Demands on technology from a human automatism perspective in manual assembly

This item was submitted to Loughborough University's Institutional Repository by the/an author.

**Citation:** THORVALD, P. ... et al., 2008. Demands on technology from a human automatism perspective in manual assembly. IN: Proceedings of 2008 18th International Conference on Flexible Automation and Intelligent Manufacturing (FAIM 2008), Skövde, Sweden, 30 June–2 July 2008, vol. 1, pp.632-638.

**Metadata Record:** [https://dspace.lboro.ac.uk/2134/26624](https://dspace.lboro.ac.uk/2134/26624)

**Version:** Published

**Publisher:** University of Skövde

**Rights:** This work is made available according to the conditions of the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International (CC BY-NC-ND 4.0) licence. Full details of this licence are available at: [https://creativecommons.org/licenses/by-nc-nd/4.0/](https://creativecommons.org/licenses/by-nc-nd/4.0/)

Please cite the published version.
Demands on Technology from a Human Automatism Perspective in Manual Assembly

Peter Thorvald1,3*, Gunnar Bäckstrand1,2,3, Dan Högborg1, Leo de Vin1, and Keith Case1,3

1School of Technology and Society
University of Skövde
Skövde, Sweden

2Research & Development
Volvo Powertrain
Skövde, Sweden

3Mechanical and Manufacturing Engineering
Loughborough University
Loughborough, United Kingdom

ABSTRACT

The automotive industry is continuously challenged by the growing need for customization of cars and trucks, resulting in increasing demand on flexibility, quality and efficiency. Much investigation and development is carried out in the field of automation of processes. However, in manual assembly this automation approach might not be suitable when the flexibility that human operators contribute with is to be retained. In such manual assembly environments the presentation of information becomes essential to succeed with an assembly task. This paper focuses on supporting manual assembly workers in their information seeking behaviour which is a key factor to respond to the issues of quality, efficiency and customization. It addresses potentially important issues in information design that will allow workers to find, translate, and act on information sources in a demanding situation, for instance under time pressure. The approach will take its base in controlled and automatic human information processes and the demands this creates on information presentation in terms of identifying and acting on information sources. A pilot study in Swedish industry has been performed within the scope of the EU project myCar, which provides much data for this paper.

1. INTRODUCTION

The automotive industry with its current assembly process is constantly moving towards a higher demand for customization and efficiency. To meet the growing needs and demands of its customers, the automotive industry must constantly improve quality while, at the same time, there is a need to produce more variants and remain cost-effective. There are several approaches to meet these demands and whereas some of the more obvious approaches relate to mainly technical solutions and tools such as robots and other automation systems, this paper’s focus is on information design.

As technology advances, robots take over more and more of the work that used to require human operators, resulting in better quality and productivity. However, a robot cannot provide the flexibility of assembly to the extent that a human actor can and therefore robots might not be usable within certain work contexts [1, 2]

The way in which information is presented in a manual assembly domain can have a large impact on both quality and efficiency. It is also conceivable that it could have a positive effect on work satisfaction. Many of the information systems used in assembly today have shortcomings with respect to aspects of human factors, primarily regarding usability. The term usability, as it is used here, is not limited to the user interface but takes into account how, what, when and where information is presented. A problem that relates to all of these questions is that often information is presented in ways where the worker is expected to perform various degrees of unnecessary mental processing and actively retrieve information. This can be argued to be the result of a poor understanding of automatic information processing (automatism) and an unnecessary need for translation of data into information. It is the aim of this paper to provide an introduction to automatism, and show how these processes can be controlled for increased productivity, flexibility and quality. This can be done by providing the operator with properly designed and placed information carriers or triggers and also by supporting the users’ decision processes.

