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A COMPARISON OF PRODUCT PREFERENCE AND VISUAL BEHAVIOUR FOR PRODUCT REPRESENTATIONS

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ABSTRACT
It is critical to understand how the means of representing a product can affect an individual's preference for it. This paper investigates the effect of varying a product's representation on an individual's preference for it.
Five buildings, cars and electrical appliances were shown to 20 individuals as sketches, renders and photos. Individuals rated their preference for the product/artefact in the representation after a fixed viewing time. To provide additional context to the participant's preference, and to investigate if they perceived them differently, eye tracking was used to record their gaze as they inspected the representations.
One of the 15 groups of representations showed a significant change in preference by the participants across the representations. Ten of the 15 groups of representations showed significant difference in engagement for a limited proportion of the regions in the stimuli images.
This suggests that the process of viewing a product is independent of the means of representation and that a sketch is sufficient for an individual to form a consistent opinion of a product.

Keywords: product preference, representations, eye tracking

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1 INTRODUCTION

The way that information is represented can have an effect on a number of things such as the degree of comprehension obtained from a source to the preference for what is being described. This phenomenon is easily demonstrated by considering how typeface can construe additional meaning beyond the word's written in a document, such as brand perception or tone (Childers & Jass, 2002). Vision typically accounts for around 80% of the information that the brain receives from the senses (Nørretranders, 1991). This key pathway is a vital mechanism for designers in several tasks such as reading reports, judging aesthetics and inspecting drawings. Does the representation change the way the individual views a piece of information? And if so what implication does this have for the design and selection of how to represent said information for a given activity or desired outcome?

In order to provide some insight into this phenomenon this paper describes an exploratory study that investigates the relationship between preference of different product/artefact representations and visual behaviour. A study with 20 volunteers comprised of academic staff and students from the Department of Mechanical Engineering, University of Bath, was conducted using a Tobii X120 Eye Tracker to record the participant's gaze (Tobii Technology AB, 2013). A series of 15 products/artefacts were shown to the participants: five cars, five buildings and five electronic appliances. The products/artefacts were selected with the intention of participants possessing varying levels of familiarity with them. Each product was represented in three forms, as a sketch, a rendered image, and a photograph. Composition, scale and perspective were maintained across the different representations. After viewing each representation for five seconds the participants were asked to rate their degree of preference for the product.

The paper begins with a discussion of visual perception and interaction with design objects, and develops the motivation for using eye tracking. The experimental procedure is then described and the results presented. Implications for design representation and the development of a methodology for investigating visual perception are discussed.

2 BACKGROUND, AIMS AND OBJECTIVES

This section provides an overview of how information is represented in the design process, and how eye tracking can be used to monitor visual perception and provide additional context to individual's making judgments of a product/artefact.

2.1 Visual perception

Visual perception is how an individual interprets and understands the world through their sight (Gibson, 1950). Out of the five human senses three are regularly used in the design process, vision, hearing and touch. An analogy can be drawn between information bandwidth and the human senses, in which vision typically accounts for around 80% of the information the brain receives (Nørretranders, 1991).

Underlying the majority of activities in the design process is the need for a designer to visually perceive a design object e.g. reading a document or inspecting a drawing. The branch of cognitive psychology known as visual psychophysics describes the link between ocular motor movements and cognitive processes (Gescheider, 1997). In effect, it provides a theory and understanding of how eye movements can be used to describe and measure internal thought processes of an individual. Traditionally, internal thought processes have been investigated using Think-Aloud. A non-invasive means of monitoring cognitive behaviour removes many of the issues typically associated with protocol-analysis, such as mental over-work and non-reporting of unconscious actions. As the visual sense is predominantly involuntary, investigating eye movements can give pointers into how people undertake tasks using implicit knowledge.

2.2 Design representations and their effect on purpose

Hubka (Hubka & Eder, 1982) states that engineers need to represent the final product during the design process and do so by creating various physical, conceptual or mathematical relations. Hubka's representations are abstractions of the final product and he defines three types:

1. Iconic representations – a visual record of the original form of the finished product e.g. sketches, drawings, photographs, physicals models.

