Studies of Human Perception on Design Products

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Observation of eye movements can provide insight on human perception of objects in the surroundings, as there is a close connection between vision and cognition. Eye movements may reveal the cognitive information indirectly in a series of fixations and saccades, called gaze path. Fixations are brief periods of relative stability of the eyes on specific locations, whereas saccades are rapid movements of the eyes connecting fixations. Two useful measures for evaluation of perception are fixation duration and fixation count.

The study carried out a series of tests using an eye tracker to evaluate perception of five different products presented as pictures to participants in five different tasks. Statistical analysis of the gaze data showed that people look at the same product differently depending on their motivations, and perception varies by product complexity. In general, no significant differences were found between the perception of designers and non-designers. When given specific motivations for memorizing the pictures, however, some differences in perception between those two groups of participants did occur. Also, hobby and gender were found to have more influence on perception than other background factors analysed including participants' familiarity with the products and their experience with an eye tracker. Analysis of different areas for one of the products showed that the product's brand name and mechanics part received more attention than its handles.

Generally, the direction of eye gaze shows where attention is directed. It would be interesting to study what factors are the most important for perception of product design: the aesthetics, architecture, or brand. The methods and results of the analyses performed in this study can be used as the guidelines for further studies on perception.

Keywords: human perception, eye movement, eye tracking, gaze path, fixation, HCI

Contents

1. Introduction

Eyes play an important role in human perception. Perception is the process of acquiring, interpreting, selecting, and organizing sensory information to produce a meaningful experience of the world. Sight, hearing, smell, taste, and touch are five important senses influencing human perception. Among these senses, sight provides the ability to detect light and interpret it through visual perception.

People use eyes intensively for a large variety of purposes such as reading, watching, gathering information, evaluating actions, perceiving, and learning new things. Eyes can be considered both as input and output organs. Providing input for the brain by observing the surroundings is the most important role of eyes. On the other hand, eyes can also act as an output organ by producing the direction of gaze. Moreover, the direction of gaze can usually give an indication for the direction of visual attention.

Understanding how the users perceive certain products is very important for the product designers. Although cognitive processes cannot be observed directly, they are reflected in the pattern of gaze behaviour. Thus, eye movement recordings can provide implicit information for modelling the user perception of products and their design.

The gaze path of the eye movements can be recorded using an eye tracker. From these recordings, an estimate can be obtained about the distribution of visual attention in the observed scene. To facilitate interpretation of the implicit gaze data, a specific cognitive task can be used to motivate the users, which in turn affects their attention. The pioneering study by Yarbus [1967] serves as a good example for that. The study showed that the gaze path is indeed affected by the specific instructions given to the users.

Noton and Stark [1971a, 1971b] extended the results by Yarbus' by showing that even without leading questions and instructions participants tended to gaze at the identifiable regions of interest. Their study of eye movement measurements over images showed that the order of eye movements over specific regions was quite variable. For example, while viewing a picture of a square, participants gazed at the corners, although the order in which the corners were viewed differed among the participants. The order differed even between consecutive observations made by the same participants.

It should be fascinating for designers to study the visual features of a product that capture an observer's attention. Eye movement recording is a very useful method for the oculometric analysis. In the middle of 1980's, the oculometric research laboratory at the University of Essen examined how eye movement recording could be used in industrial design. Hammer [1991] used eye movement recordings to determine the most attractive parts of a product, and to discover this way whether specific details, such as the logo and brand name, attracted attention.

Earlier research work shows that people do not explore an image randomly while looking on it. For example, while viewing an image, the items in the foreground get more attention than the items in the background [Babcock *et al.* 2002]. People usually pay more attention to certain distinct features such as the edges of an object, colours, or asymmetries. DeCarlo and Santella [DeCarlo and Santella, 2002] studied a computational approach to clarify the meaningful visual structure in an image. While observing, a significant part of the visual information is processed on a pre-attention level. The pre-attentively processed features only become apparent to the user if the features do not correspond with the mental model or mental representation. For example, a shadow of an object is not perceived on a conscious level, but it still significantly affects the perception of the object [Rensink and Cavanagh, 1993]. Sometimes one may not be able to explain why one product is more appealing than another. Eye movement research could be useful to acquire more explanation than that with the conventional methods, such as "think-aloud", questionnaire/interview.

It would be beneficial to study whether the perception of a product's design is based on the aesthetics, functionality, architecture, or the brand. It is also possible that some other factors might influence the perception, which could be the scope for a study as well. Moreover, the differences in perception between an expert and a consumer also deserve a thorough analysis. All these are important aspects of eye tracking and eye movements, though there have not been enough studies conducted in this regard. Eye-tracking analysis can provide a vast amount of information regarding where the attention is captured.

Although, the “think-aloud” method or a questionnaire/interview can tell something about the users’ interest in the product, gaze path data can deliver a much better understanding of the underlying attention processes.

Thus, the main goal of eye-movement measurement and analysis is to obtain insight of the viewers’ attentive behaviour. Gaze direction shows where the attention is directed. Hence, it is worth to study the gaze path. Several eye movement studies have been conducted using an eye tracker, as outlined in Section 2. Further analysis is needed to make more quantitative and qualitative inferences about the eye movements.

This study intends to understand how people perceive design by combining knowledge from the fields of design research and human-computer interaction (HCI). The major goal of the study is to obtain information about the perception of the users during observation of the presented design products through eye tracking and gaze path analyses. This study is part of a collaboration project “Perception of Design” conducted by Tampere Unit for Computer-Human Interaction (TAUCHI) and University of Art and Design Helsinki (UIAH). More specifically, the objectives are;

- to determine if there are any differences in viewing design products for different motivations,
- to determine if there are any differences between designers and non-designers in viewing design products,
- to analyze the effect of background information of the participants on perception, and
- to analyse different areas of interest of design products.

In order to meet the objectives, a test is carried out using different product pictures for five different tasks. The tasks are considered as different motivations. The products selected for the study are mobile phone, hedge clippers, headphones, camera, and cup. Producers of the two of the products (Fiskars, Nokia) are partners in this project. The test, tasks, and products are described in detail in Section 3.

Statistical analysis of the study shows that people look at the same product differently depending on their motivation. It also shows that perception varies by product complexity. The analysis did not found concrete differences in perception between designers and non-designers. Though, with specific motivation, while memorizing pictures, there exists difference in perception between designers and non-designers. It is also found that hobby and gender have more influence on perception than other background information, such as familiarity with products, experience with eye-tracker. Different areas of a product were also studied. While analyzing area of interest for the product picture of hedge clipper's, it is observed that brand name and mechanics parts got more attention than handles.

The thesis is structured with several sections and sub-sections. Background of the study is described in Section 2, which gives some basic concepts and literature review. Methods and experimental set-up of the tests carried out are described in Section 3. Results and discussion is provided in Section 4. Finally, Section 5 concludes the thesis by summarising the key findings of the study.

2. Background

2.1 Basic concepts

As mentioned briefly in Section 1, eye movements can be recorded using an eye-tracker, which produces the gaze path. Gaze path is a sequential combination of fixations and saccades produced by the eyes. Fixation is a relative stability of the eyes for a brief period of time on a specific location. On average, fixation lasts for 200-300 milliseconds. In general, more than 150,000 eye movements occur each day for one person [Abrams, 1992]. Thus, eyes do not stay stable for a long time and they move continuously. A rapid motion of the eyes from one position to another is called a saccade. Saccades usually last between 50 and 150 milliseconds and occur 2-3 times per second. People have clear vision during the fixations, not during the saccades. Gaze path depicting the fixations and saccades produced by the eye tracker used in this study is shown in Figure 1. Circles represent positions of fixations and lines represent saccades. Radius of the circle illustrates duration of the fixation. Details about the eye tracker used in this study can be found in Section 3.

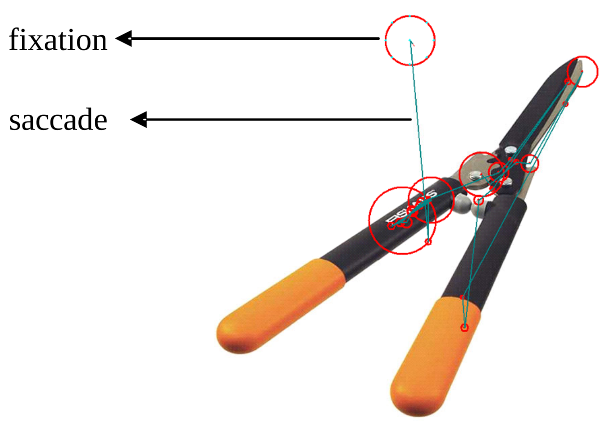

Figure 1: Gaze path with fixations and saccades

2.2 Literature review

Eye movement studies have started a century ago. There are several applications of eye movements, such as usability research, user interfaces, and human cognition. They are also used to study airplane pilots' eye movements inside cockpit controls around instruments while landing an airplane [Fitts *et al.*, 1950]. Eye movement research flourished with improved technologies of eye-tracking system in 1970s. The work during the late 70s mostly focused on psychology and physiology. It was mostly concentrated on exploring how human eye operated and what it could reveal about perceptual and cognitive process.

The active combination of head and eye positioning, known as gaze changes, provides a satisfactory illusion of high resolution vision. When performing everyday tasks, the point of gaze is often shifted toward task-relevant targets even when high spatial resolution from the fovea is not required. Monitoring these eye movements that are made without conscious intervention often provides us a window into cognition [Liversedge and Findlay, 2000; Pelz et al., 2000]. Thus, unless exposing the full cognitive processes underlying perception, most of the time eye movements provide an indication of where attention is deployed.

Eye-tracking devices record eye movement mostly by providing a close-up video image of the pupil of eye. Eye-tracking technology is being used in an increasing number of applications and research fields [Duchowski, 2003], such as in the studies on perception of physical objects. There is a distinct connection between eye movements and hand movements. Researchers from the University of Rochester measured patterns of eye-hand coordination while manipulating objects like simple blocks [Pelz *et al.*, 2001], or making a sandwich [Hayhoe *et al.*, 2003]. While making a sandwich, Hayhoe and others focused on the temporal dependencies of natural behaviour. Perception can be seen as an active process of interaction between internal schema and the outer information. People use gaze in a proactive manner: we look at things before we act on them [Land and Furneaux, 1997]. Furthermore, people focus at different aspects of an object, depending on the task at hand [Hayhoe *et al.*, 2003], or previous experience [Lu *et al.*, 2001].

Land and Hayhoe [Land and Hayhoe, 2001] investigated similar natural tasks by examining the relations of eye and hand movements in extended food preparation tasks, tea-making, and making peanut butter and jelly sandwiches. According to their study, gaze usually reached the next object in the sequence of work before the sign of manipulative action occurred. The results indicated that eye movements were planned into the motor pattern and led each action. However, their findings showed that in general the eyes provided information on an “as needed” basis.