* Corresponding author: Tel.: (+46) 500-448543; Fax: (+46) 500-448599; E-mail: peter.thorvald@his.se
An unfortunate development, which has been identified in previous studies, is that technology often determines the terms of work [3, 4]. In contrast, in human-computer interaction (HCI), the normative aim is to put the human in the centre and develop tools that support human behaviour and limitations. However, in manufacturing domains, this is rarely the case. Instead, one tends to force users to work in accordance with the technological tool provided. Technology is allowed to have demands on quality, productivity and so forth, and not vice versa. Figure 1 shows an illustration of both normative and descriptive views of this.

![Figure 1. Descriptive and normative views of the role of technology.](image)

The approach in this paper is both normative and descriptive. It is descriptive from a user perspective in the sense that certain human behaviours are described and it is normative from a technology perspective where the aim is to outline some basic guidelines on the demands that controlled and automatic human information processing make on technology. The outline of the paper consists of describing automatism and the types of errors that arise from this phenomenon. Suggestions are made, primarily regarding triggers and decision point support, which will relate to how technology can be used to either support or control the automatic processes. Triggers can be viewed in two ways; either as simple attention getters, designed to merely snap the subject out of passive attention and into an active information seeking mode or as an integrated part of the information system where the trigger itself carries information. The latter view can be implemented by using picking indicators or to some extent, triggers that are related to their referents. For example, if an item is to be chosen, a pick indicator in the form of a light indicates both that something is to be picked and also, by its geographical position, what is to be picked.

2. HUMAN AUTOMATIC INFORMATION PROCESSING

It is widely accepted in the scientific community that humans continuously strive towards less effort in their everyday lives [5-7], within both physical and mental aspects of work. As a result of this, recurring tasks often become automated processes and naturally coincide with a passive attention mode. Consider the task of driving a car. As you are learning to drive, it takes all the attention you can procure to keep the car on the road, switch gears and to keep track of the road signs. Later on, when you have become an experienced driver, all these things seem to have become automatic. They are done without a thought at times, passively. As early as the 19th century, William James described the distinction between active and passive attention [8]. He described active attention as a state where humans actively seek information whereas passive attention is when humans are passively awaiting a situation where active attention is required. Another key difference between the two is the fact that, while in passive attention, a stronger, immediate stimulus is required for something to be noticed. In active attention, this is not required as a stimulus or a chunk of information can be derived from previous mental processing.
Shiffrin and Schneider [6, 9] investigated the role of automatism in the 1970s and discovered that tasks that require a reasonable amount of cognitive processing, sooner or later become automated in the sense that they are performed while in a passive attention state, such as in the case of driving a car. After a task has recurred several times, it is eventually performed without conscious processing. In the case of assembly personnel it might be that the subject is so automated in the assembly behaviour that he or she passively performs the work, leading to potential problems. Pilot studies performed in Swedish industry within the EU Integrated Project myCar have shown that workers, depending on the information system, have problems noticing changes to the information while in an automated behaviour mode as the nature of automatism also implies that these modes are very hard to break as the subject is in passive attention mode, resulting in different types of errors.

2.1. **HUMAN ERROR**

There are several ways to classify the errors we, as humans, make each day. Relevant approaches to human error might be to classify them as intentional or unintentional [10], to use a simple dichotomy between errors of commission or errors of omission [7], to consider errors in problem detection or errors in problem diagnosis. Certain classifications of errors have been performed, focusing on mistakes, slips, lapses and mode errors [5, 11] and the particular focus of this paper lie on slips, which are errors where the correct intention is incorrectly carried out. Slips are often caused by attention limitations, associations etc., things closely related to automatic information processing. Norman [11] describes several kinds of slips; capture errors, description errors, data-driven errors, associative activation errors and loss-of-activation errors. A few of these slips and how they can relate to quality risks in manual assembly are discussed below.

