“ Could you open this jar for me please”: a pilot study of the physical nature of jar opening.

"COULD YOU OPEN THIS JAR FOR ME PLEASE": A PILOT STUDY OF THE PHYSICAL NATURE OF JAR OPENING

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The Department of Trade and Industry have recently published a report highlighting the problems of opening foodstuff packaging. The aim of this pilot study was to observe and document the different techniques used by a range of male and female subjects as they tried to open one of the packaging types highlighted in the report as difficult to open, a vacuum-sealed fruit jam jar. Three types of fruit jam jars were assessed with four subjects, two males and two females. Each subject was physically characterised. During the task performance upper limb posture and the forces applied through the jam jar were recorded using a video camera, a CODA motion capture system and a universal grip dynamometer (UGD). The relationship between the physical characteristics and task performance will be discussed in relation to vacuum jar packaging design, and the appropriateness of the assessment methods used.

Introduction

The Department of Trade and Industry (DTI) indicates that shape, size, weight, surface finish, visuals and opening devices all play a part in the ease of package opening for all age groups. (DTI, 2000) The three physiological functions used in opening packs are visual, cognitive and manual (muscle). Visual function is employed in reading and in inspecting and identifying the mode of opening, cognitive function relates to understanding and adopting to perhaps unfamiliar mechanisms whilst the manual and muscular function relates to the force required to open the pack.

The DTI assessment of broad age-related issues for packaging states that after the age of 25-30 years there is a gradual reduction in the power and speed of muscular contraction, together with decreased capacity for sustained muscular effort. The report also states that if muscle strength deteriorates then there may also be a reduction in the relative accuracy of the movements. A 70 year is as weak as a 10 year old and only 65% as strong as a 20 year old. If the person also has a condition in the wrist and fingers such as arthritis then they will have further difficulties with packaging. The difficulties may be due to a lack of overall strength, weak grip, inability to squeeze, inability to press or lack of manual dexterity. (DTI, 1999)

There are no formal guidelines that lay down opening torque requirements for the full range of jar/bottle diameters; industry is generally governed by the loose ‘rule of thumb’. It is suggested that the vacuum accounts for 80% of the torque required to open this pack type. (DTI, 2000) Recent tests by the DTI have indicated that the ‘rule of thumb’ significantly overestimated the torque capabilities of consumers, especially the elderly and disabled.

This pilot study is contributing to a European Commission sponsored project named PACKAGE. The aims of the project are to improve upon the range of opening devices already available on the market and to provide suggestions minor modifications to packaging to assist in the ease of opening. However, if the redesign of packaging is to be successful it is essential to observe the ways in which people currently open jars and to examine the various physical techniques applied.

As the title of the paper suggests, many people have to ask other people to assist with opening and in the case of disabled and elderly people living alone, they quite often just have to wait.

Method

The assessments were carried out rooms with ambient temperature and limited direct sunlight. Four subjects, two female and two male, were chosen to provide a wide range of physical differences from a small sample population. The test procedure was discussed with each subject. Subjects were asked to confirm that they had no history of neuromuscular or musculoskeletal injuries, or diseases. They were also asked if they had a skin condition that might be affected by cleansing of the finger prior to the assessments. The assessment of each subject was divided into two phases; (i) physical characterisation, and (ii) task performance.

(i) Physical characterisation

The physical characterisation of each subject was assessed using a previously documented series of methods (Torrens and Gyi, 2000). The measurements taken included:

- Stature
- Weight
- Fingertip arm length
- Fingertip to first wrist crease
- Hand width (across MCP joints of digits 2-5)
- Hand depth
- Fingertip to first crease (DIP, digit 2)
- Fingertip depth
- Fingertip width
- Finger vertical compliance (vertical displacement of ungula proximal pulp between two parallel platens under a 10N force) using a prototype device developed in the Department.
- Grip strength
- Pinch strength

The results from the measurement of each subject’s anthropometrics were related to a United Kingdom population from the software package PEOPLESIZE (Open Ergonomics, 1999). Grip and pinch strength, finger compliance and weight were related to unpublished data collected from students within the department of Design and Technology, Loughborough University, over the last four years. The comparison provided some context for the assessments of the sample group within a larger U.K. population, to enable a more meaningful discussion of the outcomes.

