more motivated when observing the part of the teaching material that described the practical aspects of assembly instructions (for example, on how to install and remove the computer components). Textual descriptions of practical procedures are likely to be more vivid descriptions than the more theoretical material that described attributes of the components and other peripheral information. Another possible reason is the lower complexity of that teaching material which described the various attributes of the computer components (and which led to a similar performance of all participants in this part of the test, regardless of the media combination that was used to deliver the material), in contrast with the higher complexity of the part of the teaching material that included the instructions on how to replace and install the computer components.

9.2.2 Second hypothesis examined

Previous research on computer-based multimedia learning had demonstrated that diagrammatic information leads to better learning outcomes when it is accompanied by
voice narration than by on-screen text. Alty and his colleagues (Alty et al., 2003; 2006) had found significant differences in performance between Text + Diagrams and Sound + Diagrams (the Text + Diagrams was outperformed by the Sound + Diagrams). However, they suspected that this was due to the text not being close enough to the diagrams (Mayer's Spatial Contiguity Effect). Furthermore, Mayer and Moreno (Mayer and Moreno, 1998; Moreno and Mayer, 1999) have demonstrated through their experimental work that students learn better when animated diagrams are accompanied by voice narration than by on-screen text (Modality Principle).

Both experiments have made use of the Spatial Contiguity Principle by placing diagrammatic information close to textual material. Furthermore, in relation to the Modality Principle, the two experiments have included static diagrams in presentations that involved diagrammatic information (animation was limited and rarely applied). Analysis of the scores obtained by the participants in the second experiment yielded no significant difference in the performance of the Text + Diagrams and the Sound + Diagrams presentations in any part of the analysis. This result, compared with the findings of the empirical work of Beacham and Alty (2003; 2006), supports the Spatial Contiguity Principle, since placing the diagrams close to textual material led to similar performances between the participants of the two presentations. In addition to this, the use of static diagrams led to different results in relation to the Modality Principle. Presumably, if diagrams were animated, the results would be in accordance with the work of Mayer and Moreno, since animated diagrams carry more information details than static diagrams and they are likely to overload the visual channel if verbal information is presented via text.

However, the efficiency of the Text + Diagrams presentation to deliver instructions to learners on how to perform computer-based practical tasks seems to be more efficient than the Sound + Diagrams presentation. The Text + Diagrams participants were the only ones that significantly outperformed the Text-Only participants in the practical part of the test when information was re-examined (Across-Scene subgroups). Furthermore, the Text + Diagrams participants were the only ones that significantly outperformed the Text + Video participants in the practical part of the test.
9.2.3 Third hypothesis examined

This hypothesis reflects the expectations of the experimenters, regarding the performance of the participants who would be presented with video material. The use of video material was rarely encountered in multimedia learning experiments, so this experimental work could not be readily compared with previous results. Video material was particularly used to aid learners in the completion of the practical tasks, since in the rest of the teaching material (in the Text + Video presentation) video material was limited and replaced by real images or diagrams. In the first experiment no improvement was observed, although it was not clear because of the limited number of participants. Surprisingly, analysis of the overall scores of the participants in the completion of the practical tasks in the second experiment did not yield any improved performance of the Text + Video participants compared with the other participants either. What is more, they performed significantly worse than the Text + Diagrams presentation. This result indicates that the video material did not aid in recalling and comprehending information in the completion of the practical tasks. This is likely to be in accord with the predictions of Cognitive Load Theory.

Based on the principles of Cognitive Load Theory, the design of the four multimedia presentations in both experimental studies of this research endeavoured to eliminate any unnecessary cognitive load posed on the memory of the participants (for instance, in the Text + Diagrams presentation, diagrams were placed closely to the textual material to avoid causing a split-attention effect). Thus, cognitive load was likely to be caused only by the attributes of specific media. From all the media combinations, the Text + Video presentation was the one that was more likely to cause excessive cognitive load due to the video material, which inevitably carries a considerable amount of redundant (or irrelevant) information (which is not necessary in delivering a teaching message).

The poor performance of the Text + Video participants in the completion of the practical tasks justifies the predictions of Cognitive Load Theory and suggests that the amount of information included in each video clip accounted for the low scores of the participants of the second experiment in the practical part of the learning test. Furthermore, apart from poor recall, cognitive load affected comprehension as well. When a multimedia presentation describes a complex procedure (particularly a novel one for a learner), it is
essential that the learner adheres to the key points of this procedure (for instance, in the removal of the CPU chip, one key point was the handle that had to be lifted to unlock the chip). Within video material however, key points are presented together with other information that is not necessary for the task. These details are likely to distract learners away from these key points, even though they were clearly stressed within each presentation in both experiments. Thus, cognitive load may well have an adverse effect on learning when video material was used in these experimental studies.

Another possible reason for the low scores of the participants who were presented with video material might be that it does not encourage cognitive processes in human memory, and such processes are usually necessary in learning. Video material presents information via the combination of voice narration and a series of real images. Connection of these media is done automatically by the presentation itself and it is likely that no additional cognitive processes are carried out by learners, who probably feel that the material has been successfully comprehended. This is different from the other presentations where diagrams are included. In such cases, cognitive processes are essential to accomplish the connection of the verbal and nonverbal representations. As a result, learners who watch the video material are likely to imitate the actions that are displayed via video material, without involving any cognitive process when carrying out a practical task. This learning behaviour results in a poor performance, because when difficulties appear in the completion of a practical task, learners are not likely to make referential connections between verbal and nonverbal information (this procedure is activated in the cases of other media combinations including diagrammatic information), in order to overcome these difficulties. It is therefore imitation versus learning.

9.2.4 Fourth hypothesis examined

Although learning styles models have been examined in previous research for the validity of their questionnaire and the distribution of learning styles across students, limited research has been carried out on the potential differences in the learning performance of students with different learning styles. Using the Felder-Soloman test (based on the Felder-Silverman learning model), Alty identified significant differences in the learning
performance of sensing and intuitive learners. In particular, intuitive learners outperformed sensing learners, and although Alty was unable to explain this difference he suggested that it might be due to the theoretical nature of the domain studied (Statistics) which could favour intuitive learners.

Based on Alty’s suggestion, the results of the second experiment were expected to yield significant difference across the performance of sensing and intuitive learners. In addition to this, it was expected that sensing learners would outperform intuitive learners due to the practical nature of the tasks (sensing learners tend to be more practical). In addition the research would also examine if learning styles were affected by different media combinations.

Indeed, analysis of the scores obtained by participants with different learning styles (Active/Reflective, Sensing/Intuitive, Sequential/Global), yielded a significant difference only between sensing and intuitive learners. However, this difference was not affected by the media combinations. In addition to this, intuitive learners once again outperformed sensing learners.

The results firstly confirm the earlier results that the learning achieved by people with different learning styles (in particular sensing and intuitive learners) is not affected when the teaching material is presented via different media combinations. It is therefore the content of the teaching material that is mostly likely to affect the learning achieved by sensing and intuitive learners. The experimental studies of Alty and this research involved teaching materials of different nature (theoretical versus practical). Interestingly, the second experiment of this research recorded a better performance of intuitive learners in the written part of the test, but no significant difference was recorded in the practical part of the test. Thus, it does appear that when the material became more practical in nature, the sensing learners found it more interesting, more understandable and more in sympathy with their learning style. This could be an important point to bear in mind when designing presentations for sensing learners.

A further common feature of the two studies is the delivery of the teaching material via computer-based multimedia presentations, instead of the traditional lectures. This novelty
in the delivery might better suit intuitive learners who are regarded as more innovative than sensing learners.

9.2.5 Other conclusions

Both experiments demonstrated that there is no relationship between time and performance. Particularly in the second experiment, scores were randomly connected with the times spent in watching the corresponding presentation. In addition to this, re-learners (participants who re-examined information and therefore spent more time in watching the corresponding presentation) did not perform better than passive learners (participants who watch the presentation without interacting with it). This finding stresses the importance of the media used in the experiments, since the learning was affected by media combinations but not by the time spent to observe information. Time spent in watching each presentation depended on the type of media involved and the reading style of the participants.

9.2.6 Drawbacks and advantages of this experimental work

There are a number of features of this empirical work that should be re-considered and improved in future work, in order to lead to more valid results. First of all, the learning test consisted mostly of questions that examined retention and of a fewer number that examined transfer of knowledge (use of knowledge in order to deal with problem-solving situations). Since the use of knowledge in problem-solving situations is more appropriate to evaluate the learning achieved, it is advisable to include more transfer questions within a learning test (and presumably compare the performance in transfer questions with the performance in retention questions).

The individual participation that took place in the running of both experiments allowed more effective supervision of each participant during the experiment, but also resulted in a time-consuming procedure, in terms of completing each experimental study. This prevented experimenters from adding more features within the experiments that could provide the research with more results (but also delay the completion of the experimental
studies). One added feature would be the completion of an additional learning test by each participant that would take place a certain period after the day of the experiment (for instance a week after the participation in the experiment). Comparison of the performance of each participant in the two learning tests (the first completed within the experiment and the second completed after a week) could yield results regarding the effects of media combinations on long-term learning.