2. Symbolic representations – a representation using assumed or conventional symbols e.g. language, mathematics.
3. Diagrammatic representations – a simplified representation of the finished product e.g. graphs, schematics, relationship diagrams.

The information in a type of representation is consistent across that type even though the artefact it is presented in may change. For example, a sketch and photo are distinct artefacts but both communicate geometric relationships, though in varying detail and fidelity. It is self-evident that the efficacy of information is dependent on the means of representing it for the intended recipient. For example, a written description of how a product feels is no substitute for a prototype of the product that incorporates sample textures. Thus, the choice of how to represent information is dependent on the intended purpose and must be balanced with the available resources such as skill and time.

Achieving the balance between the effectiveness of the representation and available resources requires a deeper understanding of what purposes a representation may fulfill. The issue is more complex than maximising detail and fidelity given available resources. Some activities may benefit from low representation detail, such as form ambiguity in sketching where constraining geometric relationships through accuracy may limit creativity and reimagining of concepts.

Rudd (Rudd, Stern, & Isensee, 1996) shows that in varying prototype fidelity for communicating potential interface layouts to users there are benefits and disadvantages to using both low-fidelity and high-fidelity prototypes beyond cost savings. One such example is customer's developing unrealistic expectations of a proposed product from interacting with the high-fidelity representation e.g. accepting a rendered computer model as the final iteration.

Of interest to the experiment described subsequently in this paper is the effect on product preference depending on the detail of the representation. The implication of any detected change in preference between representations of the same product would be beneficial in supporting the appropriate choice of representation when selecting product concepts for further development.

2.3 Adding context to preference

When investigating an individual's perception of a product a quantitative non-invasive means of adding context to their preference is highly beneficial for understanding what features they find engaging, and which they do not. Existing research into product perception that attempts to identify product attributes (e.g. durability, desirability etc.) generally relies on self-reporting of the individual, or observer deduction to determine product features that relay these attributes (Blijlevens, Creusen, & Schoormans, 2009; Park & Kim, 2003; Yamamoto, 1994).

One means of generating additional context to the individual's degree of preference is to record their gaze. Recording an individual's gaze alongside their preference of a product representation would be beneficial for identifying prominent features in each representation i.e. do the same things stand out to the individual regardless of the type of representation? Does a change in engagement distribution correlate with a change in their preference for a product representation? The additional context to product preference provided by recording gaze can potentially be used to highlight positive and negative features of the product representations.

When viewing an image an individual's gaze will tend to move around taking in the various features. The process that drives this is predominantly involuntary and is driven by pre-attentive mechanisms (Duchowski, 2007). Certain features of the image will be 'eye-catching' leading the individual to inspect them in higher detail and potentially for longer durations.

Eye trackers are capable of recording an individual's gaze relative to a plane of reference, such as a computer screen. The technology provides a non-invasive means of recording an individual's perception without having to rely on their own ability to articulate their visual process. Within the stimuli image shown to an individual, Areas Of Interest (AOIs) are created that bound features of the image that are of interest to the investigator. The eye tracking system records the central, 'high-definition' portion of an individual's gaze (their foveal vision) and generates a series of time-stamped coordinates.

For an individual to be conscious of what they are observing it is generally accepted that they must dwell on a region for around 200 ms (there is some natural variation between individuals) (Duchowski, 2007). Measuring the duration and the number of times that an individual fixates within a given AOI provides an indication as to the level of engagement of the viewer on that region. However, whilst an eye tracker can tell you where an individual is looking it does not tell you what their motivations are for looking there. One means of capturing engagement motivation is to conduct Retrospective Think Aloud (RTA), in which the participant's gaze is played back to them at a reduced speed and they are asked to talk about what they were looking at e.g. I like this, I don't like this.

3 AN EXPLORATORY STUDY

In this section the experimental set up is described as well as background of the participants that took part in the study.