When making a **capture error**, a frequently or recently performed action captures the one intended. As an example we can consider a man who every day before work, drives his children to day care. Close by where he drops them off is the supermarket where he frequently buys his groceries and every now and then, when he is to drop off his children, he ends up at the supermarket, and vice versa. An error of this type appears when two different actions begin with the same sequence [11]. In manual assembly, a similar error occurs when two work sequences overlap or have a large degree of common ground. Consider a work sequence of A, B, C, and D. In a high volume scenario, this sequence quickly becomes automated, resulting in less mental operation and higher productivity as the work is carried out by routine. The sequence also becomes hard to divert from and when the sequence is disturbed, by for example, adding a fifth task in the middle of it or replacing a task with another, the task result would more be inclined to be a capture error. The pilot studies carried out have shown that this is not an uncommon situation. When a part is replaced or a new part is introduced due to customization, the task of mounting is occasionally placed in the middle of a sequence or in direct relation to it, resulting in capture errors.

In a **description error**, the intended action might fit several possibilities. The action might be performed correctly but with the wrong object. This might be trying to change TV channel with the wrong remote control or as in an example that Norman uses where a student intends to throw a t-shirt in the laundry basket but throws it in the toilet bowl instead. Although not extremely obvious, the laundry basket and the toilet bowl do share several traits. They are both containers with a hole on top for instance and this might be sufficient to make this error [11]. Pilot studies have revealed quality issues that could be traced to such an error. When mounting a particular part, there might be several appropriate hole patterns and the wrong choice in a stressed situation can be said to be a description error.

A very common slip that many probably can relate to is simply forgetting to do something, a **loss-of-activation error**. Who hasn’t walked into a room, finding that you cannot remember why you went there? What is very interesting about these kinds of slips is that it is only the goal that is forgotten, not the action sequence. These slips occur when there is no continuous activation of the goal [5, 11]. In assembly scenarios, this error relates closely to the available information sources. These systems are very often designed as discrete information carriers, requiring an explicit action from the operator to gather the information. They can be said to be discrete in the sense that they are often only attended to once and while the information might be continuously presented, to be able to perform a task, attention needs to be focused elsewhere, preferably on the performing of the actual task. They also require an explicit action to gather the information they carry and are lacking in the intrusiveness that attracts attention passively instead of actively.

Figure 2 illustrates all three of these slips. It shows the critical common ground of a capture error before a decision point that might cause the operator to choose 3a instead of 3b, due to their similar origins. In this case, it could be argued that it is not the decision point that is causing us problems but the common ground that precedes it. When making a description error, tasks 3a and b show how the same action could be performed with different objects. Differing from a capture error when the wrong task might be performed, in a description error, the task is
correctly performed but with the wrong object. For example, assembling valve a instead of valve b is a description error and assembling valve a instead of a bracket is a capture error. There is an anecdote about a pop band that can be said to reflect both a capture error and a description error. The band announced a particular song but the guitarist started playing another song. The two songs started with the same chord and when the guitarist started playing the wrong song by the second chord, the rest of the band followed. This illustrates how vulnerable these task sequences are. A loss-of-activation error in figure two could be seen as the inability to provide adequate support at the decision point before 3a or 3b, resulting in the operator selecting the wrong part to assemble due to poor information presentation or even the absence of information.

To make concrete suggestions regarding how to remedy these problems in the complex environments that are dealt with here is very difficult. The errors relate both to the actual decision points as well as to the work sequence that precedes it. However, even though it might not always be the decision point that is causing the problem but rather the work sequence, it is possible to reduce the likelihood of these errors by supporting the operator through properly designed triggers.

3. USING TRIGGERS TO AID AUTOMATISM

A trigger, in its most basic form, is “something that prompts an activity, something that tells you that you need to do something” [12, p. 2111, emphasis in original], and by using well-designed triggers we could provide better support at the decision point [12-14]. The fashion in which one might approach the surprisingly large concept of triggers might differ from a fairly object/subject driven view of a trigger’s basic properties, i.e. its visibility, intrusiveness, and importance [14], to a more temporal view where the when and how a trigger is presented is in focus [13, 15, 16]. Although both of these views might be crucial to good trigger design, the former requires a more case-based approach where the quality of a trigger is very subjective and context dependent, whereas the latter is easier to view off-line due to its objective nature. The object/subject driven view relies heavily on a subject defining what is intrusive and important while the temporal view might be considered without it as we consider the trigger in relation to events, not subjects [13]. Relating to the descriptive vs. normative discussion earlier, the information system, of which the triggers are part, are often determining the way that operators work. A problem that has been identified in the pilot studies is that triggers are often placed in such a way that the operator has to search for them, thus negating the whole idea of a trigger. Instead these triggers should be placed so that they are accessible from where the operator is physically located in relation to the work being performed.