This experimental work took into consideration individual differences by measuring prior knowledge and, most importantly, by including the learning styles of participants in the results of this study. The existence of a number of learning models necessitated the evaluation of them (based on the work of Coffield et al., (2004)) which led to the decision to use the Felder-Silverman learning model. However, the results of both studies (the empirical work of Alty and Beacham, (2003; 2006) and this experimental study) on the effects of learning styles on the learning achieved are questioned regarding their origin (for instance, is the novel method of delivering a teaching material via computer-based multimedia presentations a likely reason why intuitive learners performed better than sensing learners in both studies?). It would be therefore helpful to use an additional learning-styles questionnaire, based on a valid learning model, and compare the results of both questionnaires for each participant regarding learning styles, such as the distribution of learning styles across participants and their interaction with media combinations in terms of learning.

Considering individual differences, this experimental work did not classify participants into learners with high and low spatial ability (ability to mentally integrate visual and verbal representations). A spatial-ability test could have been used to identify participants with high and low spatial ability and balance the groups that would be presented with diagrammatic information, in terms of more valid results.

Apart from the above drawbacks, this experimental work included features that strengthened the validity of its results. Such features were:

- The use of identical information material in all presentations. In addition to this, the Text-Only material could stand alone (it was the first presentation that was constructed).
• The design of the Text + Diagrams presentation that placed diagrams close to textual material and succeeded in efficiently connecting diagrammatic with textual information.

• Accessibility of scenes. Participants could easily access any scene of the presentation and any part of the information within each scene. In addition to this, they were constantly aware of which scenes they had already visited and which scenes were not examined. Participants were also able to scan information in auditory format almost equally with participants with other groups that were presented with textual and diagrammatic material.

• Individual participation in experimental studies aided in an effective supervision seemed to increase participants' motivation and eliminated inappropriate participation due to high prior knowledge.

• Levels of prior knowledge were effectively defined for each participant through the completion of the learning test before and after the presentation of the teaching material in the second experiment.

9.2.7 Future work

The teaching material should consist of instructions on how to fulfil various practical tasks, since little has been done on the field of practical tasks (and practical tasks form an appropriate learning task in terms of adequate complexity). Emphasis should be given to the learning styles that need to be further examined for their influence on learning, especially within computer-based environments. Thus, a future multimedia learning experiment could make use of two learning models and their inventories in order to identify the learning styles of participants. Apart from the inventory of Felder-Soloman, the inventory of Allinson and Hayes (1996) could also be considered, since evaluation has demonstrated its reliability and validity (Coffield et al., 2004).

Furthermore, future work on the effects of media learning should further investigate the effects of specific individual attributes and how these may interact with the presentation of teaching material via different media combinations. Some research has been already
carried out on the effects of dyslexia on learning within computer-based multimedia presentations (Beacham and Alty, 2003; 2006). Results have demonstrated that there is interaction of media combinations with dyslexia and that there is a need for further results on this area.

Other individual differences could include the evaluation of participants' mental abilities via the completion of valid Intelligence Quotient (IQ) tests. Therefore, each group of participants could be balanced across participants with different levels of IQ (or different levels of spatial ability, as another individual difference that might affect the learning achieved in multimedia learning experiments).

Better experiments could be designed to probe further the effects of theoretical and practical domains of learners with different learning styles. Other experiments could be developed for probing differences between sequential and global learners, and active and reflective learners using carefully chosen domain material which hopefully would exploit the different learning styles. For example, the way (or sequence) in which the material is presented could dramatically affect the learning of sequential and global learners. Information could be presented from a top-down, or bottom-up point of view.

Further research could also be carried out on the role that the complexity of teaching materials (and learning tasks included in them) might have on the results that demonstrate the effects of media combinations on learning. It has been demonstrated in this experimental work that the learning performance was different in the two parts of the test. In the practical part of the test that was addressed to the more complex part of the teaching material, participants performed better. Thus, complexity of tasks is likely to affect the motivation of students in learning how to fulfil them. However, how complex should a task be? And which media combinations favour the learning of a highly complex teaching material? Therefore, further research could carry out a series of experiments across the same participants, including teaching materials of various complexity and examining how learning is affected by different levels of complexity and how these levels interact with various media combinations.

Finally, further research could be done in multimedia learning that involves advanced experimental techniques (such as eye-trackers) which could throw more light on areas
causing difficulty or increased motivation. However, more effective research (involving
the use of appropriate scientific equipment) could involve learners watching Text +
Diagrams presentations and detect the movement of their eyes as they try to connect
textual and diagrammatic information. This research might identify different reading
styles, in terms of scanning textual and diagrammatic information. These styles could
also be combined with learning styles or other individual attributes and lead to
suggestions regarding the optimum multimedia design of Text + Diagrams presentations.
References


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Appendix A  Felder-Soloman Index of Learning Styles

INDEX OF LEARNING STYLES*
Barbara A. Soloman
First-Year College
North Carolina State University
Raleigh, North Carolina 27695

Richard M. Felder
Department of Chemical Engineering
North Carolina State University
Raleigh, NC 27695-7905

DIRECTIONS

Tick "a" or "b" to indicate your answer to every question. Please choose only one answer for each question.

If both "a" and "b" seem to apply to you, choose the one that applies more frequently.

1. I understand something better after I
   (a) try it out.
   (b) think it through.

2. I would rather be considered
   (a) realistic.
   (b) innovative.

3. When I think about what I did yesterday, I am most likely to get
   (a) a picture.
   (b) words.

4. I tend to
   (a) understand details of a subject but may be fuzzy about its overall structure.
   (b) understand the overall structure but may be fuzzy about details.

5. When I am learning something new, it helps me to
   (a) talk about it.
   (b) think about it.

6. If I were a teacher, I would rather teach a course
   (a) that deals with facts and real life situations.
   (b) that deals with ideas and theories.

7. I prefer to get new information in
   (a) pictures, diagrams, graphs, or maps.
   (b) written directions or verbal information.
8. Once I understand
   (a) all the parts, I understand the whole thing.
   (b) the whole thing, I see how the parts fit.
9. In a study group working on difficult material, I am more likely to
   (a) jump in and contribute ideas.
   (b) sit back and listen.
10. I find it easier
    (a) to learn facts.
    (b) to learn concepts.
11. In a book with lots of pictures and charts, I am likely to
    (a) look over the pictures and charts carefully.
    (b) focus on the written text.
12. When I solve math problems
    (a) I usually work my way to the solutions one step at a time.
    (b) I often just see the solutions but then have to struggle to figure out the steps to get to them.
13. In classes I have taken
    (a) I have usually gotten to know many of the students.
    (b) I have rarely gotten to know many of the students.
14. In reading nonfiction, I prefer
    (a) something that teaches me new facts or tells me how to do something.
    (b) something that gives me new ideas to think about.
15. I like teachers
    (a) who put a lot of diagrams on the board.
    (b) who spend a lot of time explaining.
16. When I'm analyzing a story or a novel
    (a) I think of the incidents and try to put them together to figure out the themes.
    (b) I just know what the themes are when I finish reading and then I have to go back and find the incidents that demonstrate them.
17. When I start a homework problem, I am more likely to
    (a) start working on the solution immediately.
    (b) try to fully understand the problem first.
18. I prefer the idea of
    (a) certainty.
    (b) theory.
19. I remember best
    (a) what I see.
    (b) what I hear.
20. It is more important to me that an instructor
    (a) lay out the material in clear sequential steps.
    (b) give me an overall picture and relate the material to other subjects.
21. I prefer to study
    (a) in a study group.
    (b) alone.
22. I am more likely to be considered
    (a) careful about the details of my work.
    (b) creative about how to do my work.
23. When I get directions to a new place, I prefer
   (a) a map.
   (b) written instructions.

24. I learn
   (a) at a fairly regular pace. If I study hard, I'll "get it."
   (b) in fits and starts. I'll be totally confused and then suddenly it all "clicks."

25. I would rather first
   (a) try things out.
   (b) think about how I'm going to do it.

26. When I am reading for enjoyment, I like writers to
   (a) clearly say what they mean.
   (b) say things in creative, interesting ways.

27. When I see a diagram or sketch in class, I am most likely to remember
   (a) the picture.
   (b) what the instructor said about it.

28. When considering a body of information, I am more likely to
   (a) focus on details and miss the big picture.
   (b) try to understand the big picture before getting into the details.

29. I more easily remember
   (a) something I have done.
   (b) something I have thought a lot about.

30. When I have to perform a task, I prefer to
   (a) master one way of doing it.
   (b) come up with new ways of doing it.

31. When someone is showing me data, I prefer
   (a) charts or graphs.
   (b) text summarizing the results.

32. When writing a paper, I am more likely to
   (a) work on (think about or write) the beginning of the paper and progress forward.
   (b) work on (think about or write) different parts of the paper and then order them.

33. When I have to work on a group project, I first want to
   (a) have "group brainstorming" where everyone contributes ideas.
   (b) brainstorm individually and then come together as a group to compare ideas.

34. I consider it higher praise to call someone
   (a) sensible.
   (b) imaginative.

35. When I meet people at a party, I am more likely to remember
   (a) what they looked like.
   (b) what they said about themselves.

36. When I am learning a new subject, I prefer to
   (a) stay focused on that subject, learning as much about it as I can.
   (b) try to make connections between that subject and related subjects.