3.1 Aims and objectives

How engineering designers perceive information is important to understand when considering the application and selection of how to represent information. The aim of the short exploratory study described in this paper is to feed into this understanding of how the means of representation affect perception and judgment. Two objectives for the study specific to Iconic Representations are:

- Determine whether engagement across representations corresponds with a change in preference
- Determine whether familiarity with a product/artefact increases consistency of preference judgement across representations

3.2 Population and set up

20 volunteers from the Department of Mechanical Engineering, University of Bath, participated in the experiment. The volunteers were a combination of academic staff and postgraduate students, all with at least a Bachelor degree in an engineering subject. 15 males and 5 females had an average age of 34.1 years (standard deviation 10.7) and an average duration of industrial experience of 7.3 years (standard deviation 5.7) for 19 of the participants, with one outlier participant having 45 years of experience.
A Tobii X120 Eye Tracker with Tobii Studio and a 20" computer monitor were used to display the stimuli images and record the participant's gaze. The participants were situated approximately 70 cm from the screen. The same test room was used for all participants and the instructor was present throughout all tests.

3.3 Construction of representations

Each product representation was generated from a common, original photograph so as to maintain perspective. The same individual generated the sketch product representations by tracing the original photographs in pencil. Applying an identical software filter to the original product photos generated the render representations.
The five buildings were from an Architecture prize shortlist and were chosen for variety in function (library, government building, dwelling etc.). The saloon cars selected were non-luxury, identical in colour, and available for comparable prices. Identifying logos were removed from the photos with image editing software prior to tracing and filtering. The Dyson electrical appliances had identifying logos removed in a similar manner but were selected for their strong brand identity.

		
Building Sketch	Building Render	Building Photo

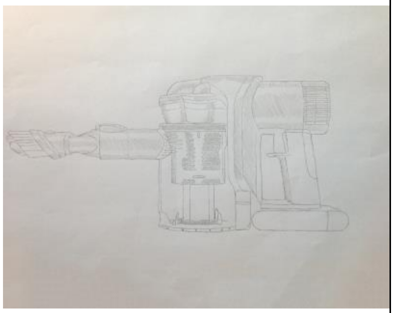
		
Car Sketch	Car Render	Car Photo
		
Electrical Appliance Sketch	Electrical Appliance Render	Electrical Appliance Photo

Figure 1. Examples of sketch and render representations. Permission to reproduce photo representations was not sought.

3.4 Procedure

Prior to the experiment participants were given a series of training tasks to settle and familiarise themselves with the eye tracking software and equipment. The sketch representations of the 15 product/artefacts were shown first to the participants in a random order. After viewing each sketch automatically for five seconds the participants were asked to rate their degree of preference for the representation by answering the following questions:

"To what extent do you agree with the following statement: I like the product depicted on the previous page"

To which the available answers were:

- Agree strongly (+2)
- Agree (+1)
- Disagree (-1)
- Disagree Strongly (-2)
- No preference (0)

Each answer was given a corresponding numeric value (+2, +1, -1, -2, 0) for the purposes of analysis, which the participant's were not made aware of.

This process was repeated for both the render and photo representations, with intervening distracter tasks to minimise fatigue and any learning bias. Each participant was shown the series of sketch representations first, then the render representations and finally the photo representations of each product. The render and photo representations were again shown in a random order. Participants volunteered for the experiment and were told in advance that it involved the use of eye tracking. Due to this there may have been some self-selection in the group based on interest in participating.

4 ANALYSIS

Analysis of variance (ANOVA) tests were performed on the participant's degree of preference scores as well as levels of engagements between representations to determine change in behaviour between the sketches, renders and photos. The results of this analysis are presented in this section.