(ii) Task performance

The methods used in the recording of task performance were based on those documented in previous studies (Torrens and Gyi, 2000, Torrens and Newman, 2000). The methods included:

- Finger friction (coefficient) when using three different jar top samples.
- Force and torque data capture using a Universal Grip Dynamometer (a prototype unit developed within Loughborough University).
- Motion capture using a CODA mpx30 system supplied by Charnwood Dynamics Limited, Leicester, UK. (http://www.charndyn.com)
- Grip pattern observation through video recording.

Finger friction

The coefficient of friction was taken from each subject's finger using a finger friction meter (a prototype device developed in the Department). The three sample tops came from proprietary brands of: **(**A) Apple, 66mm dia. Smooth edged top, 364gm; (B) Sandwich spread, 60.2mm dia. Smooth edged top; and, (C) Jam, 66.2mm dia. Knurled edged top, 650gm.. All jar tops were of a metal lug type, with a polymer-coated surface. A section of each of the jar tops had been mounted in turn, curved edge upwards, upon a fibreboard base using double-sided tape. The tape enabled a quick changeover of top sections between each sample testing.

Force and torque data capture

The subject was asked to open three types of unopened jar (A, B and C described above), repeating this task with the universal grip dynamometer (UGD) attached to the glass base of the jar. The dynamometer, with bracket attachment, weighed 4.5 Kg. Whilst the extra weight would affect how the base of the jar was held during opening, it was envisaged that it would not significantly affect the nature of the forces used to open the jar top.

Motion capture

The motion-capture system employed used infrared emitting markers that were placed over anatomical reference points on the upper limbs and head, including:

- Supraorbital foramen (right and left)
- Mandible (at the midline)
- Acromium point (right and left)
- Humerus (at the lateral epicondyle, right and left)
- Radius (at the styloid process, posterior, right and left)
- Ulna (at the styloid process, posterior, right and left)
- Digit 2 (at the Metacarpophalangeal joint, right and left)
- Digit 5 (at the Metacarpophalangeal joint, right and left)

The motion capture system was used primarily to record elbow flexion/extension and forearm/hand position through the wrist. There are many studies that indicate wrist deviation from a neutral position affects grip performance, notably Pryce (1980).

The distal phalanges were not marked for motion capture, due to the marker size in relation to the smallest fingers of the sample subjects and that the markers would be out of view of the single CODA system when the fingers curled around an object during a task. A three-system CODA set-up would be required (with CODA monitoring units set at right angles to each other in three axes) to ensure the majority of the movement of the phalanges was recorded. Pre-pilot assessments showed a jar opening task to task lest than two seconds if the subject could open it.

Grip pattern observation

A video recording ensured that the phalange positions within grip patterns used by each subject would still be documented. The changeover between each jar sample enabled each subject to rest for a period of five minutes, to recover from muscle fatigue and enable the re-inflation of soft tissues in the hand through blood pressure.

Results and discussion

The results of each subject's physical characterisation are shown in Tables 1 and 2. The results of the task performance are shown in Tables 3 and 4. A summary description of the processed results from the motion capture recordings and grip pattern observation follows Table 2. The total time taken to process sections (i) and (ii) of the trials was calculated to be two hours per subject, involving three operators. The time taken to process the physical characterisation and task performance results from the four subjects was approximately 8 hours.

The comparison of stature of the subjects and U.K. data through PEOPLESIZE (Open Ergonomics, 1999) indicates that the males in the sample group are at the extremes of stature scale and the female at the mid to high percentiles of the same dimension. The grip strength of the larger male related to the higher values recorded from Design and Technology students at Loughborough University (20Kg-40+Kg). The grip strength of the smaller male relates to a lower range value within the student sample population. The vertical finger compliance from both females and males fell within the boundaries of expected values ranging between 1mm-4mm vertical displacement for females and 2mm-5mm for males. The results from the finger friction comparison of three jar tops are shown in Table 3. The performance results from the jar-opening task are shown in Table 4. The friction assessments were repeated due to a loss of data during processing, with the three subjects who were still available. These results are shown in Table 3.