37. I am more likely to be considered
   (a) outgoing.
   (b) reserved.
38. I prefer courses that emphasize
   (a) concrete material (facts, data).
   (b) abstract material (concepts, theories).
39. For entertainment, I would rather
   (a) watch television.
   (b) read a book.
40. Some teachers start their lectures with an outline of what they will cover. Such outlines are
   (a) somewhat helpful to me.
   (b) very helpful to me.
41. The idea of doing homework in groups, with one grade for the entire group,
   (a) appeals to me.
   (b) does not appeal to me.
42. When I am doing long calculations,
   (a) I tend to repeat all my steps and check my work carefully.
   (b) I find checking my work tiresome and have to force myself to do it.
43. I tend to picture places I have been
   (a) easily and fairly accurately.
   (b) with difficulty and without much detail.
44. When solving problems in a group, I would be more likely to
   (a) think of the steps in the solution process.
   (b) think of possible consequences or applications of the solution in a wide range of areas.
### SCORING SHEET

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<th>SEN/INT</th>
<th>VIS/VRB</th>
<th>SEQ/GLO</th>
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**Total (sum X's in each column)**

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<tr>
<th>ACT/REF</th>
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<td>a b</td>
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(Larger - Smaller) + Letter of Larger (see below*)

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**Explanation of scores**

- If your score on a scale is 1-3, you have a mild preference for one or the other dimension but you are essentially well balanced. (For example, a 3a in the ACT/REF category indicates a mild preference for active learning.)

- If your score on a scale is 5-7, you have a moderate preference for one dimension of the scale and will learn more easily in a teaching environment which favors that dimension.

- If your score on a scale is 9-11, you have a strong preference for one dimension of the scale. You may have real difficulty learning in an environment which does not support that preference.
Appendix B  Teaching materials used in the two experiments

1. Teaching script used in the first experiment

First part: Video Card

Stage 1, Step 1

First of all, the workplace will be described to you, so that it will be more familiar to you. The workplace consists basically of two computers. The first computer is the one you are currently using to receive the messages of this presentation.

The second computer is on the left of the computer you are using and it is the target computer for component replacement. It is also the computer on which you will run the appropriate programs to check for improvement in performance.

To avoid confusion during instructions, we will call the computer, whose components are going to be replaced, the 'target computer', and the one that you are currently using to receive this presentation the 'instructions computer', respectively.

In addition to the two computers, the workplace also consists of a video card, a CPU chip, and a screwdriver. They have all been placed on the antistatic mat between the two computers. Now, identify in the workplace the antistatic mat and the screwdriver on it and return to the 'instructions computer' here. Do not try to identify the video card and the CPU chip, as this will take place in the next section.

In case you are not familiar with these components, the CPU chip is quite a bit smaller than the video card and has a square shape, whereas the video card is bigger and has a rectangular shape. You can check again the components on the antistatic mat, in order, this time, to distinguish the CPU chip from the video card. Return to the 'instructions computer' afterwards.

The video card and the CPU chip on the mat will be used for replacing the old ones in the 'target computer'. The screwdriver will be used whenever you need to unscrew any screws in the hardware.

The antistatic mat is necessary, and electronic parts such as the CPU chip and the video card must be placed on it to avoid damage. The mat provides an easy way of draining static electricity from the computer components.

Take a look at the workplace in order to start getting familiar with it. Then you can go to the next step.
Stage 1, Step 2

The concept of the first task you are about to fulfil is to find out the importance of the role that the video card plays in displaying the graphics on your monitor.

The video card controls the quality of what you see on your monitor. It provides the means for the computer to "talk" to your monitor so that it can display what the computer is doing.

The video card is usually a separate card that fits into the computer. Sometimes, it is incorporated into the computer system. In our case, the video card is a separate card.

You may now move on to the next step in order to check the graphics performance of the old video card.

Stage 1, Step 3

Before the video card is replaced, you need to measure its current performance, so that you can compare it with the graphics performance of the new video card.

To do this, you will open a file containing a real image. This is a photo of flowers in a forest.

The photo consists of many colours, which makes it quite demanding, in terms of an effective display of the colours. Thus, an efficient video card is necessary to ensure a proper display of all colours.

Now, go to the 'target computer'. Locate on the desktop the icon called "flowers" and then return to the instructions here.

You should double-click on the icon to display the photo. You will be given 30 seconds to watch carefully the image, in terms of the colours that it consists of. Now, press the button below, and then go to the 'target computer' to open the photo. When time is up, return to the instructions here.

Now, you are ready to fill in a small questionnaire, related to the photo that you have just watched. Press the button below and the supervisor will give you the questionnaire. After you fill in the questionnaire, return to the instructions here.

Now that you have answered the questionnaire, you may move on.

Now, turn off the 'target computer', in order to move on to the next step. In case you are not sure how to do this, click here so that you can receive extra information. Return to the 'instructions computer' afterwards.
(To turn off the 'target computer', select the START button and follow the SHUT DOWN procedure. You will be presented with the typical message "It's now safe to turn off your computer". You should then press the power button, on the right of the system's box, to turn off the 'target computer' and the button on the monitor to turn off the monitor. Now, go and turn off the 'target computer' and its monitor. Return to the instructions here afterwards.)

Now, after making sure that the 'target computer' is turned off, go and unplug both the monitor and the computer from the mains. The mains sockets are located at the rear of the workplace, behind the two computer monitors. In terms of security, the supervisor will assist you to ensure that everything is done correctly and in the right sequence.

Now that you have checked the graphics performance of the old video card, you should remove it from the 'target computer'. Therefore, you should first locate the old video card in the computer system, so you are ready to move on to stage 2.

Stage 2, Step 1

Now it is time to replace the old video card of the 'target computer' with the new one. The video card, together with other components, is located within the computer system.

The computer system is the big, rectangular 'box', located on the far left of the workplace, as you have already noticed.

The system cover of the 'target computer' has already been removed for you, which means that you have a direct view of the system inside and all of its hardware components. You may take a look at the system of the 'target computer' and return to the instructions afterwards.

If you look into the system, you will see a number of components located on the top of a green rectangular board, which is located at the base of the system. This board is called 'system board' or 'motherboard'. Identify the system board of the 'target computer' and return to the 'instructions computer'.

The system board is the circuit board to which all the other components of the computer are connected in some way. The video card, sound card, etc. all plug into the system board via a socket or a slot.

The video card is connected to the monitor. It is connected through the monitor cable (also called VGA connector), which is attached to the card.

So, to remove the video card, you will have to remove the monitor cable first. It is easy to spot the monitor cable of the 'target computer', by following the cable originating from the monitor and going to the left side of the computer system. Identify the monitor cable of the 'target computer' and return to the instructions here.
As was mentioned, the monitor cable is connected to the video card. So, by following the monitor cable, you can identify the video card. Now, identify the video card of the 'target computer' and return to the instructions here.

Remove the monitor cable from the system by unscrewing (by hand) the two screws that hold the cable.

Now, you are ready to remove the video card, so you may go to the next step.

Stage 2, Step 2

You should bear in mind that static electricity can severely damage electronic parts. Before touching any electronic parts, drain static electricity from your body (for example, by touching the metal frame of your computer).

As you may have already noticed, the video card is located in a slot on the system board. There are two main types of slots on the system board - the ISA and the PCI slots, where peripherals such as the video card or the sound card are installed.

ISA stands for Industry Standard Architecture. Since about 2002 the last ISA slots on new system boards have been replaced by extra PCI slots.

ISA slots are generally long and black and have a separator almost halfway between the ends of the slot.

In our system board, there are three (3) black ISA slots, located at the front-left corner of the system board. One of them hosts our video card. Identify the ISA slots on the system board and then return back to the instructions.

PCI stands for Peripheral Component Interconnect. PCI slots have displaced ISA slots on the new system boards as a result of higher performance, since they allow a larger and faster transfer of data.

The PCI slots are either white or brown (generally a different colour from the ISA slots) with a separator very close to one end.

There are four (4) white PCI slots, on the left part of the system board, behind the ISA slots. Identify the PCI slots on the system board and then return back to the 'instructions computer'.

Depending on its type, a video card can either be installed in an ISA or a PCI slot. Our video card is currently located in one of the three ISA slots, but you should bear in mind that the new video card will be placed in one of the four PCI slots.
Now, you are ready to remove the old video card from the ISA slot. The card is held in
the system by a screw, which is placed on the top of the card's left metallic frame.
Identify the screw on the video card and return to the instructions here.

Now, take the screwdriver, which is located on the antistatic mat, and use it to unscrew
the screw. Save the screw afterwards by placing it on the antistatic mat.

When handling a card, like the video card, carefully hold it by its edges and avoid
touching its circuitry.

Gently remove the video card from the ISA slot by pulling it out of its slot. It may be
easier to rock the card left and right a little to pry it loose, but do not break the slot. If the
video card resists being removed, it might need a little extra force. Now, go and remove
the old video card and place it on the antistatic mat.

You have just removed the old video card. Now, you are ready to move on to the next
step, where you will install the new video card.

Stage 2, Step 3

The new video card is to be fitted into a PCI slot. You have already identified PCI slots
as being the white slots on the left part of the system board, behind the ISA slots. You
can place the new video card in any of the four PCI slots, as long as they are not already
occupied by other components.

Inserting the new video card into a slot may require a little force. Line up the card above
the slot, trying to match the separator of the card's slot with the separator of the PCI slot,
and add downward pressure to the card to ensure a proper "seat". Now, go and insert
the video card into a PCI slot.