Looking at the issues discussed in the previous section, there are two aspects of the trigger that need to be considered. These are the spatial and temporal perspectives. To place a trigger correctly, we need to start considering the work piece and the task. A trigger placed in relation to its referent might lead to a better continuous activation of the goal, and thus, we could remedy the description errors that might arise otherwise. The operator would have a well-placed reminder of what part is to be assembled. The capture errors and the loss-of-activation errors could be attended to in a slightly similar way but with a focus on the temporal aspects. To clarify, let us consider a system that is used in one of the plants where initial research within the myCar project has been performed. In this information system, critical assembly actions are marked in the information system by a coloured symbol, this is to draw attention to it for further investigation of the information. When the operator is to commence work on the work piece, the information system is attended to and the trigger (the coloured symbol) is noticed.
However, without a continuous activation of this trigger and if the operator is prevented from acting on the trigger at once, it is very likely to be forgotten. Dix et al. [13] describe this as a stimulus-response gap where the gap between information and action is critical. If a subject is unable to act on the information at once, the response will get affected. There are two ways to remedy this problem. One is to simply allow the operator to act upon critical information as soon as it is received, and another is to allow the operator to continuously attend the information or the trigger. Today, the coloured symbol is generally attended to once due to its placement. The operator relies on memory to perform the correct actions and naturally, this fails regularly. Probably, the operator goes back into the automated behaviour and passive attention that the trigger is meant to break. But what if there was a way to allow the operator to continuously attend the trigger implicitly, instead of explicitly which is the case today where the operator actively has to find the trigger? This could be achieved through using a trigger which responds more to temporal aspects and provides more intrusiveness. The key is to allow the operator to receive information independently of spatial positioning. Using flashing lights or sound could provide such opportunities as their range is greater in comparison to the existing way of presenting text and symbols on a screen. Another example of this is pick-light systems where the shelves are equipped with LED’s that indicate what item is to be picked. In this case it is not necessarily the range of light or the nature of the medium that facilitate an easier information gathering but rather the geographical positioning of the trigger. An information carrier placed in close reference to the target item allows for a simpler stimulus-response mode of work and thus the operator can act on information as it is required and from a relevant geographical position. The stimulus-response conception can be seen as an action where the subject is able to act (respond) directly upon incoming information (stimulus) with little or no mental processing required. After all, the information is not needed until it is time to choose the item and presenting information before it is needed only contributes to a larger stimulus-response gap. There is also the issue of what constitutes information here. In the case where the operator has to receive information from a screen or something similar, it is really data that is being presented. The operator then has to translate this into information about what item is to be picked. In the case of a pick indicator system, there is no need for this translation or one might even argue that the translation into a geographical position already has been made by the system. Figure 3 shows how an operator has to store and translate information mentally before being able to act on it. Using picking indicators on the shelves eliminates this mental processing and the operator can act directly on perceived triggers. Today’s system view is illustrated on the left where the operator is to act upon and process data. To the right the operator acts on a trigger in the form of a picking indicator.

![Figure 3](image.png)

Figure 3. Today’s systems to the left where the operator is to act upon and process data. To the right the operator acts on a trigger in the form of a picking indicator.