The series of eye movement experiments started by Buswell [1935, cited in Babcock *et al.* 2002] have focused on the perceptual and cognitive significance of eye movements relating to photographs, line drawings, and artwork already captured by others. While these experiments have demonstrated that observers tend to deploy their attention to similar regions in an image, they have not been able to study the kinds of eye movements that occur before and during image capture. After eye-tracking more than 200 participants while viewing 55 photographs, Buswell found that eye movement behaviour can be observed in two forms. In some cases, participants made a succession of brief pauses distributing over the main features of the photographs, where viewing sequences were characterized by a general survey of the image. In other cases, participants made long fixations over smaller sub-regions of the image.

According to his study, people were inclined to make global fixations early with shorter duration, and as the viewing time increased, duration of fixation became longer with smaller saccades. It was also found that participants often fixated on the same spatial locations in an image, but not exactly in the same temporal order. These consistencies provided information that people tented to focus on foreground elements rather than background elements, and hence did not randomly explore pictures. Buswell also concluded that instructions before viewing objects significantly influenced the perception.

Brandt [1945] investigated the role of eye movements in learning strategies and in the perception of art and aesthetics by analyzing eye movement patterns while looking at advertisements. Both Buswell and Brandt found that there were individual differences in eye movements.

DeCarlo and Santella [DeCarlo and Santella, 2002] studied a computational approach to clarify the meaningful visual structure in an image. Their study presented how the information from eye movements of a user can be exploited to transform a photograph into a line-drawing. The user briefly looks at the image, and an abstraction of the image is generated based on the gaze behaviour, combined with automatic edge-detection. The elements getting more focus are highlighted and drawn in more detail, while the elements with relatively less focus are rendered with less detail. This approach can be used to exploit the information gained from gaze behaviour to guide industrial design. Information of the gaze behaviour, combined with the knowledge of the features of the product, reveals the features that capture attention.

By studying the ways human eyes examined complex objects and the principles governing this process, Yarbus [1967] found that eye movements were not simple reflexes tied to physical features of an image. His studies suggested that human eye fixates mainly on certain elements of objects that may contain useful and essential information to perception. Elements on which the eye does not fixate do not contain such information [pg. 175, Yarbus, 1967]. In his well-known example, Yarbus recorded the eye movements of participants while they examined I.E. Repin's, *An Unexpected Visitor*. During free-viewing, eye movement patterns across seven participants revealed similar areas of interest. Furthermore, he studied how motivation changed the attention. Different instructions, such as estimating the material circumstances of the family, giving the age of the people, remembering the clothes worn by the people, substantially changed the eye movement patterns for the participants while viewing the painting. Figure 2 shows the corresponding gaze path of the participants while they were viewing the picture according to given tasks. In general, the most informative regions were likely to receive more fixations. Viewing strategies can be affected by several reasons and can make inconsistency in the gaze path. Henderson and Hollingworth [Henderson and Hollingworth, 1998] pointed out that experimental parameters such as image size, viewing time, and image content can cause difficulties in comparing eye movement results. They suggested at least three important reasons to understand eye movements while viewing images. First, eye movements are critical to acquire visual information efficiently during complex visual cognitive tasks.

Second, storing and representing the visual information are also critical in the study of perception and cognition. The study of eye movement patterns while viewing images contributes to an understanding of how information in the visual environment is dynamically acquired and represented. Third, eye movement data provide an unobtrusive, online measure of visual and cognitive information.

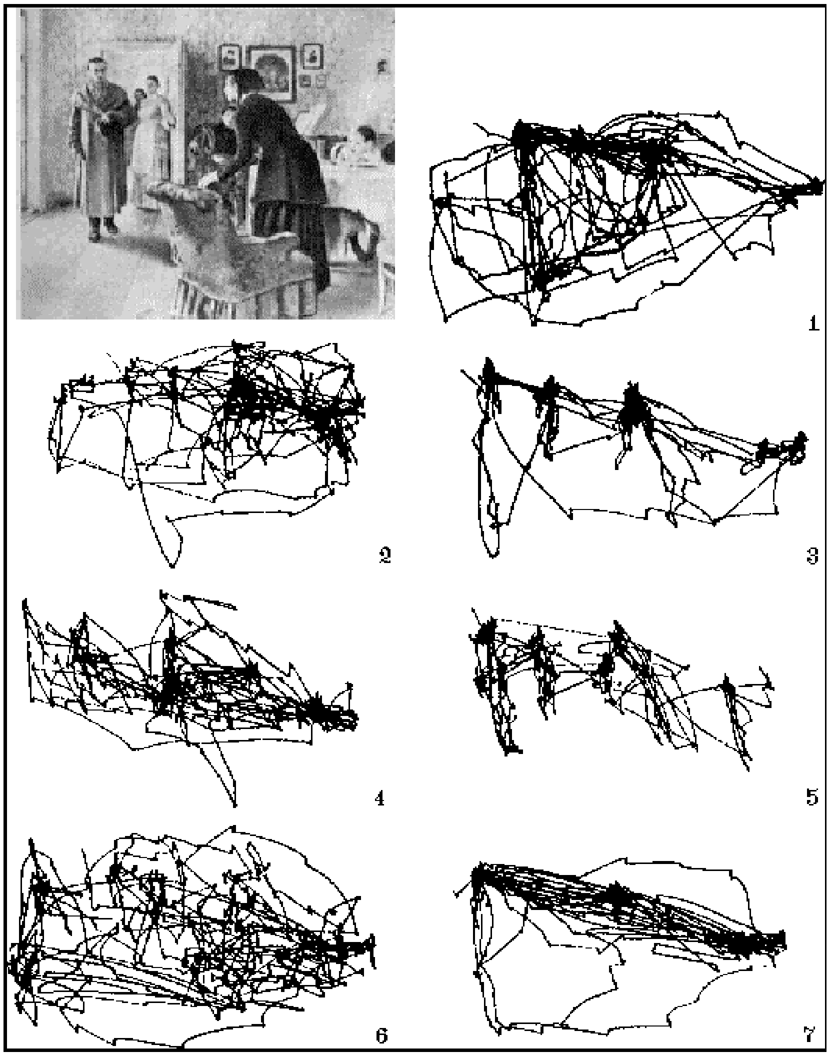

Figure 2: Eye movement patterns on I.E. Repin's "An Unexpected Visitor" while perceiving the picture with seven different tasks.

While several studies (such as studies by Buswell, Brandt, and Yarbus) stated that participants generally fixate or direct their attention to the same regions while viewing an image, several authors set out to explore how the semantic features in a scene influences eye movement behaviour [Mackworth and Morandi, 1967; Antes, 1974; Loftus and Mackworth, 1978; Henderson *et al.*, 1999]. Noton and Stark [1971a, 1971b] analyzed the chronological order of fixations in an attempt to identify recurring sequences of saccades, termed as scan paths. In the study conducted by Antes [1974], participants viewed two colour photographs, a mask, and coastline. Other than that, in most of these experiments participants viewed black and white line drawings or monochrome shaded drawings of realistic scenes. Again, the general conclusion obtained was that eye movements were not random, and various fixations of participants did land on informative regions in the picture. Furthermore, variability among the participants was also observed, although individuals often made the same scan paths to specific regions in the image. An example gaze path on a face is shown in Figure 3 below where a photograph was viewed freely without any prior instruction [Yarbus, 1967]. From the gaze path it is possible to obtain the important features of the photograph.

Figure 3: Record of eye-movements during free examination

Another eye movement study by Molnar [1981] analyzed fixations to find the effect of aesthetic judgments in viewing pictures. Half of the participants used in his study were instructed to view the pictures carefully, as they would later be questioned about what they saw. These individuals were designated as the semantic group. The other half of the participants were told by the author that they would be asked about the aesthetic qualities of the pictures. The later group was called the aesthetic group. Measures of fixation duration indicated that the aesthetic group made longer fixations than the semantic group. However, there was little difference in the magnitude of saccades between the two groups. The longer fixations for the aesthetic group provided an argument that more time was needed to make aesthetic judgments about the pictures, although aesthetic judgments did not influence the angular distance between fixations. Another experiment conducted by Nodine *et al.* [1991] later found that the composition of the image had influence on perception among trained and untrained artists while they looked at paintings. In their experiment, artists' fixation durations were longer, and their eye movement patterns had a tendency to focus on structural relationships between objects and backgrounds. For untrained viewers, fixation durations were shorter, and eye movement patterns focused mainly on foreground or pictorial elements that conveyed the most semantic information.

Loftus [1981] in his eye tracking experiment, regarding fixations on picture, found that recognition performance increased with increasing number of fixations. Loftus also argued that more information can be acquired from a picture if the viewers were allowed to look at more places in the picture.

Rayner [1998] studied eye movements while reading texts and processing the information. The study summarised three eye movement characteristics during reading. First, eye fixation lasted about 200-250 ms with mean saccade size 7-9 letter spaces while reading English. Second, fixation duration increased and saccade length decreased when the text became conceptually difficult. Thus, eye movement influenced by textual and typographical variables. Other factors, such as quality of print, length of line, and letter spacing also influenced eye movements. Third, eye movement differed when reading aloud from reading silently. By studying eye movements while viewing images, Rayner found that people got the general abstract idea of the image during the first few fixations. The rest of the fixations served to collect the details about the image. Rayner's findings were consistent with those of others stating that eye movement analysis could provide important conclusions about temporal aspects of image perception.

An eye movement study related to art was conducted by Wooding [2002]. In his study, 5638 participants viewed the digital images of paintings from the National Gallery collection. The study also introduced the “fixation map” analysis method. The analysis provided the information on where people tended to look at in the images. The “fixation map” analysis method can also be used to define various parameters of the eye movement trace, including the degree of coverage and areas of interest.

Jacob and Karn [Jacob and Karn, 2003] described the variety of eye movement research in human computer interaction field. They have considered the application of eye movement to user interfaces and usability engineering as an actual control medium within a human-computer dialogue. Eye movement research depends on the eye-tracking system. These dependencies sometimes slow down the development of the research in this field. Constrains of the physical relationship between the eye-tracker and the participant remain one of the most significant barriers for incorporation of eye movement research in usability. Nowadays, eye-tracking system developers made a great progress in reducing the barriers.

Norbert Hammer and Stefan Lengyel [Hammer and Lengyel, 1991], used the eye-movement recording in industrial design. They wanted to find out how eye-movement could be useful for designers. The study investigated those parts of a product which attract most attention. In general, oculometric analysis showed fixations on those parts of a stimulus which were most attractive and which contained the most information. Among the considered products, the most interesting part found was the company logo and brand name, which justified the assumption that most of the users were brand-oriented.

Determining those parts of a product which attract the most attention, might also be useful when it is desirable to point out some new technical feature that are visible, or very important detail such as an emergency-off-switch on a machine. An already established application of eye-movement analysis in car and aircraft cockpit designs, or other kinds of instrument panels is based on the analysis of layout instrument theory. Eye movement recording is used to optimize ergonomics in design. Norbert and Stefan found that analyzing existing products or design mock-ups in combination with a verbally given task could indicate which equivalent formal element carried the given meaning or the brand identification.