4.1 Preference

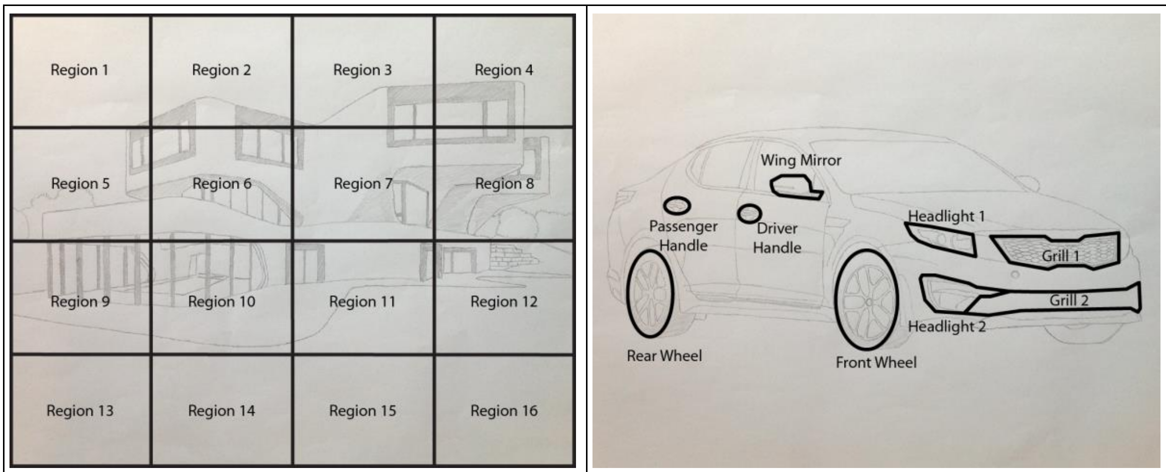
For each product the participant's degree of preference score was analysed for a significant change between each representation using single factor ANOVA (α = 0.05). There was no observed significant change in the participant's preference for 14 of the 15 products. Building 03 showed a significant difference (P-Value < 0.05) in the degree of preference indicated by the participants between representations.

Table 1. ANOVA results for change in degree of preference between sketches, renders and photo representations

	P-Value		P-Value		P-Value
Building 01	0.895	Car 01	0.608	Dyson 01	0.730
Building 02	0.755	Car 02	0.589	Dyson 02	0.830
Building 03	0.024	Car 03	0.143	Dyson 03	0.680
Building 04	0.107	Car 04	0.299	Dyson 04	0.926
Building 05	0.222	Car 05	0.113	Dyson 05	0.964

4.2 Visual behaviour

16 identical sized areas of interest were created in the sketch, render and photo representation of each electrical appliance and building. For each of the cars, areas of interest were created around discernable features within the product image, such as the front grill, wheels, door handles, headlights etc.



Building AOI grid | Car AOIs

Figure 2. Example of how Areas Of Interest (AOI) were generated for the Buildings and Cars.

Total Fixation Duration was taken to be a measure of the participant's engagement i.e. the longer the duration spent fixating on a region, the greater the level of the participant's engagement. A Fixation Filter of 150 ms was selected, meaning that fixations below 150 ms were not considered as sufficiently long enough for the user to be aware of what they were observing (Duchowski, 2007).

The Total Fixation Duration for every AOI was normalised for each participant. This provided a proportionate distribution of each participant's engagement across each representation. The eye tracking data from three participants was discounted as improper seating positions, excess head movement and varifocal glasses significantly interfered with the recording abilities of the eye tracking hardware.

ANOVA (α = 0.05) was performed on the normalised Total Fixation Durations of each participant across the product/artefact representations. The results are shown in Table 2.

Table 2. Number of AOIs with significant difference in visual behaviour following ANOVA for Total Fixation Duration,

	AOIs with significant difference in Total Fixation Duration between representations		AOIs with significant difference in Total Fixation Duration between representations		AOIs with significant difference in Total Fixation Duration between representations
Building 01	1/16	Car 01	0/10	Dyson 01	0/16
Building 02	1/16	Car 02	0/10	Dyson 02	1/16
Building 03	1/16	Car 03	1/10	Dyson 03	5/16
Building 04	2/16	Car 04*	0/11	Dyson 04	2/16
Building 05	0/16	Car 05*	1/11	Dyson 05	2/16

Four out of five buildings showed limited localised significant difference in the visual behaviour of the individuals. Building 03, the only product to show a significant difference in the participant's degree of preference, showed limited observed significant difference in the participant's visual behaviour.
Two of the five cars showed limited localised significant difference in the visual behaviour of the individuals. Car 04 and Car 05 had one additional AOI each as the vehicles had additional features, an extra set of headlights in Car 04 and an additional Grill plate in Car 05.
Four Dyson electrical appliances demonstrated a significant difference in the visual behaviour of the individuals. Dyson 03, showed substantial variation in the visual behaviour of the participants.

5 DISCUSSION

Implications for design representation choice are presented in this section as well as a discussion as to the possible causes for the limited difference in visual behaviour and preference between representations.