Use the screw, which you saved when you removed the old card, to attach the new video
card to the system.

Now, the new video card has been installed! The next step is to reconnect the monitor
cable to the new video card.

To do this, fit the pins of the cable into the holes of the socket. After inserting the cable
into the socket, tighten the two screws to make sure that the cable is properly held in the
socket.

You may connect the plugs of both the computer and the monitor to the mains. Turn on
the monitor and the computer and wait for Windows to load. When this happens, return
to the instructions here.
Before opening the file containing the photo, you need to change the settings of the screen, in terms of the total colours that each pixel can display.

To understand the meaning of what you are going to do, imagine that what you see on the screen consists of a set of dots. These dots are called 'pixels' and they can have a number of colours, which ranges from 16 up to millions of colours!

Screen colours are constructed from red, green and blue fluorescent phosphors (or other light emitting components, depending on screen type). This is known as the RGB system, which is the system that is used on display screens to generate colours. RGB stands for Red, Green and Blue.

Thus, there are three colour channels, the Red, the Green and the Blue channel that, combined, make up each pixel on the screen.

In typical RGB systems, each colour channel can take 256 values, so all three channels together represent 256 colour combinations for each pixel. In other words, each pixel can have approximately 16.7 million colours! This number of available colours is called 'True Colour'.

True Colour allows the display of more colours than the eye can distinguish, so some users choose to use the 'High Colour' option. High Colour limits each pixel in terms of the number of colour combinations, but the visual difference is almost unnoticeable and, furthermore, this reduction in colours can boost video performance.

The old video card, which you have just replaced with the new one, belongs to previous technology, allowing a pixel to have only 256 colours.

However, the new video card, which you have just installed, enables us to use the true colour or the high colour option on our display screen, resulting in images with better quality.

To enable the screen to take advantage of the abilities of the new video card, you should change the colours option from 256 to high colour. Go to the 'target computer' and right-click anywhere on the screen, apart from the icons. From the window that pops up, choose the option 'properties'.

From the new window, choose the option ‘Settings’.

Find the 'colours' drop-down menu at the bottom-left part of the window and choose the option 'high colour' from the menu.

Now you should confirm the change in the number of colours. At the bottom-right corner of the window, press 'apply' and then, as you are asked if you want to restart your computer, do so, in order to restart the 'target computer' and wait for Windows to come up again.
You have just changed the number of colours on the screen from 256 to high colour, so you may move on to the next stage.

Stage 3, Step 1

Now, go to the 'target computer' and double-click on the icon called "flowers", in order to open again the photo. Like the first time, you can watch the photo for up to 30 seconds and you are asked to notice the colours displayed on the photo. Now, press the button below and then go to the 'target computer' to open the photo. When time is up, return to the instructions here.

You are ready to fill in the related questionnaire, so press the button below and the supervisor will give the questionnaire to you. After filling it in, return to the instructions here.

Congratulations! You have finished the first task. You may now move on to the second task.

Second part: CPU

Stage 1, Step 1

Now you are ready to proceed to the CPU chip replacement. CPU stands for Central Processing Unit. As its name suggests, the CPU is the control unit that processes all of the instructions for the computer.

The CPU can be considered as the 'brain' of the computer. It does all the calculations, which makes it the most important part of the computer. The efficiency of a CPU is measured by speed, for example, how fast instructions are carried out.

Thus, the installation of the new and better CPU chip is going to improve the processing speed of the 'target computer' and eventually you will measure this improvement. Your first task therefore is to run an appropriate program, whose time of execution depends mostly on the CPU.

The program we have chosen is one that calculates and displays all prime numbers from 1 to 100000.

The mathematical term 'prime number' refers to all integer numbers that can be divided only by themselves and 1 and no other number. For example, 5 is a prime number because it can only be divided by 5 or 1, 7 is a prime number because it can only be
divided by 7 or 1 and so on. 6 is not a prime number because it can be divided by 2 and 3 as well.

Calculating all prime numbers from 1 to 100000 is a rather time consuming procedure, whose total time of execution depends on the CPU of the computer.

The total time of execution of this specific program should therefore be measured twice, once with the old CPU chip and once with the new one, so that you can compare the improvement in processing speed. The time measurement is done by the program itself, and it measures the time from the beginning until the end of the program's execution.

The beginning of the program is when you trigger its execution, by double-clicking on the corresponding icon, and the end of the program is when all prime numbers are displayed on the screen. The time is displayed just below the last prime number in the sequence.

Now, go to the 'target computer'. Locate on the desktop the icon called 'primes' and then return to the instructions here.

Double-click on the icon and wait for the program to be executed. As expected, you will come up with a long list of all the prime numbers from 1 to 100000, followed by the total time of the program's execution. Now, click on the button below and then go to the 'target computer' to run the prime-numbers program. Return to the instructions here afterwards.

Now, you are ready to answer the questionnaire related to the 'prime numbers' program, so click on the button below and the supervisor will give you the questionnaire. Return to the instructions here afterwards.

Now that you have answered the questionnaire, you may move on.

Now, go and shut down the computer, switch off the monitor and unplug both the computer and the monitor.

You may go to the next stage of the task, where you will identify the old CPU chip on the system board and replace it with the new one.

Stage 2, Step 1

In this stage, you will replace the old CPU chip with the new (and better) one. That means that you should first identify the exact place of the old CPU chip on the system board of the 'target computer'.

You should be quite familiar with the system board due to your previous task, where you had to spot the video card.
The CPU chip cannot be seen directly on the motherboard. This is due to the CPU fan and heatsink attached to the top of the CPU chip.

The CPU fan and heatsink form one unit, as the fan is attached to the top of the heatsink.

This unit is necessary for the CPU's proper function, as it prevents it from getting overheated. The fan cools the CPU chip and the metal heatsink absorbs the heat from the CPU chip.

As soon as you locate the CPU fan and heatsink, you can locate the CPU chip as well, because it is just under the CPU heatsink. This will be done in the next sections.

It is easy to spot the unit of these two components due to the CPU fan that stands out from the system board and from the other components.

Furthermore, the unit is at the front-right corner of the system board, just on the right of the video card and the ISA slots. Now, look at the system board of the 'target computer' to locate both the CPU fan and the heatsink.

You should remove the unit of the two components, so that you are able to get access to the CPU chip.

Go to the 'target computer' and notice that on the left and right sides of the heatsink there are metallic clips that hold it to the CPU socket, where the CPU chip is inserted.

Notice that one clip is a bit curvy and smaller, whereas the other one is more upright and slightly bigger.

To release the heatsink (and the fan), release the upright clip first by pushing it down and then left, towards the heatsink. When pushing the clip, you should touch it from the top, otherwise it might break loose. Now, go to the 'target computer' and release the upright clip.

As soon as this side has been released, the heatsink is held only by the small, curvy clip, which can be easily released just by pushing the heatsink slightly towards this clip. Now, go to the 'target computer' and release the curvy clip.

Since the fan and the heatsink are connected with the system through cables, they have to remain within the system. Thus, go to the 'target computer' and place them anywhere at the rear of the system, so that they will not get into your way during the next practical tasks.

Now that you have put aside the set of the CPU fan and heatsink, the CPU chip can be clearly seen. It is the metallic plate inserted in the socket, exactly the same as with the new CPU chip, which is located on the antistatic mat. Identify the CPU chip of the 'target computer' and return to the instructions here afterwards.
Now you are ready to remove the old CPU chip, so go to the next step.

Stage 2, Step 2

It is necessary to mention again that before touching any electronic parts, such as the CPU chip, you should drain static electricity from your body, by touching, for example, the metal frame of one of the computers, because static electricity can damage electronic parts. Now you are ready to remove the old CPU chip.

As you have already noticed, the CPU chip is inserted in a socket. Go to the 'target computer' and identify a light-brown handle at the back of the socket.

Go to the 'target computer' and raise the handle of the socket, so that the CPU chip can be removed afterwards. To do so, push the handle down, slightly pull it out to the back, and then raise it until it is vertical, which is actually as far as it goes. If you fail to raise the handle, click here for more information.

(If you failed to lift the handle, bear in mind that it may be necessary to initially apply a small amount of sideways force to free the handle from its retaining 'tab'. Once clear of the 'tab', the handle will open relatively easily. Now, try again to lift the handle and return to the instructions here afterwards.)

Once the handle is completely up, remove the old CPU carefully by lifting it straight out of the socket. Place it on the antistatic mat, but remember its exact place on the mat so that you will not confuse it with the new CPU chip, which is already on the mat.

You are now ready to insert the new CPU chip, so you may go to the next step.

Stage 2, Step 3

The new CPU chip is lying on the antistatic mat, among the other components. You will install it on the system board.

After a careful examination, it will be noticed that there is one pin 'missing' in one corner of the CPU chip. We will call this corner pin 1. Check for pin 1 on the new CPU chip and return to the instructions here.

There is a corresponding pin 1 on the CPU socket, where there is one hole 'missing' at the back right corner of the socket. Now, go to the 'target computer', check for pin 1 on the CPU socket and return to the instructions here.