On the basis of eye movements, a gaze-assisted application iDict [Hyrskykari *et al.*, 2000] was developed for reading electronic documents written in a foreign language. While reading documents, iDict observes the reader's eye movements and act proactively by providing help when the user has comprehension problems with the text [Hyrskykari *et al.*, 2003].

Using the eye-tracking technology and applying the established methods, a recent study by K. Koivunen, S. Kukkonen, S. Lahtinen, H. Rantala, and S. Sharmin [Koivunen et al., 2004] intended to study how people perceive the design of products. The gaze path analysis of the study showed that people observed the same product differently when given different motivation, which was consistent with Yarbus's [1967] findings. The study also indicated that people had at least three different perception strategies: narrow, holistic, and a combination of the first two.

The research reviewed above clearly demonstrates that eye movements can be applied in several research fields to get insights into human perception and cognition. However, the information about the gaze direction alone is not enough without the knowledge of the features of the object and the intention of the observer. Thus, there is a need to combine eye tracking with other methods of investigation. Also, there is a need to develop methods for distinguishing the features of the product that capture the consumer's attention, such as the colour or the shape of the object. Nowadays, development of eye-tracking systems has increased a lot with advanced technologies, which provides more efficient data about eye movements. Although several studies were conducted to gain insights on visual cognition through eye movements, it is still challenging to generalize the findings to natural vision. Hence, it is necessary to concentrate more on studies of eye movements to achieve a better understanding of visual perception.

The present M.Sc. thesis aimed to conduct different statistical analyses for studying the perception of design products. Methods and experimental set-up of the tests carried out are described in the following section.

3. Methods and Experimental Set-up

An eye movement experiment was carried out under the Perception of Design project using a head mounted eye-tracker. The experiment took place at the laboratories of the University of Tampere and the University of Art and Design in Helsinki. The tests were recorded using a video camera after being granted permission from participants.

Information about the background of participants and their prior experiences regarding the product pictures presented in the experiment was gathered using questionnaires. Some of those questionnaires were presented to participants prior to starting of the test, whereas the remaining ones had to be answered at the end of the experiment.

The subsections below describe in detail about the participants, questionnaires used, apparatus, procedure, and variables.

3.1 Participants

The test involved 21 participants (9 female, 12 male). All participants had normal or corrected vision with normal perception of colours. All but two participants were Finnish. Eleven participants were designers by profession, whereas the rest were either researchers at a local university or in another profession that is not related to product design. The mean age of the participants was 33 with the range from 26 years to 46 years. Among 21 participants, 10 had previous experience with an eye tracker. As their hobby, 10 participants specified drawing, four painting, four sculpture, 12 handicraft, 13 design, six visual arts, and nine photography.

3.2 Questionnaires

Two different questionnaires were provided to the participants before and after the tests. The former consisted of questions regarding contact and background information of the participants. The questionnaire also included a question about any problem participants might have with colour perception. In the post-tests questionnaire the questions were about hobbies, experience with an eye tracker, familiarity with the products shown during the tests, and also the quality of the experimental set-up. Participants were asked to choose a multiple-choice answer for the question regarding familiarity of the product. The options were: “Never seen before”, “Have seen a picture”, “Have seen in nature”, “Have used”, and “I don’t know”. There was also free space provided for writing comments. The questionnaires were prepared both in Finnish and English.

3.3 Apparatus

3.3.1 Eye-tracking instrument

EyeLink head-mounted eye-tracking system was used in the experiment for recording eye movements of the participants while perceiving given tasks on the computer monitor screen. There are two custom-built ultra-miniature cameras located in the head mounted

Figure 4: The test set-up and the eye tracker

system. Two computer monitors referred to as Subject PC and Operator PC were used in the set-up. Pictures of products were shown to participants on the Subject PC monitor using an eye-tracking analysis tool iComponent [iComponent, 2004]. Resolution of the Subject PC was 1024 by 768 pixels. The experimental set-up including the eye tracker and monitors is shown in Figure 4.

3.3.2 Picture series screens

The stimuli for the tests were pictures of five products with varying degree of visual complexity. The products were selected and categorized by the product designers involved in the planning of this experiment on the basis of their subjective impressions. The products selected for visual presentation were as follows (in the order of increasing visual complexity): Arabia's "Teema" cup, Fiskars hedge clippers, Sennheiser headphones, Nokia 7600 mobile phone, and a Sony digital camera (Figure 5). Different categories of products were chosen to initiate various viewing strategies that could then be compared.

The main objective for designing the test screens was to have as natural representations of the products as possible (Figure 5). Another important aspect was showing the key details of the products. All the products were shown in their natural size; only the hedge clippers were downscaled.

Figure 5: Display screens with five selected products

The five products were presented to participants in a series of 81 display screens. The series was structured in several parts. In the introductory part, a relaxation picture (Figure 6) was shown for 10 seconds. The purpose of doing this was to obtain the primary gaze path of the participants. Gaze path of one participant on the relaxation picture is shown in Figure 6.

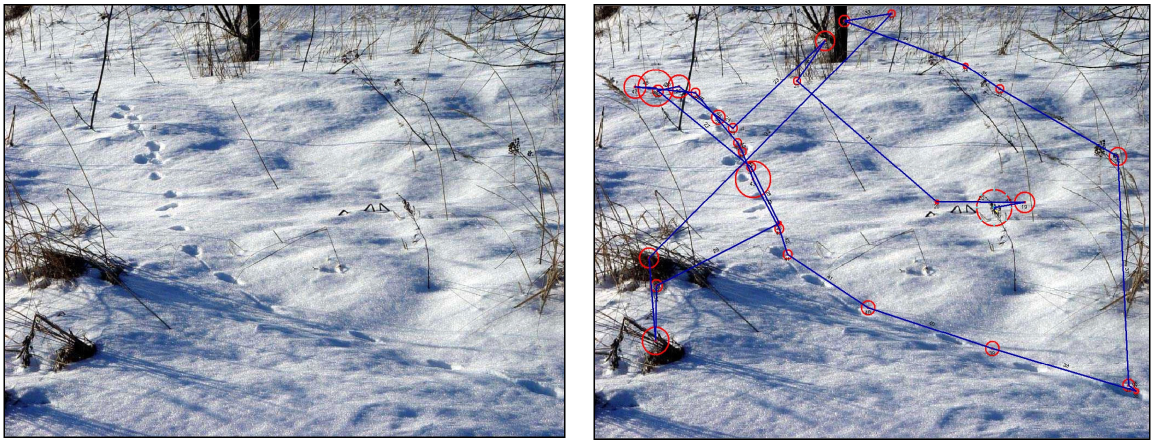

Figure 6: Relaxation picture with gaze path

After the relaxation picture, there were five other parts related to specific tasks. The purpose of the first part was to record the gaze behaviour of participants not subjected to any instructions. The following task-related parts aimed to motivate the participants to memorize the products, evaluate their aesthetics, usability, and durability. All these parts are described in more detail below with a sequence of screens.

Part 1: 1st Impression

As mentioned above, this part was designed specifically for obtaining the 1st impression of participants while freely viewing the products. The sequence of displays was arranged so that there were screens with numbers on them between the product pictures (Figure 7). The numbered screens were used for calibration purposes. Each product picture was shown for 10 seconds and the numbered screens for 2 seconds.

Figure 7: Sequence of displays in Part 1

Part 2: Memory

In the second part, the participants were instructed to memorize the product pictures displayed on the screen and then answer one question regarding the product. There were different questions for different products. The question about the headphones was: “What is the price group of the headphones?”. The possible answers to that question were: “cheap”, “middle price”, and “expensive”. During the test in Part 2, participants first saw an instruction on the screen saying: “Try to memorize next product”. Then, the picture of one product appeared on the next display screen followed by another screen with the question and possible answers. The instruction and product picture screens were presented for 5 and 10 seconds respectively. The time for watching the displayed screen with the question and answers was not limited, as it was controlled by the test coordinator. Participants were told beforehand to choose an answer while viewing it and also say it aloud. After the test coordinator had marked the answer on paper, s/he changed the display by pressing a key on the keyboard or clicking the mouse.

A sample sequence of display screens with the product video camera is shown in Figure 8 with the accompanying gaze path superimposed. The other products were presented to participants in the same way. The various products had different questions and answers

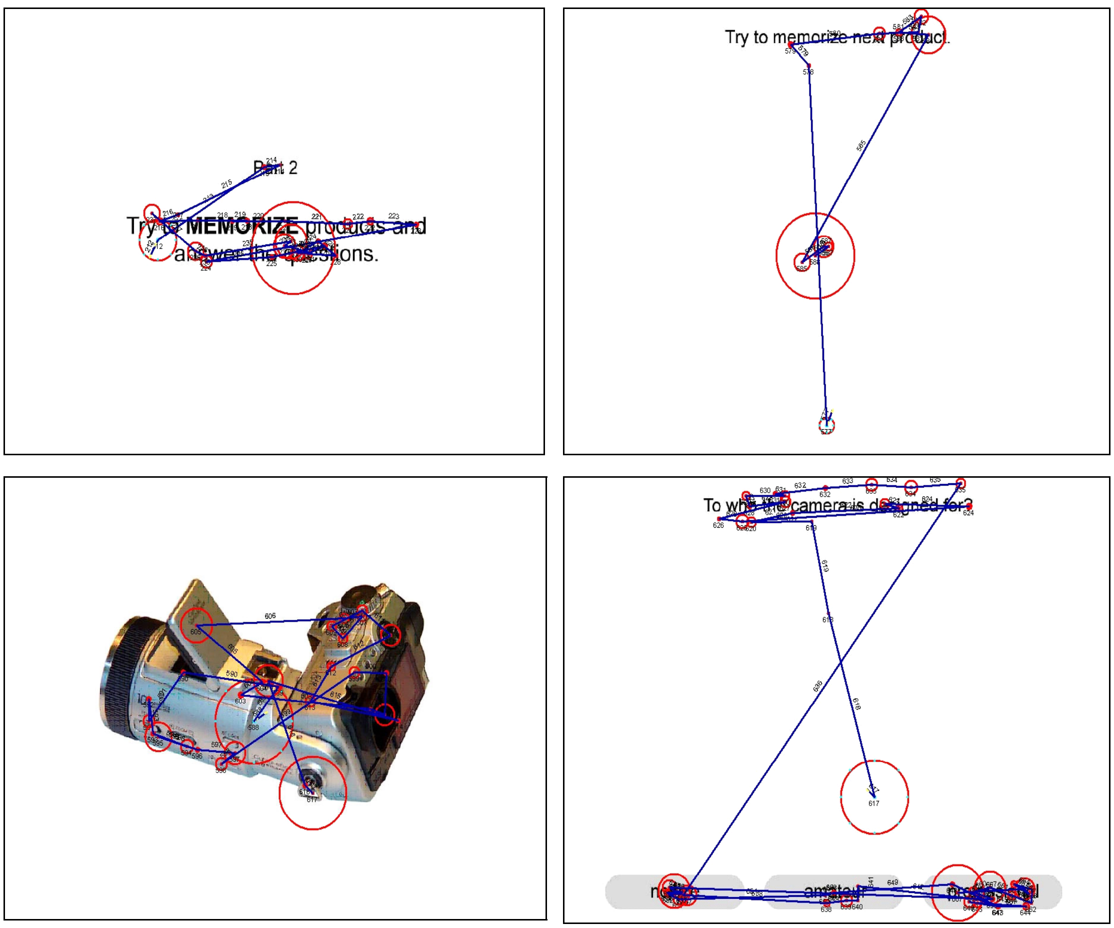

Figure 8: Camera pictures with gaze path from Part 2

attached to them. For instance, the question about the hedge clippers read: “How many shiny axles are in the clippers?”. The possible answers were: ‘1’, ‘2’, and ‘3’. For the cup, the question was: “What is the colour of the cup?”, and the answers were: “green”, “white”, and “blue”. The question for the camera was: “To whom the camera is designed for?”, and the answers were: “novice”, “amateur”, and “professional”. Lastly, for the mobile phone the question was: “What is the brand of the phone?”, and the answers were: “Nokia”, “Sony”, and “Siemens”.