5.1 Preference

For all but one set of representations no significant difference was observed in the change of degree of preference. From some of the comments made by participants during the experiment it is strongly suspected that a portion of the individuals rated their degree of preference for each product representation on pre-existing knowledge of the product, not the sketch, render or photo of the product. Statements such as "I don't like Dysons" were not uncommon and suggest this behaviour.
A possible explanation for the observed difference in degree of preference for Building 03 is substantial compositional difference between the sketch, render and photo. As the sketch and render are abstractions of the photo, the texture, lighting, background etc. within the sketch and render will vary to that of the photo. Most participants indicated no preference for the building in the sketch form, but progressively disliked the building as the fidelity of the representation increased. It is therefore, probable that in the case of Building 03 the increase in fidelity from the sketch to the photo added detail that substantially changed the participant's degree of preference for the building.
Edge density is a compositional element of the representations that can be calculated via software and used as measure of fidelity. To determine if edge density could explain this change in degree of preference for the buildings additional compositional analysis was performed on the Building representations within Matlab.
Edge density analysis of the image content for the Building set of representations showed no observable distinction for Building 03. The change in degree of preference for Building 03 is likely due to a different compositional element, such as colour. Additional understanding for which image compositional elements such as edge density, contrast and colour, have the most effect on changing preference is a proposed area of future research.

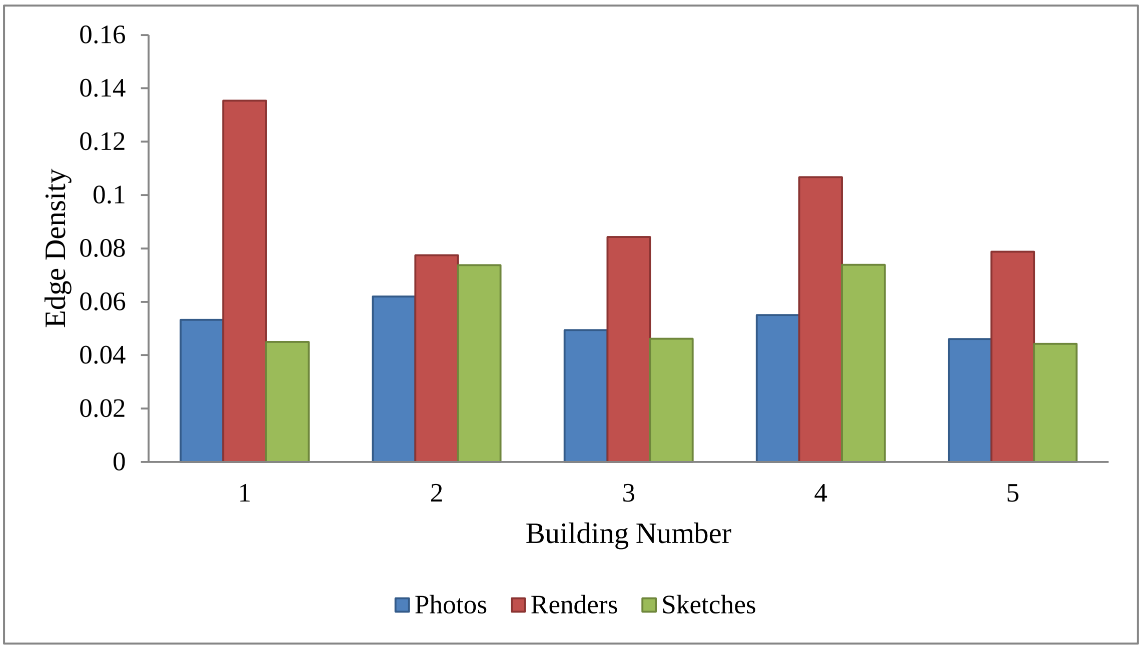


Figure 3. Edge Densities Within Various Representations of the Same Scene - With Thresholding

5.2 Experimental procedure effect on results

The experiment was relatively short, taking less than 15 minutes. This may result in the participants learning and then remembering their preference by forming an initial opinion based on the sketches and then maintaining it throughout for the render and photo representations. Conducting the experiment for each type of representation, sketch, render and photo, on different days with a numeric sliding scale rating system would be a more robust means of determining preference. Repeating the experiment would also provide confidence in the consistency of the participant's responses. However, limited resources made this unfeasible for this study.