To install the new CPU, there are two procedures to follow. First of all, the CPU chip should be inserted into the socket and, secondly, the CPU chip should be locked in the socket.
Position the CPU chip above the socket. Make sure pin 1 of the CPU is aligned with pin 1 of the socket. Lower the chip until the pins are inserted properly in their corresponding holes. Remember that very little force is needed to install the CPU. Now, go to the 'target computer' and insert the CPU chip into the socket. If you fail to insert the CPU chip, click here for more information.

(If the CPU is not easily inserted, verify whether or not pin 1 of the CPU is aligned with pin 1 of the socket. Applying too much pressure can damage the CPU or the socket. Now, try again to insert the chip into the socket and return to the instructions here afterwards.)

Now, you have to secure the chip in the socket. Push the handle of the socket down until the handle locks into place. The top plate will slide forward. You will feel some resistance as the pressure starts to secure the CPU in the socket. This is normal and will not damage the CPU. Now, go and lock the CPU chip in the socket.

Now, that you have installed the new CPU chip, you should replace the CPU fan and heatsink, so that the new CPU can function properly.

On the socket itself, there are two little plastic latches at each side to hold the heatsink's clips, as you might remember from the time when you removed the unit. You need the smaller latches from each side. Go to the system board to identify them and return here to the instructions.

You should hook the two clips of the heatsink on these two plastic latches of the CPU's socket. It does not matter which clip goes to which latch. However, you should hook the smaller and curvy clip first. Now, go to the 'target computer' and hook this clip to one of the smaller latches of the socket.

After hooking the curvy clip, pull the heatsink away from this clip so that the upright clip can reach its own latch. Push the upright clip down and then left and right in order to hook it to the latch of the socket. Again, when pushing the clip, you should touch it from the top, otherwise it might break loose. Now, go to the 'target computer' and install the CPU fan and heatsink. If you fail to hook the upright clip, click here.

(If the upright clip resists moving down, push the heatsink slightly towards the curvy clip, which is already hooked, and try again. Return to the instructions afterwards.)

You have just installed the new CPU chip on the motherboard so you may go to the final stage of this task, where you will check its performance.

Stage 3, Step 1

The final stage requires you to run again the 'prime numbers' program so that you can compare the processing speed of the new CPU with the old one.
Now, go and plug in both the 'target computer' and its monitor. Turn on the computer and the monitor. Wait for the Windows operating system to load.

Double-click the icon called 'prime numbers' in order to execute the corresponding program. Again, the program will display all prime numbers up to 100000 and, in the end of this sequence, the time that passed from the beginning until the end of the program's execution. Press the button below and then go to the 'target computer' to run the program. Return to the instructions here afterwards.

Now, press the button below and the supervisor will give you the questionnaire to fill in. Return to the 'instructions computer' afterwards.

You have answered the questionnaire, so you may move on.

Congratulations! You have finished the second task and the experiment. Thank you very much for your time and for your valuable help in this experiment.
2. Teaching script used in the second experiment

First part: Video Card

Stage 1

The video card controls the quality of what you see on your monitor. It provides the means for the computer to "talk" to your monitor so that it can display what the computer is doing.

The video card is located within the computer system. The computer system is the big, rectangular 'box', which hosts all the computer components, such as the video card.

In the following parts, this presentation assumes that the cover of the computer system has been removed and that you have a direct view of the computer components. A green rectangular board is located at the base of the computer system. This board is called 'system board' or 'motherboard'. The system board is the circuit board to which all the other components of the computer are connected in some way. The video card, sound card, etc. all plug into the system board via a socket or a slot.

The video card is connected to the monitor through the monitor cable, which is attached to the card. So, by following the monitor cable, you can identify the video card.

Before handling any computer components inside the computer system turn off the computer and unplug both the monitor and the computer from the mains socket. Remove the monitor cable from the system by unscrewing (by hand) the two screws that hold the cable.

There are two main types of slots on the system board - the ISA and the PCI slots, where peripherals such as the video card or the sound card can be installed. ISA stands for Industry Standard Architecture. PCI stands for Peripheral Component Interconnect. In the last couple of years, PCI slots have displaced ISA slots on the new system boards as a result of higher performance, since they allow a larger and faster transfer of data.

ISA slots are generally long and black and have a separator almost halfway between the ends of the slot. The PCI slots are either white or brown (generally a different colour from the ISA slots) with a separator very close to one end. In our system board, there are three (3) black ISA slots, located at the front-left corner of the system board. One of them hosts our video card. There are four (4) white PCI slots, on the left part of the system board, behind the ISA slots.
Having been inserted into a slot, the video card is held in the system by a screw, which is located on the top of the card's metallic frame. Take the screwdriver, which is located on the antistatic mat, and use it to unscrew the screw. Save the screw afterwards by placing it on the antistatic mat. When handling a card, like the video card, carefully hold it by its edges and avoid touching its circuitry. Gently remove the video card from the ISA slot by pulling it out of its slot. It may be easier to rock the card left and right a little to pry it loose, but do not break the slot. If the video card resists being removed, it might need a little extra force. After removing the video card, place it on the antistatic mat.

You should bear in mind that static electricity can severely damage electronic parts. Before touching any electronic parts, drain static electricity from you body, for example, by touching the metal frame of your computer. The antistatic mat is necessary, and electronic parts such as the CPU chip and the video card must be placed on it to avoid damage. The mat provides an easy way of draining static electricity from the computer components.

Stage 2

Inserting the new video card into a slot may require a little force. Line up the card above the slot, trying to match the separator of the card's slot with the separator of the PCI slot, and add downward pressure to the card to ensure a proper "seat". Use the screw, which you saved when you removed the old card, to attach the new video card to the system.

Reconnect the monitor cable to the new video card, trying to fit the pins of the cable into the holes of the card's socket. After inserting the cable into the socket, tighten the two screws to make sure that the cable is properly held in the socket.

To enable the screen to take advantage of the abilities of the new video card, you need to change the settings of the screen, in terms of the total colours that each pixel can display. Imagine that what you see on the screen consists of a set of dots. These dots are called 'pixels' and they can have a number of colours, which ranges from 16 up to millions of colours!

Screen colours are constructed from red, green and blue fluorescent phosphors (or other light emitting components, depending on screen type). This is known as the RGB system, which is the system that is used on display screens to generate colours. RGB stands for Red, Green and Blue. Thus, there are three colour channels, the Red, the Green and the Blue channel that make up each pixel on the screen.
In typical RGB systems, each colour channel can take 256 values, so all three channels together represent 256 colour combinations for each pixel. In other words, each pixel can have approximately 16.7 million colours! This number of available colours is called 'True Colour'.

True Colour allows the display of more colours than the eye can distinguish, so some users choose to use the 'High Colour' option. High Colour limits each pixel in terms of the number of colour combinations, but the visual difference is almost unnoticeable. Furthermore, this reduction in colours can boost video performance resulting, for instance, in smoother animation within movies. ISA video cards, like the one that we have removed from our computer system, belong to previous technology allowing a pixel to have only 256 colours. This is the '256 colours' option. However, PCI video cards enable us to choose the options of 'High Colour' and 'True Colour'.

Connect the plugs of both the computer and the monitor to the mains. Turn on the monitor and the computer and wait for Windows to load. Now, you should change the colours option from 256 to high colour. Right-click anywhere on the screen, apart from the icons. From the window that pops up, choose the option 'properties'. From the new window, choose the option 'Settings'. Afterwards, find the 'colours' drop-down menu at the bottom-left part of the window and choose the option 'high colour' from the menu. Confirm the change in the number of colours. At the bottom-right corner of the window, press 'apply' and then, when you are asked if you want to restart your computer, do so, in order to restart the computer.

The old video card that we have replaced allowed us to use up to 256 colours, resulting in low image quality. However, the new video card enables us to use the options of 'High Colour' and 'True Colour', resulting in much better image quality.

Second part: CPU

Stage 3

CPU stands for Central Processing Unit. The CPU can be considered as the 'brain' of the computer. As its name suggests, the CPU is the control unit that processes all of the instructions for the computer, by performing mathematical calculations on data and communicating with the various peripherals. The efficiency of a CPU is measured by speed, for example, how fast instructions are carried out.
An appropriate program that can give an estimate of the speed of a CPU is one that makes mathematical calculations, for instance, one that calculates and displays all the prime numbers from 1 to 100000.

The mathematical term 'prime number' refers to all integer numbers that can be divided only by themselves and 1 and no other number. For example, 5 is a prime number because it can only be divided by 5 or 1, 7 is a prime number because it can only be divided by 7 or 1 and so on. 6 is not a prime number because it can be divided by 2 and 3 as well.

The program identifies a prime number by successively dividing this number by all integer numbers less than it. The same procedure takes place for all numbers between 1 and 100000, so that all prime numbers are identified within this range.

The CPU chip cannot be seen directly on the motherboard. This is because the CPU fan and heatsink are attached to the top of the CPU chip.

The CPU fan and heatsink form one unit, as the fan is attached to the top of the heatsink. This unit is necessary for the CPU's proper function, as it prevents it from getting overheated. The fan cools the CPU chip and the metal heatsink absorbs the heat from the CPU chip.

The unit is located at the front-right corner of the system board, just on the right of the ISA slots.

On the left and right sides of the heatsink there are metallic clips that hold it to the CPU socket, where the CPU chip is inserted.

One clip is a bit curvy and smaller, whereas the other one is more upright and slightly bigger.