Part 3: Aesthetics

Third part investigated participants’ perception of the product aesthetics. For each product, participants had to answer the same question: “How beautiful the product is?” Participants had to rate the products using the scale from 1 to 10, where 1 was for “ugly” and 10 for “beautiful”. Figure 9 shows a sample sequence of displayed screens for the mobile phone

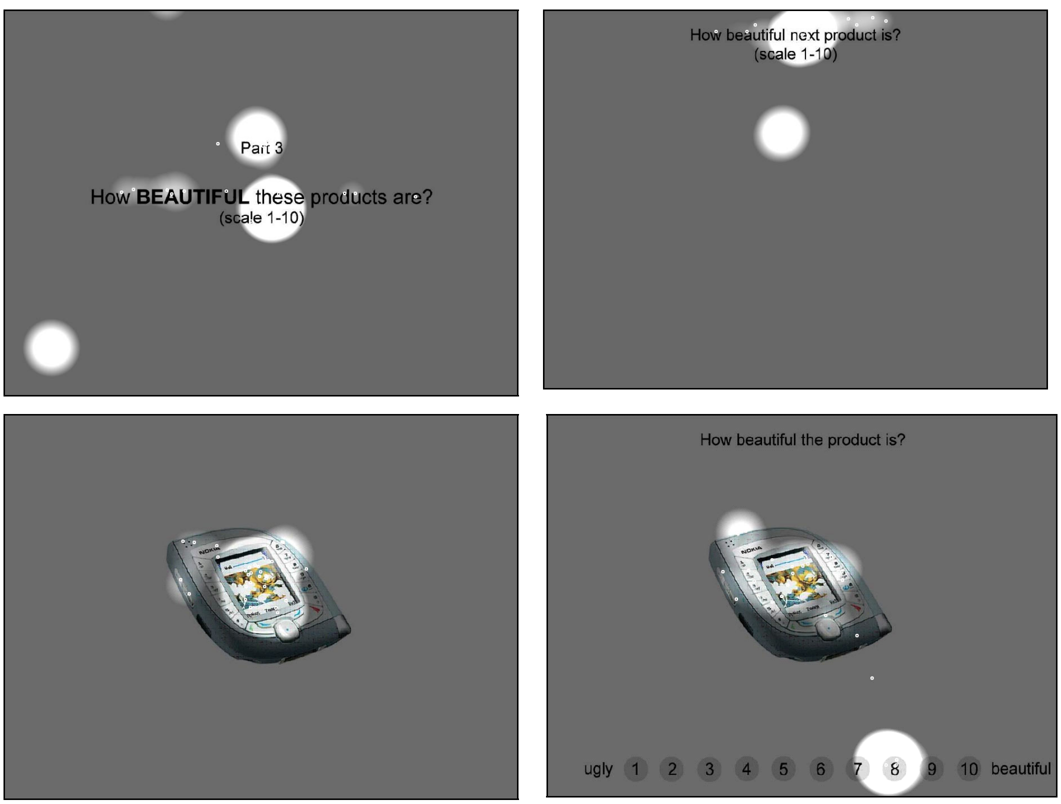

Figure 9: Screens for mobile phone with density map from Part 3

along with the density maps of the fixations. Similarly to the second part, participants were asked beforehand to answer the questions by looking at the answers, and at the same time say the answer aloud.

Part 4: Usability

Fourth part also contained one question for all the products. Participants had to rate each product by answering the question: “How easy is the product to use?” the answering scale ranged from 1 to 10, where 1 standing for “difficult” and 10 for “easy”. A sequence of displayed screens for the mobile phone is shown in Figure 10 along with the gaze path for one participant. The same sequence was followed for other products.

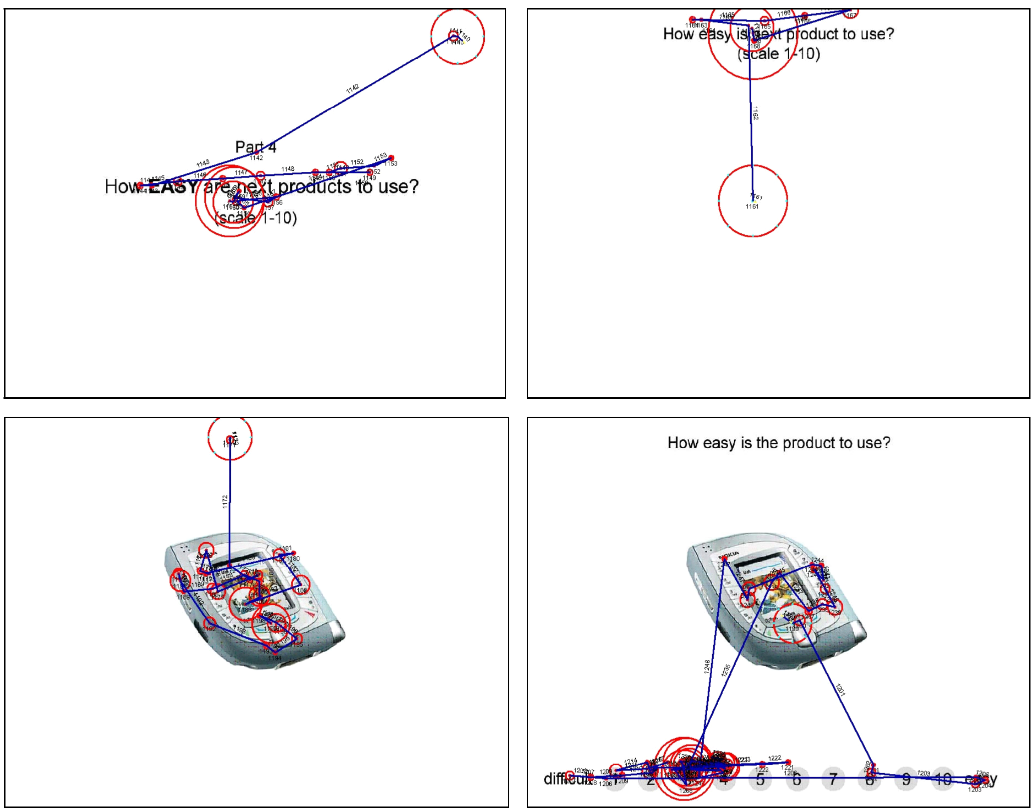

Figure 10: Display screens of mobile phone with gaze path from Part 4

Part 5: Durability

Similarly to part three and four, Part 5 had also the same question "How enduring the product is?" for all product pictures followed by the display screens for collecting feedback from participants. The ratings were from 1 (weak) to 10 (enduring). Again, participants also said the answer aloud. The procedure of presenting the display screens was the same as in Parts 3 and 4. As an illustration, Figure 11 presents the screens for the hedge clippers with the gaze density maps superimposed.

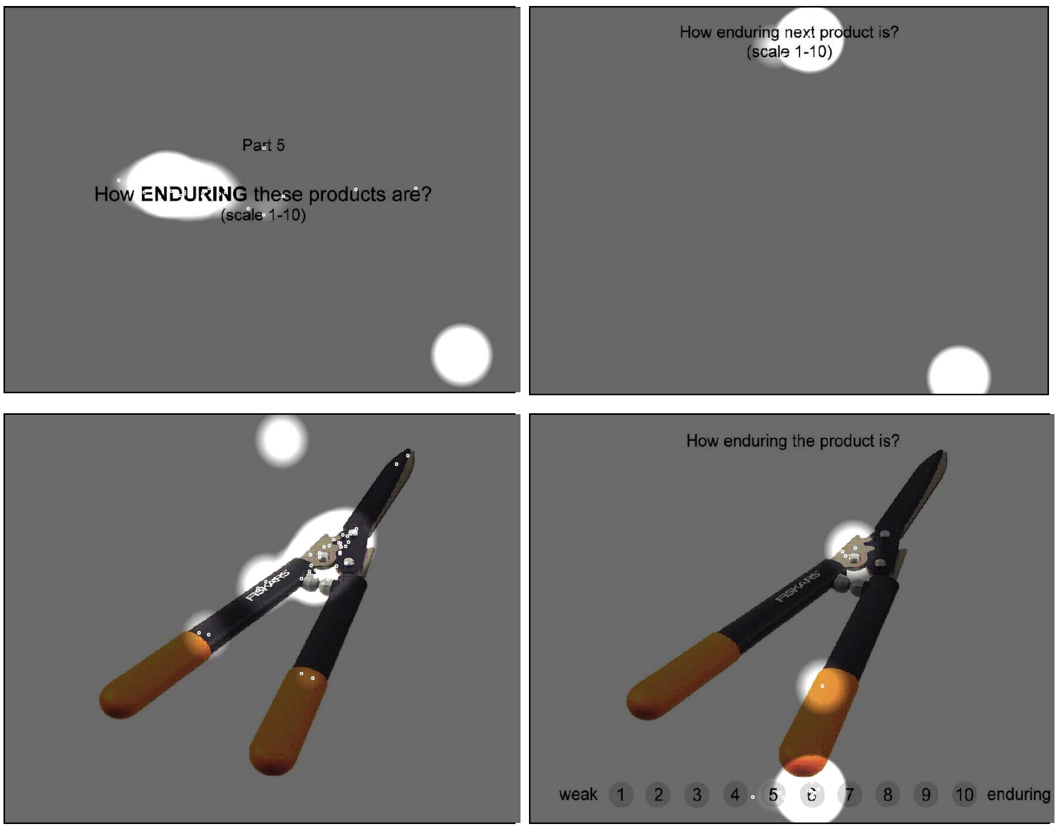

Figure 11: Screens for hedge clippers with density maps from Part 5

3.4 Procedure

The test procedure was arranged in such a way that two persons were enough to control the experiment. Necessary care was taken so that all members involved in the project could carry out the test in the same manner.