5.3 Visual behaviour

There was limited localised difference in visual behaviour between representations for most of the buildings and some of the cars. One of the Dyson electrical appliances, a handheld Dyson vacuum cleaner (Dyson 03), showed significant difference in the visual behaviour across a wide proportion of AOIs for the representations. This signifies that the participants were engaged to different degrees for the product for each representation e.g. in the sketch they did not engage fully with the handle but in the photo they did. However, a larger sample size than 17 is required to categorically state that the engagement between representations of Dyson 03 was significantly different.

5.4 Implications for design representations

No significant change in preference for the majority of products/artefacts between representations would imply that the sketches in this study were sufficient for the participants to develop a consistent opinion. Ranscombe (Ranscombe, 2012) describes how vehicle outlines are sufficient for communicating brand, in that individuals could successfully identify makes of cars by their feature silhouettes. Macomber and Yang (2011) made a similar conclusion in their series of experiments. In most cases the additional effort to create a high-fidelity representation may only provide marginal benefit when rating the degree of preference for a product. Repeating the study with a larger sample size would help to confirm this.

5.5 Experimental lessons learnt

There is insufficient information to be able to suggest a correlation between preference and visual behaviour, as eye trackers do not provide motivation for gaze, only the degree of engagement. Supplementing gaze data with Retrospective-Think-Aloud (RTA), in which the participants are played their gaze over an image back to them and asked to comment on their motivations for engagement, is a potential means of addressing this (Cooke & Cuddihy, 2005). In conducting RTA a clearer understanding of the preference of individual regions or features of a representation could be built up.

Eye trackers are only able to detect foveal vision, which is the central 'high-definition' region of the human eye. This region has the highest capability for detecting detail in the eye and is assumed to be where the individual's attention is placed (Duchowski, 2007). However, it only accounts for around 50% of the visual information that the brain receives and a substantial amount of additional information is obtained from the parafoveal and peripheral regions of vision.

Humans tend not to look at large homogenous areas; instead concentrating on regions where there is greater detail e.g. they look at the corners and edges of a cube, not the faces. In determining form of an object the entire field of vision is used, though the eye tracker would give the impression that only certain portions of the image have been viewed. The screen used in the experiment was relatively small, meaning that the parafoveal region of vision (the intermediary region between foveal and peripheral which has moderate capacity for detail detection) would have likely provided a large amount of visual information to the users negating the need for them to inspect the regions with their foveal vision. It is therefore necessary to emphasise that the eye tracker only records a limited portion of the participant's visual behaviour. Increasing the display size to artificially promote foveal vision, which the eye tracker does record, would address this.

6 CONCLUSIONS

Single factor ANOVA ($\alpha = 0.05$) was performed on the participant's preference scores of each representation, as well as for their Total Fixation Duration. No significance was observed for 14 of the 15 products in the change of degree of preference, with one building showing a significant difference in the change of preference between representations. Limited Areas Of Interest (AOIs) displayed significant difference in the visual behaviour of the participants between representations for four of the Buildings and two of the Cars. A moderate number of the Dyson electronic appliances demonstrated significant difference in the visual behaviour of the participants.

Several participants commented during the experiment of their pre-existing preference of some of the cars and particularly the electronic appliances (all of which were manufactured by Dyson). The shortness of the experiment, about fifteen minutes, suggests that participants were not truly judging their preference of the product in the representation, rather making a judgement of the first representation and maintaining it throughout or relying on pre-existing product knowledge. Analysis of the AOIs to determine compositional elements such as edge density, contrast etc. is required to verify whether pre-attentive mechanisms are responsible for the observed difference in behaviour.

The short exploratory study described in this paper is to be used to develop a methodology for investigating visual perception and information use in the design process using eye tracking. Eye tracking is a powerful measurement tool but needs to be supplemented with additional data to provide understanding as to the motivation for engagement. Certain tasks, such as reading, are more readily investigated using eye tracking. However, there is substantial potential for using the technology in the investigation of visual perception of other information sources such as prototypes.

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