To release the heatsink (and the fan), release the upright clip first by pushing it down and then left, towards the heatsink.

When pushing the clip, you should touch it from the top, otherwise it might break loose. As soon as this side has been released, the heatsink is held only by the small, curvy clip, which can easily be released just by pushing the heatsink slightly towards this clip.

Now that you have put aside the set of the CPU fan and heatsink, the CPU chip can be clearly seen. It is the metallic plate inserted in the socket.

Raise the handle located at the back of the CPU socket, so that the CPU chip can be unlocked from its socket.

To do so, push the handle down, slightly pull it out to the back, and then raise it until it is vertical, which is actually as far as it goes.

Once the handle is completely up, remove the old CPU carefully by lifting it straight out of the socket and place it on the antistatic mat.

Stage 4

After a careful examination, it will be noticed that there is one pin 'missing' in one corner of the CPU chip. We will call this corner pin 1.
There is a corresponding pin 1 on the CPU socket, where there is one hole 'missing' at the back right corner of the socket.

Position the CPU chip above the socket. Make sure pin 1 of the CPU is aligned with pin 1 of the socket.
Lower the chip until the pins are inserted properly in their corresponding holes.
Remember that very little force is needed to install the CPU.
Now, you have to secure the chip in the socket. Push the handle of the socket down until the handle locks into place. The top plate will slide forward.
You will feel some resistance as the pressure starts to secure the CPU in the socket. This is normal and will not damage the CPU.

Now, that you have installed the new CPU chip, you should replace the CPU fan and heatsink, so that the new CPU can function properly.
On the socket itself, there are two little plastic latches at each side to hold the heatsink's clips.
You need the smaller latches from each side.
You should hook the two clips of the heatsink on these two plastic latches of the CPU's socket.
It does not matter which clip goes to which latch. However, you should hook the smaller and curvy clip first.

After hooking the curvy clip, slightly push the heatsink away from this clip so that the upright clip can reach its own latch.
Try to push the upright clip down.
If the clip resists moving down, it means that you have pushed the heatsink more than enough.
After making sure that the upright clip can move down, push it down and then left and right in order to hook it to the latch of the socket.
Again, when pushing the clip, you should touch it from the top, otherwise it might break loose.

The old CPU that we have removed, is working in the frequency of 133MHz, allowing us to run a program which calculates and displays all prime numbers from 1 to 100000 in approximately 17-18 seconds.
However, the new CPU that we have installed, is working in the frequency of 166MHz, allowing us to run the same program in approximately 13-14 seconds.
Appendix C Questionnaires used in the first experiment

1. Pre-questionnaire

Please give initials and date of birth

SEX:  M [ ]  F [ ]

DATE: ..................

Is English your first language?  YES [ ]  NO [ ]

If not, what is your competency in English?  POOR [ ]  GOOD [ ]  EXCELLENT [ ]

<table>
<thead>
<tr>
<th>Questions regarding background knowledge</th>
<th>Yes</th>
<th>No</th>
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</thead>
<tbody>
<tr>
<td>1. Have you ever seen a video card before?</td>
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<td>2. Can you identify a video card among other computer components?</td>
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<td>3. Have you ever been involved in an event of installing a video card?</td>
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<td>4. Do you know what role the video card plays for the computer's function? If 'yes', please explain briefly in the space below:</td>
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<tr>
<td>5. Have you ever seen a CPU chip before?</td>
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<td>6. Can you identify a CPU chip among other computer components?</td>
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<td>7. Have you ever been involved in an event of installing a CPU chip?</td>
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<tr>
<td>8. Do you know what role the CPU chip plays for the computer's function? If 'yes', please explain briefly in the space below.</td>
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<tr>
<td>Questions regarding background knowledge</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td>9. Do you know what an antistatic mat is?</td>
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<td>If ‘yes’, please explain briefly in the space below.</td>
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<tr>
<td>10. Do you know what ISA slots and PCI slots are?</td>
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<td>If ‘yes’, please explain briefly in the space below.</td>
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<tr>
<td>11. Do you know what a pixel is?</td>
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<td>If ‘yes’, please explain briefly in the space below.</td>
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<tr>
<td>12. Do you know what an RGB system is?</td>
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<td>If ‘yes’, please explain briefly in the space below.</td>
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<tr>
<td>13. Do you know what a prime number is?</td>
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<td>If ‘yes’, please explain briefly in the space below.</td>
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</tbody>
</table>
2. **Questionnaire answered while watching the presentation**

![Please give initials and date of birth](image)

**Task 1: Replacing the video card**

**Opening the photo for the first time**

1. How would you describe the quality of the photo in terms of colours?
   - Poor □
   - Fair □
   - Good □
   - Excellent □

   Return to the ‘instructions computer’.

**Opening the photo for the second time**

2. How would you describe the quality of the photo in terms of colours?
   - Poor □
   - Fair □
   - Good □
   - Excellent □

3. What difference did the new video card make in the quality of the photo?

   Return to the ‘instructions computer’.

**Task 2: Replacing the CPU chip**

**Running the program for the first time**

1. Write the time needed for the execution of the ‘prime numbers’ program: ...........
   Return to the ‘instructions computer’.

**Running the program for the second time**

2. Write the time needed for the execution of the ‘prime numbers’ program: ...........

3. What difference did the new CPU chip make in the execution of the ‘prime numbers’ program?

   Return to the ‘instructions computer’.
3. Post learning test (recall questions)

Please give initials and date of birth

This questionnaire is meant to test your understanding of the material recently presented to you in the computer presentation. You should answer each question in as much detail as you can in the blank areas provided. Partial answers are ok. If you can remember part of the answer please answer.

For each answer also indicate (by placing a tick in columns A, B, C, or D) whether you:
A. Already knew the answer fully before seeing the material
B. Had met the material before and the lesson reminded you of it
C. Vaguely remember something before but you relied on the lesson to answer
D. Had not met the concept at all before today

<table>
<thead>
<tr>
<th>Questions Page 1</th>
<th>Information Recall</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Knew it already</td>
</tr>
<tr>
<td>1. Why is it important to use an antistatic mat when handling computer components?</td>
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<tr>
<td>2. What functions does a video card perform?</td>
<td></td>
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<tr>
<td>3. How was the performance of the new video card measured?</td>
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<tr>
<td>4. What is the difference in appearance and performance between an ISA slot and a PCI slot?</td>
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<tr>
<td>5. If you had to tell a user, who had no previous knowledge of the inside of a computer system, how to find the video card, what would you say?</td>
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<tr>
<td>Questions Page 2</td>
<td>Information Recall</td>
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<td>---------------------------------------------------------------------------------</td>
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<tr>
<td></td>
<td>A</td>
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<tr>
<td>6. Where are the separators of the ISA and PCI slots located?</td>
<td></td>
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<tr>
<td>7. What should you always do before touching any electronic part?</td>
<td></td>
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<tr>
<td>8. What does ISA stand for?</td>
<td></td>
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<tr>
<td>9. What does PCI stand for?</td>
<td></td>
</tr>
<tr>
<td>10. Why PCI slots are replacing ISA slots on the new motherboards?</td>
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<tr>
<td>11. Where is it best to take hold of the video card and why?</td>
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<tr>
<td>12. A pixel displays a colour in a dot on the screen. Does the new video card increase the number of colour options in a pixel, or the number of pixels on the screen?</td>
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<tr>
<td>13. What is an RGB system?</td>
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<tr>
<td>14. Is there any difference between ‘True Colour’ and ‘High Colour’ as far as image quality is concerned?</td>
<td></td>
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<tr>
<td>Questions Page 3</td>
<td>Information Recall</td>
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<td>---------------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>15. In the 'High Colour' option, the values that the three colour channels can take are: 32, 32 and 64. How would you calculate the total available colour combinations of 'High Colour'?</td>
<td>A Knew it already</td>
</tr>
<tr>
<td>16. Which are the three colour channels that determine the colour of a pixel?</td>
<td></td>
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<tr>
<td>17. What do the letters CPU stand for?</td>
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<tr>
<td>18. What does the CPU do in general?</td>
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<tr>
<td>19. How is a prime number defined?</td>
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</tr>
<tr>
<td>20. Which computer component helped you to locate the exact place of the CPU on the motherboard?</td>
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<tr>
<td>21. How do we measure the efficiency of a CPU in general?</td>
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<tr>
<td>22. Where is the CPU fan located in relation to the CPU heatsink?</td>
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<tr>
<td>23. Why are the CPU fan and the CPU heatsink necessary for the proper function of the CPU?</td>
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<td>24. How is the unit (of the CPU fan and heatsink) attached to the CPU chip?</td>
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<tr>
<td>Questions Page 4</td>
<td>Information Recall</td>
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<tr>
<td></td>
<td>A</td>
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<tr>
<td></td>
<td>Knew it already</td>
</tr>
<tr>
<td>25. Which metal clip of the heatsink should be released first in order to remove the heatsink from the CPU socket?</td>
<td></td>
</tr>
<tr>
<td>26. Where should you place the unit (of the CPU fan and heatsink) after it has been removed?</td>
<td></td>
</tr>
<tr>
<td>27. What is the mechanism for releasing the CPU chip?</td>
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<tr>
<td>28. What should you check before inserting the CPU chip into the CPU socket?</td>
<td></td>
</tr>
<tr>
<td>29. How do you secure the CPU chip into the socket?</td>
<td></td>
</tr>
<tr>
<td>30. Which number of colours would you choose in order to achieve a satisfying display of a movie file, especially if your computer system is of low memory? Justify your answer.</td>
<td></td>
</tr>
</tbody>
</table>
31. Assuming that you are watching a diagram using the ‘256 Colours’ as the number of colours displayed on your screen. How much improvement would you expect in colour quality if you went from ‘256 Colours’ to ‘True Colour’ and why? (note that a diagram uses palette colours to be displayed)

32. Let us say you open the ‘flowers’ file and then run the ‘prime numbers’ program. Given that your computer system uses an ISA video card and a Pentium 133MHz processor (CPU), the approximate timings are: Opening the ‘flowers’ file and displaying the photo: 1.5 seconds Running the program and displaying the prime numbers: 21 seconds In total: 22.5 seconds (assuming that there is no interval time between opening the photo and running the program). Which hardware changes would you make in order firstly to achieve a total time of about 12 seconds and secondly to achieve a total time of about 22 seconds? Justify your answers.
This questionnaire is meant to test your understanding of the material recently presented to you in the computer presentation. The questions are in the form of multiple choices. Only one answer is correct, unless it is stated otherwise.