At the beginning of the test, there was a brief demonstration to the participants with several power point slides to give a general impression of the experiment. The demonstration took about five minutes. Then, participants were asked to fill in the first questionnaire for collecting information on their background. At the same time, permission for video recording the whole test was received from the participants.

Before participants could start the experiment, their eyes needed calibration. This was done using the iComponent software. Besides, during the whole test sequence, there appeared several screens with dots in different colours and located at various parts of the screen (Figure 12). The screens were presented in a random order with an exposure period of two seconds. Purpose of those screens was to re-calibrate the system and participants were asked to look at these dots.

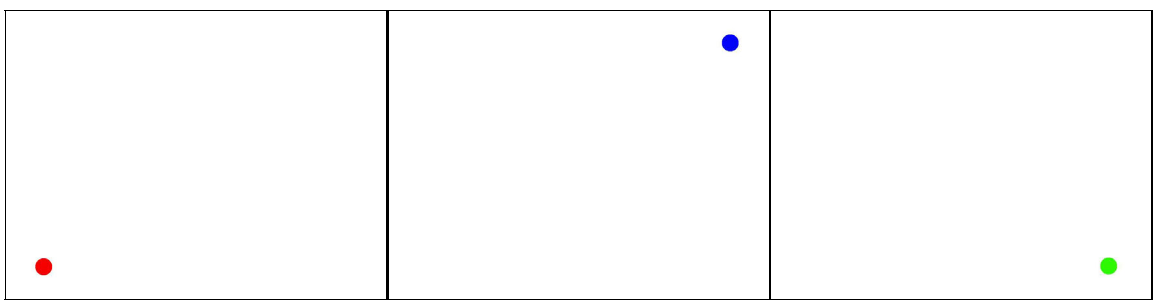

Figure 12: Screens with dots

On the average, participants spent 15 minutes for the tests. After the experiment, the post-test questionnaire was given to the participants that contained questions related to the tests. In total, the whole experimental session lasted approximately 30 minutes. Participants were asked to be relaxed during the test. They were allowed to quit the test at any time they felt frustrated.

3.5 Variables analysed

Gaze data can be analysed to obtain some useful information by using different variables relating to time, fixation, saccade, etc. The variables to be analysed must be relevant to the experimental task and corresponding cognitive activities. After reviewing 24 studies, Jacob and Karn [2003] listed six variables most commonly used for analysing gaze data. Brief descriptions of these variables are given bellow.

Number of fixations, overall: the number of fixations overall is thought to be negatively correlated with the efficiency of given tasks in usability research [Goldberg and Kotval, 1998; Kotval and Goldberg, 1998].

Gaze percentage (proportion of time) on each area of interest: gaze percentage or the proportion of time looking at a particular area of an object on a display screen could reflect the importance of that part of the object.

Fixation duration mean, overall: longer duration of fixations generally indicate difficulty to extract information from the displayed object [Goldberg and Kotval, 1998; Fitts *et al.*, 1950].

Number of fixations on each area of interest: similar to gaze percentage, the number of fixations on a particular area of an object could reflect the importance of the area. According to Fitts *et al.*, [1950] more important display elements will be fixated more.

Gaze duration mean, on each area of interest: longer gaze duration on a specific area of an object on the display could indicate difficulty to extract or interpret information from that area [Fitts *et al.*, 1950].

Fixation rate overall (fixations / Sec): fixation rate overall is approximately the inverse of fixation duration.

There are also other variables used in usability studies.

The dependent variables used in this study for analysing gaze data are: fixation count and fixation duration.

The independent variables in this study were related to the background of participants and included: profession, hobby, gender, previous experience with eye trackers, and familiarity with the products. Moreover, profession, gender, previous experience with eye trackers, and familiarity with the products were treated as nominal variables. On the other hand, hobby was treated as ordinal variable determined by the number of hobbies listed in the questionnaire (see subsection 3.2).

Statistical software package SPSS and Microsoft Excel were used for processing and analysis of the data. Results are presented in the following section.

4. Results and Discussion

For the analysis, the five parts of the tests were considered as different tasks named 1st Impression, Memory, Aesthetics, Usability, and Durability. Out of 81 screens of the test, 25 were chosen for the statistical analysis. These 25 screens consisted of five screens from each part and included only the pictures of the products. The screens with the questions and other text were omitted to concentrate on the task-relevant situations. iComponent software was used for analyzing gaze paths.

Data from 20 participants was used for the analysis; one participant's data was omitted. Figure 13 presents the frequency distribution of fixation durations for all participants in the five tasks. In the figure, fixations lasting more than 1000 milliseconds (ms) were discarded. As seen in Figure 13, fixation durations from approximately 120 to 330 ms were the most frequent.

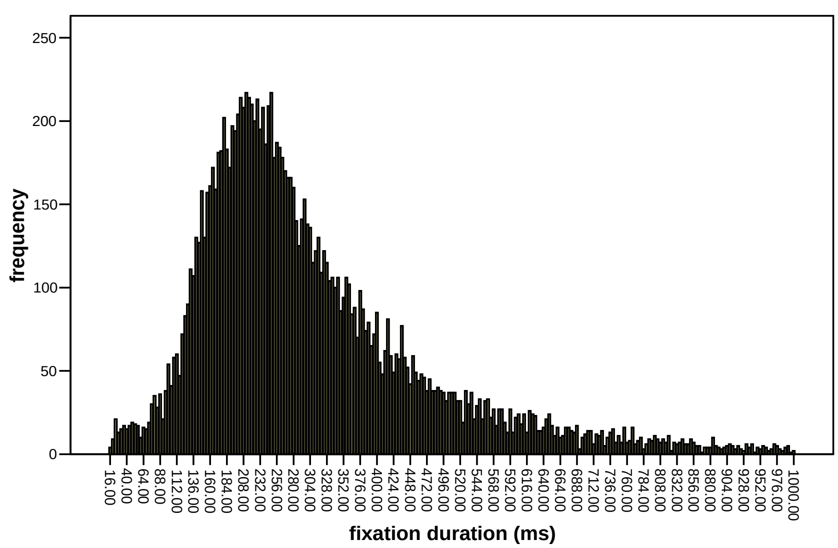

Figure 13: Distribution of fixation durations. Average of all participants

The data was analysed statistically using the following tests: paired-samples t-test, independent-samples t-test, analysis of variance (ANOVA), and multiple linear regression.

4.1 Between-task Differences

Different tasks were chosen for the test to give different motivations to the participants while perceiving the product pictures. The idea behind it was to compare different tasks and find out if there were any differences in the viewing strategies of participants given the different motivations. Hence, the approach was similar to that used in the original study by Yarbus [1967].

In parts 1 and 2, fixation count was on average 27.7 ($N = 20$) for 1st Impression and Memory tasks. For the remaining three tasks (Aesthetics, Usability, and Durability), the average fixation counts were 28.7, 28.1, and 27.3, respectively.

In the Memory and Durability tasks, the average fixation duration was on average 342 ms; for the 1st impression, Aesthetics, and Usability tasks the average fixation duration was 344, 332, and 333 ms, respectively. Although the average fixation counts are not much different for the five tasks, the differences between the average fixation durations are slightly higher (Figure 14).

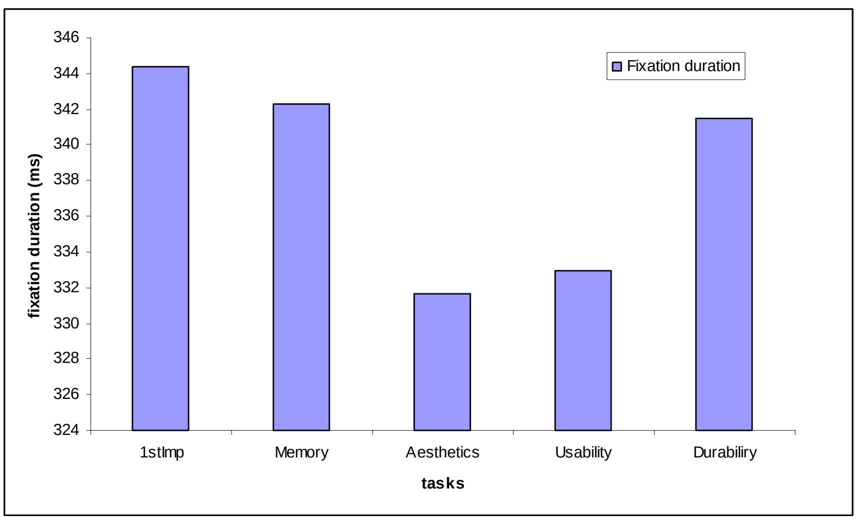

Figure 14: Fixation duration for different tasks

For individual products, paired-samples t-test revealed that fixation duration differs significantly between the tasks (Table 1). While perceiving the product mobile phone in the

1st Impression task, participants tended to have significantly shorter fixations than during the Durability task.

For the product hedge clippers, fixations were shorter in the Memory task than in the 1st Impression and Aesthetics tasks, and they were longer in the Aesthetics task than in the Usability task. Similarly, the headphones had longer fixation duration during the Memory task than for the 1st Impression, Aesthetics, and Usability tasks. The product cup had longer fixation duration during the 1st Impression task than for the Aesthetics and Memory tasks. While viewing the camera, fixation duration in the Memory task also differed significantly from the Aesthetics task.

Apart from the above, there were no other statistical differences in fixation durations between the tasks for any of the products. As an example, Figure 15 shows the average fixation duration (N = 20) for the different tasks (with standard deviation error bars) while viewing the product hedge clippers.