Table 1. Subject physical characteristics

Subject	Gender	Stature mm	Percentile equivalent PEOPLESIZE	Weight Kg	Fingertip to elbow mm	Hand width MCP joints mm	Hand Length mm
1	M	1950	>99	96	525	93	210
2	F	1664	80	52	415	70	161
3	F	1775	>99	101	452	85	185
4	M	1601	1	79.9	428	85	172

Table 2. Subject physical characteristics

Subject	Grip strength Kg	Pinch strength Kg	Dominant hand	Fingertip Length mm	Fingertip width mm	Fingertip depth mm	Finger temperature C°	Finger vertical compliance mm
1	50	7.5	Right	30.34	18.3	16.19	30	2.84
2	26	2.65	Right	25.09	14.19	11.51	26	2.95
3	20	5.5	Right	26.38	16.03	13.65	34	2.88
4	33	4.25	Right	27.18	16.28	13.81	27	2.96

Table 3. Coefficient of friction values of right-hand digit 2 using three different jar tops

Subject	Finger temperature C°	Jar A	Jar B	Jar C
1	23	0.54	0.50	0.50
2	27	0.69	0.47	0.57
4	35	0.60	0.65	0.50

Table 4. Peak force (Kg) value from X, Y or Z axis for each of 4 subjects when opening three types of jar top with other axes values and x, y, z axes torques (Kg m) from same point in time. Positive force values are upward, positive torque values are clockwise.

Sample A	Force (x)	Force (y)	Force (z)	Torque (x)	Torque (y)	Torque (z)
1	-1.95	1.70	1.70	0.02	-0.10	0.40
2	-0.50	0.43	-0.10	0.00	0.06	0.03
3	-0.77	1.31	1.03	0.02	-0.07	0.07
4	2.78	-0.57	-12.6	0.03	-0.26	0.90
Sample B	**Force (x)**	**Force (y)**	**Force (z)**	**Torque (x)**	**Torque (y)**	**Torque (z)**
1	0.11	0.48	0.64	0.01	0.04	0.05
2	-0.11	0.66	1.30	0.01	-0.08	0.10
3	0.08	-1.80	-0.94	-0.04	0.07	-0.44
4	0.50	0.90	-4.1	0.03	-0.15	0.43
Sample C	**Force (x)**	**Force (y)**	**Force (z)**	**Torque (x)**	**Torque (y)**	**Torque (z)**
1	-0.32	2.62	-0.80	0.08	0.00	0.97
2	0.21	0.48	1.4	0.00	-0.15	0.08
3	0.57	1.08	-3.78	0.02	0.29	0.20
4	0.10	-0.90	-11.43	0.07	-0.29	1.72

The finger friction results did indicate that more friction for grip on to the jar top was available using sample A. However, further investigation is required to provide more robust evidence. The coating on the surface of the jar top could change the friction qualities. It was not obvious if there was any difference in surface coating.

The grip patterns used in the task by all four subjects involved a clamping power grip in a mid-supinated position and a manipulating grip with the other. The non-dominant (left) hand in three of the four subjects was used as the clamp hand. All subjects used a composite grip of a power and lateral pinch grip with their manipulating hand. The extent to which the grip pattern could be identified as a lateral pinch came with increased difficulty of the female subjects in opening the jar or gripping the jar top size. The motion capture data indicated an increase in flexion in both hands when the subject found it difficult to open the jar.

The force data indicates that most of the forces and torques were low, under +/-2 Kg and +/-2Kg m respectively. The force values correspond to static torque dynamometer measurements taken by one of the authors. The forces and torques that exceeded these values were in the z (vertical) axis of the jar body and top. The largest force was –12.6 Kg exerted by subject 4 (small male), indicating some downward force. However, subject one (large male) produced the highest y-axis forces 1.70 Kg, indicating some side force application. The apparent difficulty of opening a jar compared to the forces measured seems incongruous. However, this phenomenon has been previously identified when assessing the difficulty of cutting meat with subject who had limited grip strength. This pilot study has raised issue that require further investigation.

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