For each answer also indicate (by placing a tick in columns A, B, C, or D) whether you:

- A: Already knew the answer fully before seeing the material
- B: Had met the material before and the lesson reminded you of it
- C: Vaguely remember something before but you relied on the lesson to answer
- D: Had not met the concept at all before today

<table>
<thead>
<tr>
<th>Questions Page 1</th>
<th>Information Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>Knew it already</td>
</tr>
</tbody>
</table>

1. We use an antistatic mat on which we place computer components in order:
   - a) To absorb any static electricity from the components
   - b) To maintain the static charge on the components

2. Which of these statements about the video card are true? (more than one answer is possible)
   - a) It controls the quality of what you see on the monitor screen
   - b) It can only be fitted into an ISA slot
   - c) It provides a means of communication between the computer and the monitor
   - d) It speeds up the processing of calculations like the 'prime numbers' example

3. To measure the performance of the new video card:
   - a) We timed how long it took the 'prime numbers' program to be executed
   - b) We examined the increase in the number of colours displayed on the photo
   - c) We timed how long it took the photo to be loaded
   - d) We timed how long it took the 'prime numbers' program to be loaded
### Questions Page 2

<table>
<thead>
<tr>
<th>Information Recall</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Knew it already</td>
<td>Met before and was reminded</td>
<td>Vague memory?</td>
<td>Never met before</td>
</tr>
</tbody>
</table>

4. What are the differences between an ISA slot and a PCI slot? (more than one answer is possible)

   a) There is no difference  
   b) There is a difference in colour  
   c) There is a difference in width  
   d) The PCI slot supports higher performance components than the ISA slots

5. If you had to tell a user, who had no previous knowledge of the inside of a computer system, to find the video card, you would tell him/her that:

   a) It is next to the CPU  
   b) It is inserted into a PCI slot  
   c) It is connected to the monitor cable

6. Mark on the following card diagrams which one would fit into a PCI slot and which one would fit into an ISA slot:

   ![Card Diagram A](image1)  
   ![Card Diagram B](image2)  
   ![Card Diagram C](image3)  
   ![Card Diagram D](image4)
### Questions Page 3

<table>
<thead>
<tr>
<th>Information Recall</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knew it already</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Met before and was reminded</td>
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<tr>
<td>Vague memory?</td>
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</tr>
<tr>
<td>Never met before</td>
<td></td>
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</tbody>
</table>

7. Before touching any electronic part, you should:
   a) Touch a metal object
   b) Not touch anything else
   c) Touch the plastic frame of the keyboard

8. What does ISA stand for?
   a) Interconnected System Adaptor
   b) Integrated Systems Architecture
   c) Industry Standard Architecture
   d) Industry Systems Adaptor

9. What does PCI stand for?
   a) Personal Computer Interface
   b) Peripheral Component Interconnect
   c) Practical Component Inserter
   d) Protected Communications Interface

10. New types of motherboards tend to have:
    a) A mixture of PCI and ISA slots
    b) Only PCI slots
    c) Only ISA slots
### Questions Page 4

#### Information Recall

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Knew it already</td>
<td>Met before and was reminded</td>
<td>Vague memory?</td>
<td>Never met before</td>
</tr>
</tbody>
</table>

11. Where is it best to take hold of the video card? Choose the appropriate diagram from below.

- **a)**
- **b)**
- **c)**

12. The new video card:
   - a) Increased the number of colour options in a pixel
   - b) Increased the number of pixels on the screen

13. What is an RGB system?
   - a) A system used to protect the CPU chip from getting overheated
   - b) A system used to generate colours on the screen
   - c) A system used to control the number of pixels on the screen
   - d) A system used to describe the type of the motherboard, depending on the number of PCI and ISA slots

14. What is the difference between ‘True Colour’ and ‘High Colour’ as far as image quality is concerned?
   - a) No difference
   - b) Almost unnoticeable difference
   - c) Small but noticeable difference
   - d) Big difference
15. 'True Colour' allows a pixel to have about 16.7 million colours. Which number of colours do you think that corresponds to 'High Colour'?  

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<tr>
<td>A</td>
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<td>C</td>
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<tr>
<td>Knew it already</td>
<td>Met before and was reminded</td>
<td>Vague memory?</td>
<td>Never met before</td>
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<tr>
<td>a) About 18 million colours</td>
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<td>b) About 65 thousand colours</td>
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<tr>
<td>c) 512 colours</td>
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</table>

16. Which are the three colour channels that determine the colour of a pixel?  

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<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>a) Grey, Red, Blue</td>
<td>b) Brown, Green, Red</td>
<td>c) Red, Green, Black</td>
</tr>
<tr>
<td>d) Green, Blue, Red</td>
<td>e) Red, Grey, Brown</td>
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</tbody>
</table>

17. CPU stands for:  

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<tr>
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</thead>
<tbody>
<tr>
<td>a) Computer Program Unit</td>
<td>b) Computer Protection Unit</td>
<td>c) Central Protection Unit</td>
<td>d) Central Processing Unit</td>
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</tr>
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</table>

18. The CPU:  

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<tr>
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<tbody>
<tr>
<td>a) Processes the colours displayed on a photo</td>
<td>b) Processes the calculations made in a program</td>
<td>c) Controls the performance of the video card</td>
<td></td>
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</tbody>
</table>
## Questions Page 6

### Information Recall

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
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<th>D</th>
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<tbody>
<tr>
<td></td>
<td>Knew it already</td>
<td>Met before and was reminded</td>
<td>Vague memory?</td>
<td>Never met before</td>
</tr>
</tbody>
</table>

19. Which of the numbers below are prime numbers?

- a) 9
- b) 13
- c) 15
- d) 17
- e) 29
- f) 39
- g) 41

20. The easiest way to identify the location of the CPU on the motherboard is to:

- a) Find the video card first
- b) Find the CPU socket first
- c) Find the ISA slots first
- d) Find the CPU fan and heatsink first

21. The efficiency of a CPU chip is generally measured by:

- a) How fast instructions are carried out
- b) The number of colours on the screen
- c) How efficiently instructions are carried out
- d) The quality of the colours on the screen

22. The CPU fan is located:

- a) On the left of the CPU heatsink
- b) On the right of the CPU heatsink
- c) On the top of the CPU heatsink
- d) Under the CPU heatsink
### Questions Page 7

<table>
<thead>
<tr>
<th>Information Recall</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Knew it already</td>
<td>Met before and was reminded</td>
<td>Vague memory?</td>
<td>Never met before</td>
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</tbody>
</table>

23. Which of the statements below is true?

<p>| | | | | |</p>
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<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>a) The fan absorbs the heat from the CPU chip and the heatsink cools the CPU chip</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>b) The fan absorbs the heat from the CPU socket and the heatsink cools the CPU socket</td>
<td></td>
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<tr>
<td>c) The fan cools the CPU chip and the heatsink absorbs the heat from the CPU chip</td>
<td></td>
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<tr>
<td>d) The fan cools the CPU socket and the heatsink absorbs the heat from the CPU socket</td>
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</table>

24. The CPU heatsink is attached to the CPU chip through clips that hook to the:

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<thead>
<tr>
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<tbody>
<tr>
<td>a) CPU chip</td>
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<tr>
<td>b) CPU socket</td>
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<tr>
<td>c) CPU fan</td>
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</table>

25. Which is the suggested way of removing the CPU heatsink?

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<thead>
<tr>
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<tbody>
<tr>
<td>a) You release either the small or the big clip first.</td>
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<tr>
<td>b) You release the smaller clip first.</td>
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<tr>
<td>c) You release the bigger clip first.</td>
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</table>

26. After the unit (of the CPU fan and heatsink) has been removed, you place it:

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<thead>
<tr>
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<tbody>
<tr>
<td>a) On the antistatic mat</td>
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<tr>
<td>b) Anywhere on the workplace</td>
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<tr>
<td>c) Anywhere within the computer system</td>
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</table>

27. To release the CPU chip from its socket, you lift the handle until:

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<tbody>
<tr>
<td>a) It makes a 45° angle</td>
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<tr>
<td>b) It makes a 60° angle</td>
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<tr>
<td>c) It makes a 90° angle</td>
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<tr>
<td>d) It makes a 120° angle</td>
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</table>
### Questions Page 8

<table>
<thead>
<tr>
<th><strong>Information Recall</strong></th>
<th><strong>A</strong></th>
<th><strong>B</strong></th>
<th><strong>C</strong></th>
<th><strong>D</strong></th>
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<tbody>
<tr>
<td><strong>Knew it already</strong></td>
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<tr>
<td><strong>Met before and was reminded</strong></td>
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<tr>
<td><strong>Vague memory?</strong></td>
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<tr>
<td><strong>Never met before</strong></td>
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</tbody>
</table>

28. To insert the CPU chip into its socket, you:

- a) Test and try until the chip is properly inserted
- b) Match the missing pin of the CPU chip with the missing hole of the socket
- c) Align the CPU chip with the CPU socket

29. To secure the CPU chip into the socket, you:

- a) Hook the smaller metal clip of the heatsink to its corresponding latch
- b) Hook both metal clips of the heatsink to the latches
- c) Pull the handle down until you feel some resistance
- d) Pull the handle all the way down until it locks into place

30. Assuming that your computer system is of low memory and that you want to open a movie file, which number of colours would you choose to achieve a satisfying display of the movie?