Table 1: Comparing different tasks for different products

Product	**Pairs of tasks**	**t**	**df**	**Sig. (2-tailed)**
Mobile phone	1st Impression – Durability	-2.195	19	0.041
Hedge clippers	1st Impression - Memory	2.315	19	0.032
	Memory - Aesthetics	-2.219	19	0.039
	Aesthetics - Usability	2.091	19	0.050
Headphones	1st Impression - Memory	-2.122	19	0.047
	Memory - Aesthetics	3.224	19	0.004
	Memory - Usability	2.394	19	0.027
Cup	1st Impression - Memory	2.388	19	0.027
	1st Impression - Aesthetics	2.607	19	0.017
Camera	Memory - Aesthetics	2.695	19	0.014

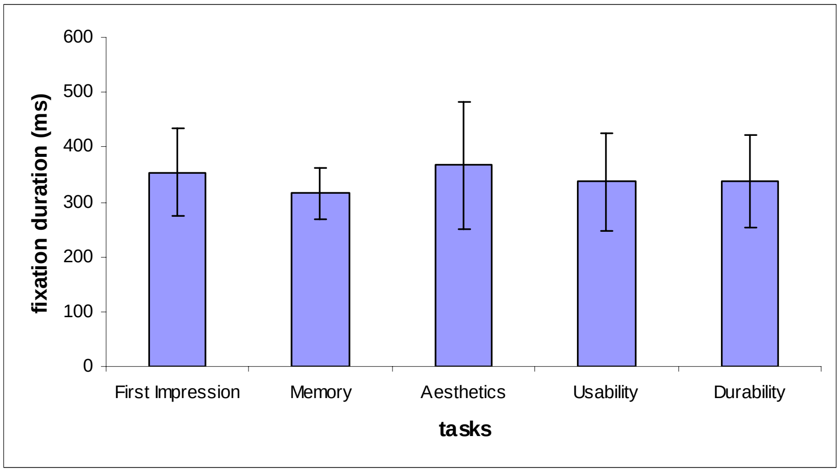

Figure 15: Comparison of different tasks for clippers

The analysis of fixation durations indicates that people look at the same product differently depending on their motivation. The task affects their gaze path as well. These findings are consistent with the pioneering study by Yarbus [1967].

Another finding is that the Memory and 1st Impression tasks differ more noticeably from the other task. As shown by the significant differences in fixation duration, people tend to evaluate the products more carefully during the Memory task than during the other tasks. On the other hand, during the task 1st Impression people may look more generally than the task Aesthetics or Usability and thus the duration of fixation also differ.

4.2 Product Comparison

Average fixation count for the five products in the different tasks is presented in Figure 16. The products are ordered on the horizental axis from simple to relatively complex. As can be seen from Figure 16, the cup received fewer fixations than the other products. According to paired-sample t-test, fixation count for the product cup differs significantly ($p < 0.01$) from all the other products (Table 2). Meanwhile, fixation count for the hedge clippers is significantly smaller than that for the camera. Fixation count for the other combinations of products did not produce any significant difference.

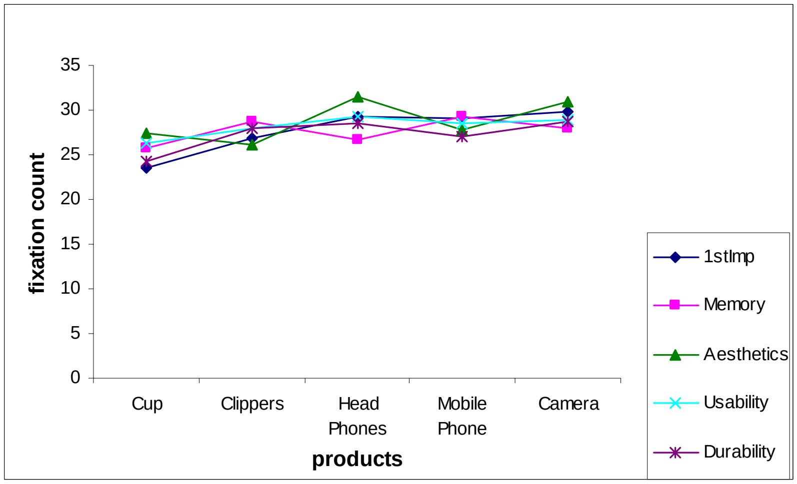

Figure 16: Average fixation count for different products in different tasks by all

Table 2: Comparing fixation count of different products with paired-samples t-test

Pairs of products	**T**	**df**	**Sig.(2-tailed)**
Cup – Mobile phone	4.211	19	0.000
Cup – Hedge clippers	2.904	19	0.009
Cup – Headphones	5.239	19	0.000
Cup – Camera	-4.881	19	0.000
Hedge clippers – Camera	-2.561	19	0.019

Thus a conclusion can be made that a simple product gets fewer fixations (with higher duration) than a complex one. A complex product contains more small details than a simple product (for example, cup), and thus the number of fixations increases. This can also shows that people's fixations land on meaningful and informative parts of a product picture, instead of looking around at random.

4.3 Comparison between designers and non-designers

Out of the 20 participants, half were designers and half non-designers. Figure 17 compares average fixation durations recorded for each participant during observation of the selected 25 pictures. The dotted line diagrams with participant number d1, d2, ……, d10 are for designers and participant numbers n1, n2, ……, n10 are for non-designers. The grand mean of fixation duration for designers is 333 ms, and 345 ms for non-designers. The difference is not statistically significant. As seen from Figure 17, participant d5 had noticeably smaller fixation duration. The extreme value of participant d9, however, might have affected the general result for the designer group.

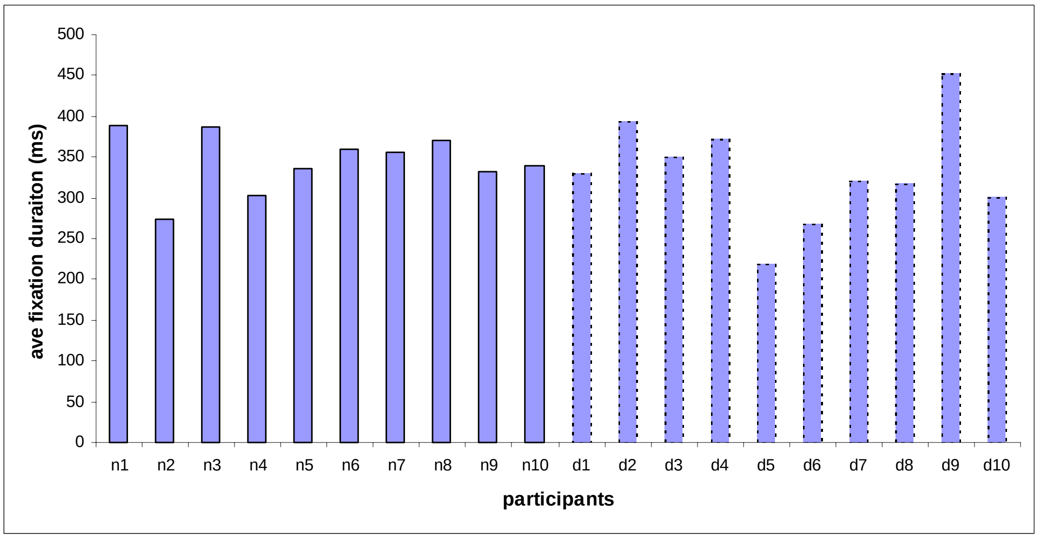

Figure 17: Average fixation duration by participants

More specifically, average fixation duration (ms) and average fixation count were calculated for designers and non-designers for all the products. Figure 18 compares fixation durations for the five products. Other than the hedge clippers, non-designer participants got longer fixation durations than designer participants for all the products. According to independent-samples t-test, the difference is statistically significant for the product headphones with probability less than 0.05, t = 2.354, df = 18. The difference is also significant for fixation count as well with the same probability level and degrees of freedom, t = -2.164.

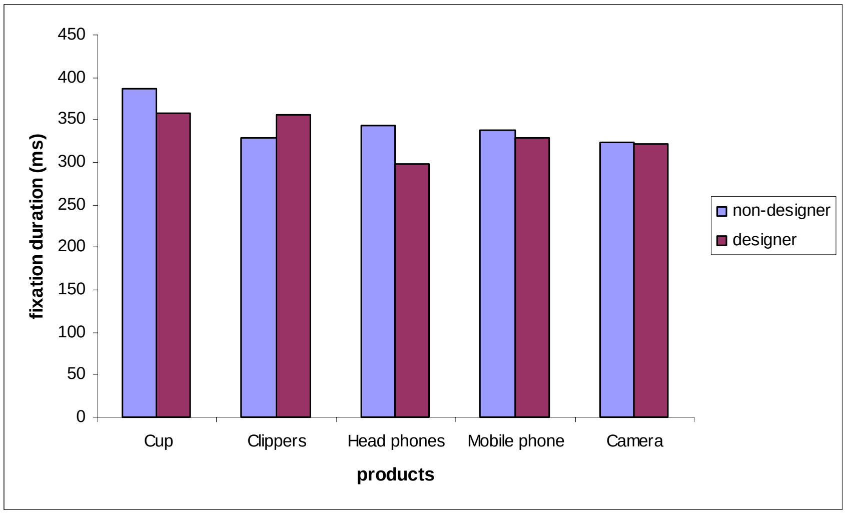

Figure 18: Fixation duration for designers and non-designers for different products

Fixation count and fixation duration (ms) for all the products during each task were also calculated (Table 3). Figure 19 presents the fixation count for different tasks for all the participants grouped as designers and non-designers. Designer participants got more fixation count than non-designers in all the tasks but Aesthetics.

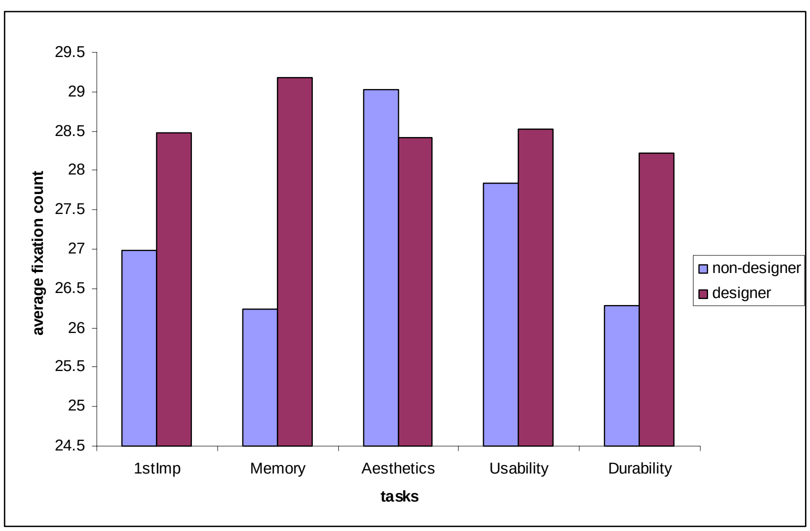

Figure 19: Fixation count for designers and non-designers for different tasks

Independent-samples t-test shows that fixation count differs significantly for these two groups during the Memory task, $t = -2.141$, $df = 18$, and $p < 0.05$. The difference is not significant for the other tasks and for fixation duration.