4. **The Advantages of Automatism**

From what has been discussed so far in this paper, one might conclude that automatic information processing is a bad thing. However, this is not by far the case. The reasons why these processes can cause problems are the same reasons why they can contribute to a better product quality. The fact that they are very hard to break when moving from a high volume scenario to a low level scenario can work as an advantage in a strictly high volume scenario. They allow the operator to work on a routine basis and the risk for slips becomes significantly lower [6]. Another major advantage of allowing for a certain degree of automatism is the fact that it also allows for a higher degree of
parallel processing. Due to the low level of attention in an automatic processing mode, resources are freed to be reallocated elsewhere [9]. Naturally this is also restrained by physical limitations of the human body but an example of this reallocation of mental capacity might be when a user is able to perform one action while at the same time preparing for the next. If a task requires little or no attention, one can use unallocated resources to plan future work. Another recurring example, perhaps easier to relate to, is the task of driving a car. It has already been clarified how, when the task becomes automated, it can be performed with less explicit focus. Many use these resources to perform other tasks while driving. One might fiddle with the stereo, talk to a passenger or talk on the phone. There are even examples of people having breakfast and using electric razors while driving. An interesting effect has been identified on several occasions where the driver stops talking to the passenger or on the phone when something occurs in traffic that requires the driver’s full attention.

5. Future work

An important aspect that has not been discussed in this paper but which will be further investigated in future work is what information is to be presented. Among other things, future work will focus on minimalism in information design where, similarly to lean manufacturing, one strives towards presenting as little information as possible to better amplify what is truly important. For example, if an operator at a work station has two valves to choose from depending on the work piece, and these are both mounted using the same bolts, then perhaps presenting the bolts on the information system is unnecessary. What the operator needs to know is what valve is to be chosen and if information about the bolts is required, this should be covered in the training phase or perhaps it could be made available through explicit search for more information. Minimalist design, which is frequently employed within HCI [17], allows for a significant reduction of noise within the interface. The operator is only presented the information that is needed when it is needed, which also results in a more easily navigated interface.

In future studies, among other things, a range of different information systems will be investigated. The screen-based systems of today are generally limiting the operator to be positioned in a certain way to be able to read the screen. Using flashing lights or even sound instructions would probably increase the range of information and would allow the user to move away from the information source and still receive information. To investigate this, and to gain a greater understanding of the effects of controlling automated processes, studies will take place both in labs and in live assembly domains. Furthermore, a case study will be carried in an assembly factory where the focus will lie on the existing information context and how it is designed in terms of cognitive capacity limitations.

A very relevant issue that has not been handled here is the information value of a trigger. As stated, triggers can be seen both as simple attention getters and as actual information carriers. When discussing the information value of different objects, it is unavoidable to consider the affordances or semantics of a product [18, 19]. This will be an important part of future studies in information design and should be a factor when evaluating new and existing information mediums.

6. Summary

One of the most critical points in information presentation in manual assembly is the question of how to catch the users’ attention and keeping it. As we have discussed, it is the nature of human attention to generate its own extinction in that all repeated actions sooner or later become automated [6, 8]. This automated information behaviour can be seen from two sides, it can be viewed as an opportunity in high volume scenarios where the operator can be argued to be less prone for error due to the fact that he acts on reflex and performs the same action over and over again. On the other hand, when we introduce a low volume scenario where a work piece is to be assembled in a different way, the automated information behaviour becomes a liability. In these scenarios we need to support the operator in a way that allows breaking away from the automated behaviours. This can be done, as described, by giving support, not only at decision points, but during the entire work sequence. This mainly includes allowing the operator to receive information without necessarily having to employ an active information search but rather receiving the information implicitly and independent of the operator’s position relative to the work piece. Pilot studies have shown that a large amount of current focus is on what information should be presented. However, as discussed, the temporal and geographical factors are just as important. It is not enough to consider what information is to be conveyed to the operator but for increased quality, when and where information is presented is equally important to be able to break automatic processes when appropriate and support the operator’s work.
ACKNOWLEDGEMENTS

This work has been made possible through the EU Integrated Project myCar.

REFERENCES