- a) True colour
- b) High colour
- c) 256 colours

31. Assuming that you are watching a diagram using the '256 Colours' as the number of colours displayed on your screen. How much improvement would you expect in colour quality if you went from '256 Colours' to 'True Colour' and why? (note that the diagram uses palette colours to be displayed)

- a) No improvement, because '256 Colours' are adequate for a proper display of the diagram
- b) Small improvement due to the addition of some colours
- c) Big improvement due to the addition of many colours and the proper display of the existent ones
32. Let us say you open the 'flowers' file and then run the 'prime numbers' program. Given that your computer system uses an ISA video card and a Pentium 133MHz processor (CPU). The approximate timings are:
Opening the 'flowers' file and displaying the photo: 1.5 seconds
Running the program and displaying the prime numbers: 21 seconds
In total: 22.5 seconds (assuming that there is no interval time between opening the photo and running the program).
Which hardware changes would you make in order to achieve a total time of about 22 seconds?

b) PCI video card
c) Pentium 266 MHz
d) PCI video card and Pentium 200 MHZ
e) Pentium 200 MHz
Appendix D  Learning test used in the second experiment

Post Questionnaire

Please give initials and date of birth

This questionnaire is meant to test your understanding of the material recently presented to you in the computer presentation. You should answer each question in as much detail as you can in the blank areas provided. **Your answers should be based only on the material presented to you.** Partial answers are ok. If you can remember part of the answer please answer.

<table>
<thead>
<tr>
<th>Questions Page 1</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Why is it important to place computer components on an antistatic mat?</td>
<td></td>
</tr>
<tr>
<td>2. State two basic functions that a video card performs within a computer system.</td>
<td></td>
</tr>
</tbody>
</table>
| 3. a) Which computer hardware enables the communication of all computer components?  
   b) Go to the computer system and identify it. | |
| 4. Give an example of how we can compare the graphic performance of two different video cards. | |
| 5. Go to the computer system and  
   a) identify the PCI slots  
   b) identify the CPU heatsink | |
<p>| 6. What is the difference in performance between an ISA slot and a PCI slot? | |
| 7. If you had to instruct a user, who had no previous knowledge of the inside of a computer system, on how to find the video card, what would you say? | |</p>
<table>
<thead>
<tr>
<th>Questions Page 2</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>8. Two PC cards will be shown to you. Which one is an ISA card and which one is a PCI card? Justify your answer.</td>
<td></td>
</tr>
<tr>
<td>9. What should you always do before touching any electronic part and for which purpose?</td>
<td></td>
</tr>
<tr>
<td>10. What does ISA stand for?</td>
<td>a) Interconnected Standard Adaptor</td>
</tr>
<tr>
<td></td>
<td>b) Integrated Systems Architecture</td>
</tr>
<tr>
<td></td>
<td>c) Industry Standard Architecture</td>
</tr>
<tr>
<td></td>
<td>d) Industry Systems Adaptor</td>
</tr>
<tr>
<td>11. What does PCI stand for?</td>
<td>a) Peripheral Component Interconnect</td>
</tr>
<tr>
<td></td>
<td>b) Personal Computer Interface</td>
</tr>
<tr>
<td></td>
<td>c) Protected Component Interface</td>
</tr>
<tr>
<td></td>
<td>d) Peripheral Communications Interconnect</td>
</tr>
<tr>
<td>12. Go to the computer system and remove the video card. Afterwards, place it on the antistatic mat.</td>
<td></td>
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<tr>
<td>13. Go to the computer system, insert the new video card into the PCI slot and do any additional tasks so that the video card is ready to function properly.</td>
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<tr>
<td>14. Having installed a better video card, we are enabled to improve image quality. What causes this improvement? (your answer should be related to the pixels on the screen)</td>
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<tr>
<td>15. What does the RGB system do?</td>
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<tr>
<td>Questions Page 3</td>
<td>Answer</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>16. How much improvement would you expect in an image if you watched it using first the 'True Colour' option and then the 'High Colour' option?</td>
<td></td>
</tr>
<tr>
<td>17. In the 'High Colour' option, the values that the three colour channels of the screen can take are: 32, 32 and 64. How would you calculate the total available colour combinations of 'High Colour'?</td>
<td></td>
</tr>
<tr>
<td>18. Which are the three colour channels that determine the colour of a pixel?</td>
<td></td>
</tr>
<tr>
<td>19. What do the letters CPU stand for?</td>
<td>a) Computer Protecting Unit</td>
</tr>
<tr>
<td></td>
<td>b) Central Programming Unit</td>
</tr>
<tr>
<td></td>
<td>c) Computer Peripheral Unit</td>
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<tr>
<td></td>
<td>d) Central Processing Unit</td>
</tr>
<tr>
<td>20. State two basic functions that a CPU performs within a computer system.</td>
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<tr>
<td>21. Which of the numbers on the right are prime numbers?</td>
<td>a) 9</td>
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<tr>
<td></td>
<td>b) 13</td>
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<tr>
<td></td>
<td>c) 15</td>
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<td></td>
<td>d) 17</td>
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<td></td>
<td>e) 23</td>
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<tr>
<td></td>
<td>f) 29</td>
</tr>
<tr>
<td></td>
<td>g) 34</td>
</tr>
<tr>
<td></td>
<td>h) 39</td>
</tr>
<tr>
<td>22. Which computer component helps you to locate at once the exact place of the CPU on the motherboard?</td>
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<tr>
<td>23. How do we measure the efficiency of a CPU in general?</td>
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<tr>
<td>Questions Page 4</td>
<td>Answer</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>24. Which function does the CPU heatsink perform?</td>
<td></td>
</tr>
<tr>
<td>25. How is the unit of the CPU fan and heatsink attached to the CPU chip?</td>
<td></td>
</tr>
<tr>
<td>26. Go to the computer system and remove the CPU fan and heatsink, following</td>
<td></td>
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<tr>
<td>the procedure you have been just taught in the presentation.</td>
<td></td>
</tr>
<tr>
<td>27. Go to the computer system and remove the CPU chip. Afterwards, place it</td>
<td></td>
</tr>
<tr>
<td>on the antistatic mat.</td>
<td></td>
</tr>
<tr>
<td>28. Go to the computer system, insert the new CPU chip into the socket and do</td>
<td></td>
</tr>
<tr>
<td>any additional tasks so that the CPU is ready to function safely.</td>
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<td>29. a) Which number of colours (256, High Colour, True Colour), would you</td>
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<td>choose in order to achieve a satisfying play of a movie file, especially if</td>
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<td>your computer system is of a low memory?</td>
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<tr>
<td>b) Justify your answer.</td>
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<tr>
<td>c) Go to the computer, and make all the appropriate settings to apply this</td>
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<tr>
<td>number of colours to the computer screen.</td>
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</table>
30. Let us say that you open a file containing an image and then you run the 'prime numbers' program. Given that your computer system uses an ISA video card and a Pentium 133MHz processor (CPU), the approximate timings are:
Opening the image and displaying the photo: **1.5 seconds**
Running the program and displaying the prime numbers: **21 seconds**
**In total: 22.5 seconds** (1.5 + 21), assuming that there is no interval time between opening the photo and running the program.
Which hardware changes would you make (just one per time) in order to achieve:
- **a) a total time of about 12 seconds**
- **b) a total time of about 22 seconds**

Take into account that:
- The CPU affects only the time of the 'prime numbers' program and the video card only the time of opening the image file
- We suppose that there is analogy between CPU frequency and time (e.g. we double the CPU frequency and the program runs in approximately half time)

You can use any of the below components:
Pentium 166MHz, Pentium 200MHz, Pentium II 266MHz, Pentium II 333MHz, PCI video card

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<tr>
<th>SEX:</th>
<th>M</th>
<th>F</th>
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</thead>
<tbody>
<tr>
<td>Is English your first language?</td>
<td>YES</td>
<td>NO</td>
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<tr>
<td>If not, did you find the english used in the presentation difficult to understand?</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Are you dyslexic?</td>
<td>YES</td>
<td>NO</td>
</tr>
</tbody>
</table>