Table 3: Average fixation duration and fixation count for different tasks

p. #	Average fixation duration (ms)					Average fixation count				
	1stImp	Memory	Aesthetics	Usability	Durability	1stImp	Memory	Aesthetics	Usability	Durability
n1	409.37	380.82	366.76	378.39	406.69	24.4	24.6	25.4	24.8	23.2
n2	297.40	314.76	233.40	250.02	273.15	30.6	29.2	36.2	34	33
n3	396.38	387.73	359.65	378.72	413.18	24.2	24	25.2	24.8	22.4
n4	285.28	316.80	298.53	305.07	309.04	33.4	29.2	31.6	30	30.2
n5	325.36	363.02	359.12	308.14	324.31	29	25.8	25.8	28.8	27.4
n6	396.41	357.04	331.60	334.63	376.85	24	25.8	26.8	27.8	24.4
n7	409.60	342.81	363.73	324.58	342.11	23.2	27	26.6	28.2	26.8
n8	392.14	412.20	347.87	337.31	362.65	24.8	24	26.2	26.2	24.6
n9	341.71	383.67	241.15	340.16	355.73	28.2	25.2	35.8	27.6	25.6
n10	329.05	337.84	292.10	362.62	372.08	28	27.6	30.6	26.2	25.2
d1	316.95	362.21	317.01	336.54	314.29	28.6	25.4	28.2	26.8	27.8
d2	371.05	375.37	473.65	364.84	388.04	25.2	25	21.6	26.6	25.4
d3	333.67	292.22	379.34	404.22	345.72	27.6	31	25.6	23.4	26.2
d4	339.51	348.60	377.63	392.66	405.24	27.6	26.8	24.2	22.6	22.8
d5	250.55	238.76	215.48	185.58	208.22	33.6	35.6	37.2	40.6	37.4
d6	296.17	299.32	240.67	255.13	246.05	31.2	31.2	36.6	34.6	35.2
d7	272.67	295.38	322.19	342.68	369.54	32.8	31.8	28.4	27.6	26
d8	384.65	313.99	271.47	287.71	327.61	25	30.2	32.8	31.6	29.2
d9	421.68	429.84	532.50	489.69	386.88	23.8	23.2	20	19.6	21.8
d10	317.50	294.08	309.58	279.53	301.82	29.4	31.6	29.6	31.8	30.4

Fixation duration and fixation count has also been analysed individually for each product and task combination to compare differences between designers and non-designers. In the Memory task, fixation counts differ significantly between designers and non-designers for the headphones, $t = -4.133$, $df = 18$, and $p < 0.01$. The same applies to fixation durations, $t = -3.683$, $df = 18$, and $p < 0.01$. Designers were found to have significantly different fixation duration than non-designers during the 1^{st} Impression task for the product cup with probability level less than 0.05, $t = -2.476$, $df = 18$. Otherwise, there are no significant differences for the other task and product combinations.

In summary, the analysis shows that there are only slight differences between designers and non-designers. Among all the tasks, only the memory task reveals significant difference between designers and non-designers. It might be that the way of memorizing differs between these two categories of participants. The 1st Impression task also indicates significant difference between designers and non-designers, but only for the product cup.

4.4 Association with participants' background information and perception

In this subsection, statistical analysis is carried out to find out whether the average fixation counts and durations of the participants differ depending on their background (for example, profession, hobby, experience with eye tracker, gender, and familiarity with the five products). Either independent-samples t-test or analysis of variance (ANOVA) was used depending on the applicability of the test. For further exploring the results, multiple linear regression analysis was conducted with different specific background information, which produced significant values less than 0.25 in the analysis of ANOVA or t-test. The way of collecting the background information from the participants is discussed in subsection 3.2. Different tasks of the test along with the different background information are analyzed gradually from the general level (for example, considering all the tasks together) to the specific level (for example, considering each product for the different tasks), as described below.

On the general level, neither fixation count nor fixation duration were significantly affected by participants' profession, experience with eye tracker, gender, hobby, or familiarity with the products.

Fixation count for all the products during the five tasks (1st Impression, Memory, Aesthetics, Usability, and Durability) was analysed to find the effects of the participants' background. In subsection 4.3, it was already established that designers had significantly higher fixation counts and correspondingly shorter fixation durations than non-designers while perceiving all the products during the Memory task. No significant differences were found for the other combinations of tasks and backgrounds. Nevertheless, multiple linear regression revealed that gender significantly affected fixation count for all products during the Aesthetics task (*p* < 0.05) after adjusting for hobby; although the effect of hobby is not significant after adjusting for gender.

Similarly, fixation durations for all the products during the five tasks were also analysed. Independent-samples t-test shows that during the 1st Impression task mean fixation durations differ significantly between the participants having previous experience with an eye tracker and those without experience , $t = -2.166$, $df = 18$, $p < 0.05$. Other combinations of tasks and backgrounds showed no significant effects. Multiple linear regression revealed, however, that gender had a significant effect on fixation duration for all the products during the Aesthetics task ($p < 0.05$) after adjusting for hobby and familiarity with the product camera. On the other hand, the effect of hobby after adjusting for gender and familiarity with the camera is not significant. Moreover, the effect of familiarity with the camera after adjusting for gender and hobby is not significant either.

Fixation count and fixation duration was also analysed using ANOVA and independent-samples t-test for all the products individually crossed with the different tasks and background information.

For the product cup, fixation count and fixation duration during the Aesthetics task differ significantly among the participants having different hobbies, such as arts, sculpture, handicraft, design, etc. ($F_{5,14} = 3.835$ and $F_{5,14} = 3.242$, $p < 0.05$ for fixation count and fixation duration, respectively). We already found in subsection 4.3 that during the 1st Impression task, profession had a significant effect on fixation duration while viewing the product cup. For the same product, other combinations of tasks and background information were not found to have a significant effect on either fixation count or duration. Multiple linear regression was not carried out for the cup, since the values from the previous t-test or ANOVA were larger than 0.25.

For the product mobile phone, independent-samples t-test showed that both fixation count and fixation duration during the Aesthetics task were significantly affected by gender of participants ($t = 2.371$ for fixation count, and $t = -2.507$ for fixation duration, $df = 18$, p < 0.05). Meanwhile, other combinations of the tasks and background information were not shown to affect any of the two dependent measures. As revealed by multiple linear regression, however, there was a main effect of gender on fixation count for the product mobile phone during the Aesthetics task after adjusting for hobby ($p < 0.05$). In contrast, the effect of hobby on that dependent variable was not significant after adjusting for gender.

For the product camera, independent-samples t-test showed that fixation duration during the Aesthetics task was significantly affected by gender of participants (t = 2.121, df = 18, $p < 0.05$). Meanwhile, other combinations of the tasks and background information were not shown to affect any of the two dependent measures.

Although in subsection 4.3 we found that fixation count for head phones during the Memory task differed significantly for designers and non-designers, the difference was not significant for other combinations of tasks and background. Multiple linear regression showed that the effect of participants' profession on fixation count was highly significant ($p < 0.01$) for the product headphones during the Memory task after adjusting for experience with an eye tracker. The effect of experience with an eye tracker on that dependent variable was not significant after adjusting for profession. The effect of gender on fixation count for the product headphones during the Aesthetics task was significant ($p < 0.05$) after adjusting for hobby; but the effect of hobby on that dependent variable is not significant after adjusting for gender.

Fixation duration for the product headphones during the 1st Impression task was significantly affected by participants' previous experience with an eye tracker (t = -2.596, df = 18, $p < 0.05$). During the Aesthetics task, fixation duration for the same product was also affected by hobby ($F_{5,14} = 3.984$, $p < 0.05$). Other combinations of the tasks and background information were not shown to affect any of the two dependent measures for the headphones. Multiple linear regression showed that there was a main effect of gender on fixation duration for the product headphones during the Aesthetics task after adjusting for hobby ($p < 0.05$), but the effect of hobby on that dependent variable was not significant after adjusting for gender.

ANOVA showed that hobby significantly affected both fixation count ($F_{5,14} = 3.357$, $p < 0.05$) and fixation duration ($F_{5,14} = 3.073$, $p < 0.05$) while perceiving the product hedge clippers during the Durability task. For the same task, gender also significantly affected both fixation count ($t = 2.765$, $df = 18$, $p < 0.05$) and fixation duration ($t = -2.802$, $df = 18$, $p < 0.05$). Other combinations of the tasks and background information were not shown to affect any of the two dependent measures for the hedge clippers. Multiple linear regression showed that there was an effect of gender on both fixation count and fixation duration for the product headphones during the Aesthetics task after adjusting for hobby ($p < 0.05$), but the effect of hobby on the two dependent variables was not significant after adjusting for gender.

In summary, the main findings of the above analyses are as follows. There is an effect for gender on both fixation count and fixation duration during the Aesthetics task after taking into account different hobbies of participants, such as drawing, painting, sculpture, handicraft, architecture, design, visual arts, and photography. As mentioned in the previous section, hobby is considered an ordinal variable. The order is ascending depending on the number of hobbies one have. Therefore, male and female participants have different perception of aesthetics, which is related to the different artistic hobbies above. Hobby and gender also have significant influence on fixation count and fixation duration while perceiving the product hedge clippers during the Durability task.

4.5 Area of interest studies

Eye movement recordings can be used to study the key perceptual points of an object. During the analysis, the brand name, mechanics part and handles of the hedge clippers were regarded as the areas of interest. Number of fixations or fixation count over these three selected areas of interest recorded for each participant during the 1st Impression task are presented in Figure 20. Participants with non-designer profession numbered n1, n2, ……, n10 are placed on the left of the horizontal axis, while designers numbered d1, d2, …….., d10 are placed on the right. As seen from the figure, fixation count in the areas of interest varies among participants. The brand name and mechanics parts of the hedge clippers were fixated more frequently. Fixation count on the mechanics part for participant n10 is 13, while the numbers for the brand name and the handles are 2 and 3, respectively. For participant d5, fixation count on the brand name is 16, whereas for the mechanics it is 9, and for the handles it is only 1. Participant n8 did not fixate the handles at all.

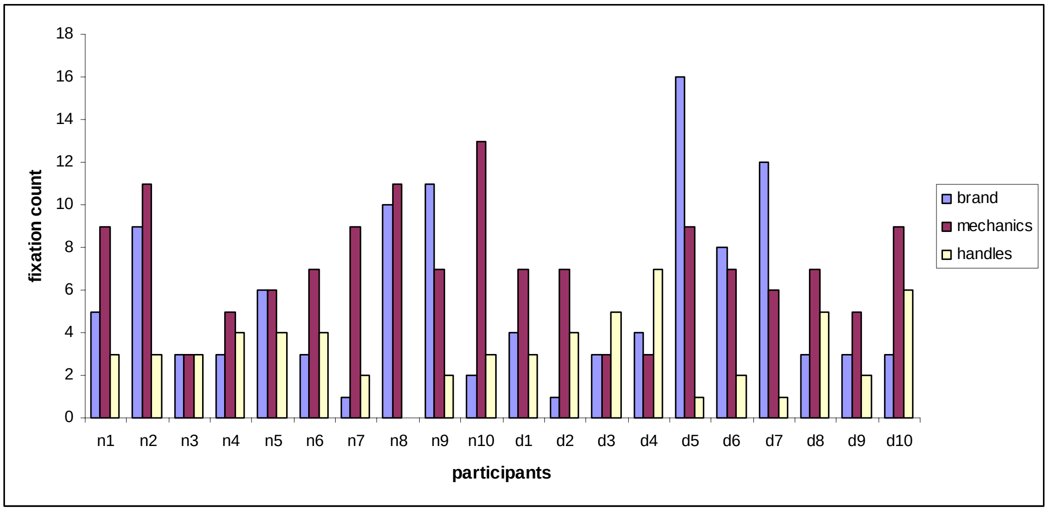

Figure 20: Fixation count for different parts of the product hedge clippers

Averaged across participants, fixation count for the mechanics part is 7.2 with standard deviation 2.73 (Figure 21). For the brand name, the average number is 5.5 with standard deviation 4.12, while for the handles the average number is 3.2 with standard deviation 1.74. Paired-samples t-test shows that there is a significant difference between the fixation counts on the mechanics and the handles (t = 4.745, df = 19, p < 0.001). No significant differences were found for other combinations of the factors.

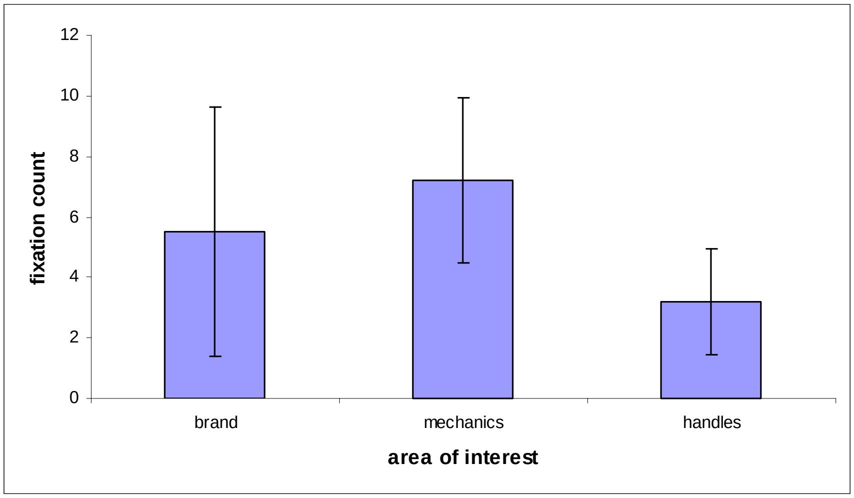

Figure 21: Average fixation count on different parts of the product hedge clippers

Average fixation durations for different parts of the product hedge clippers are shown in Figure 22 with standard deviation error bars. Even though the three error bars are different in height, paired-samples t-test does not reveal any significant difference in fixation duration for those selected areas on the clippers.

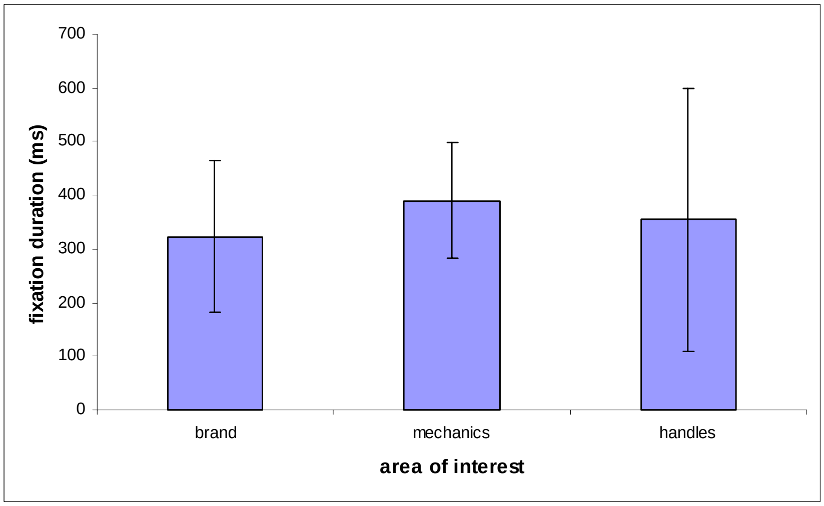

Figure 22: Average fixation duration on different parts of the product hedge clippers

Overall, the total percentage of time spent on the selected areas of interest for hedge clippers is given in Figure 23. As seen from the figure, the share for the mechanics part is larger than that for the brand name and handles. The diagram also shows the share taken by fixations on those parts of the product that were not predefined as areas of interest (for example, the blades and background on the screen), and it is legend by "other".

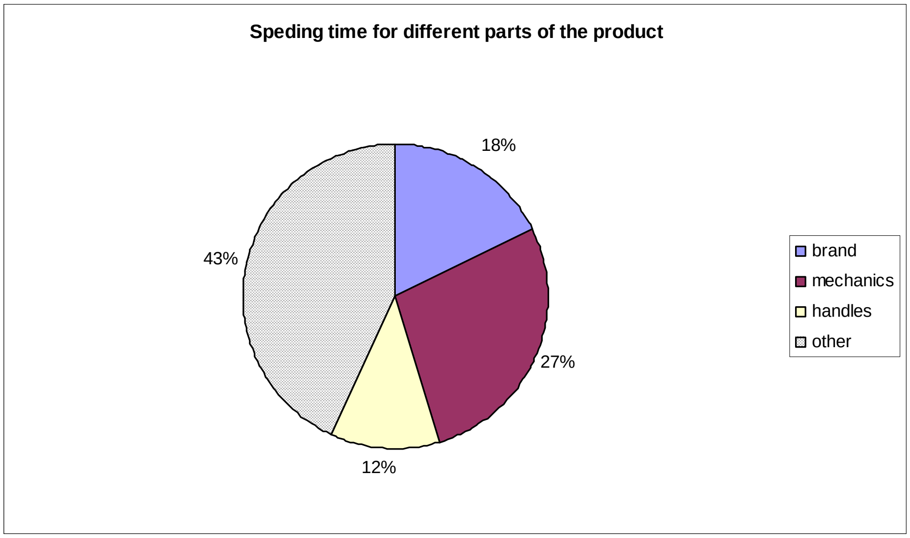

Figure 23: Time spent on different parts of the product hedge clippers

The mechanics part attracts people's attention trying to understand how the object works. Design of the mechanism is important for efficient use of the product. The text of the brand name also attracts attention a lot. Those who are less familiar with the brand name might want to read it, as opposed to those that are already familiar with it. On the other hand, the handles of the hedge clippers are very simple in design. They have only two colours. Moreover, the handles are big enough to be perceived by peripheral vision. This could explain the relatively low number of fixations directed at the handles.

5. Conclusions

Eyes are considered the windows to human mind. Along with gestures and speech, eye movements are an informative indicator of human behaviour. It is possible to gain insight about the ways humans perceive product designs by observing eye movements, as there is a close connection between vision and cognition. People examine the surroundings making a series of fixations and saccades. In this process, only the meaningful and informative parts of the images are observed, instead of looking around at random. The fact that viewing was highly influenced by the task (motivation) was already discovered in the early work by Yarbus [1967]. Fixation duration and fixation count can be used as indirect measures of perception.

The objective of this study was to analyse perception of design by gaze-path analysis for a few products presented to observers as pictures using eye tracker. A test with five different tasks (1st Impression, Memory, Aesthetics, Usability, and Durability) was carried out to analyse perception of five different products (cup, hedge clippers, headphones, mobile phone, and camera). 20 participants took part in the study. Details of participants' background (profession, gender, hobby, experience with an eye tracker, and familiarity with the products) were treated as experimental factors. The test is described in detail in Section 3.

Statistical analysis was carried out using paired-samples and independent-samples t-test, ANOVA, and multiple linear regression. The latter was performed to find the effects of multiple factors on the dependent variables. In some cases, a factor may not have a significant effect on the dependent variable, but it might have a significant effect when combined with the other factors. The most important findings of the analysis are presented below.

Upon analysis of the data from all the participants, it was found that frequency of fixations lasting from 120 ms to 330 ms is very high. As described in subsection 4.1, people look at the same product differently depending on their motivation. This finding is consistent with the original observation by Yarbus [1967].

Comparison of the data recorded for the five products reveals that the number of fixations is related to the product's complexity: the simpler the product, the lower fixation count. Thus, perception varies by product complexity. This can also imply that people's fixations land on meaningful and informative parts of the product pictures, instead of looking around arbitrarily to blank areas of the screen.

Fixation durations and fixation counts recorded for all participants while observing each product in the five tasks were analysed for the second objective of the study (to find out difference between designers and non-designers while viewing product pictures). The analysis is described in subsection 4.3. The results obtained using ANOVA do not show any clear difference between designers and non-designers. However, based on fixation counts, perception of designer participants in the memory task was found to be significantly different from that of non-designer participants. Meanwhile, perception of the two participant groups in the other motivation tasks was not found to be significantly different. The only exception here was the product cup during the 1st impression task. Therefore, based on these findings, one cannot conclude about existence of any differences between designers and non-designers in their perception of the products. To do this, further tests are needed that will have more participants and motivation tasks.

The third objective was to analyse the effects of participants' background on their viewing strategies. Independent-samples t-test and ANOVA were performed to find the effects of each factor on the two depended measures: fixation count and fixation duration. When considering all the tasks on the general level, background was not found to significantly affect either fixation count or fixation duration.

Significant differences were found, however, when performing more specific analyses on individual tasks and products. For example, gender was found to significantly affect fixation count during observation of all the products in the Memory task. Meanwhile, experience with an eye tracker has a significant effect on fixation duration for all the products in the 1st impression task.

Although in the Aesthetics task hobby and gender were not found to have any significant effect on fixation count individually, multiple linear regression revealed a significant effect of gender on fixation count after adjusting for hobby. On the contrary, for the product hedge clippers in the durability task, hobby and gender had a significant effect on fixation count individually; but hobby did not have a significant effect on fixation count after adjusting for gender. More detailed results of the analyses are presented in subsection 4.4.

As revealed by the statistical analysis above, hobby and gender affect perception to a greater extent than the other background factors including familiarity with the products and experience with an eye tracker. Familiarity with the products has no direct impact on perception. For most of the products, background was found to affect fixation count and/or duration almost exclusively during the Aesthetics task. A significant effect was also found in the 1st Impression, Memory, and Durability tasks, but just for some of the products. No background factor was found to be significant for any product in the Usability task.

The product hedge clippers were used for analysis of the areas of interest. The brand name, mechanics part, and handles of the product were defined as the areas of interest. As described in subsection 4.5, number of fixations in those areas varied considerably among the participants. This indicates that areas of interest are quite individual. The brand name and mechanics parts of the hedge clippers have larger fixation counts than that of the handles. Due to some limitations, the study could not analyze the areas of interest for other products. This will be an objective for future work.

As already mentioned in Section 1, this work is part of a project about perception of design. The thesis presents results of statistical analyses carried out to meet specific objectives, which also answers to a few key questions related to the project. The methods and results of the analyses presented here are important for the follow-up studies on perception of product designs.

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