The Gestalt Principle of Continuation Applies to both the Haptic and Visual Grouping of Elements

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Abstract

The multi-sensory display of abstract data is a new and emerging area of study in the area of computer interfaces. Unfortunately the design of multi-sensory displays is complex and it is necessary to carefully consider the perceptual capabilities of humans. Therefore we aim to both collect useful guidelines that help designers of multi-sensory displays and to structure these guidelines by using appropriate high-level principles. Gestalt principles suggest themselves as one possible framework for structuring multi-sensory design guidelines. Gestalt theory explains how humans organise individual elements into groups and how humans perceive and recognise patterns. Unfortunately very little work has been done in evaluating how well these principles apply to the haptic sense. This paper focuses on how individuals use the sense of haptic (touch) to group display elements using the Gestalt principle of continuation. The hypothesis of the experiment is that people will use their haptic perceptions to group display elements in the same way they group elements visually. Overall we find this hypothesis to be true and that a significant number of subjects group haptic elements so that they can be interpreted as continuous lines and forms. This supports our hypothesis that the Gestalt principle of continuation is applicable for both visual and haptic grouping and therefore provides a useful principle for structuring multi-sensory design guidelines.

1. Introduction

Advanced computer interfaces provide new opportunities to develop more complex multisensory displays. When designing such displays it is necessary to consider human perceptual capabilities and understand how people find patterns, recognise forms and organise individual elements into structures and groups [11]. The design of multisensory displays is still an embryonic area of research and the process of how we perceive and process multisensory perceptions is still not well understood [4]. Currently we are investigating new and existing guidelines to support multisensory display designers, as well as higher-level principles that can be used to structure these guidelines [6].

One way to structure these guidelines is founded on Gestalt theory. Gestalt theory is one of the well-known perceptual theories for perceptual organisation. Gestalt theory attempts to explain how humans organise individual elements into groups and how humans perceive and recognise patterns.

The authors have previously argued that the Gestalt principles provide a useful framework to categorise multisensory display guidelines [5], [7]. More recently an experiment was conducted which determined that humans group both perceived visual and haptic elements in the same way [5]. Although there is little work in relation to haptic Gestalt principles, some researchers have studied the role of the touch in the recognition of patterns. For example, Sathian (1989) studies how tactile objects are recognised from their surface features and the underlying spatial and temporal distribution of neuronal activity that may encode these surface features [23]. Kaitz (1992, 1994) examines how adults are able to recognise their partners by touch and shows that both the mother and the father are able to recognise their newborn children by touch [13], [14]. Picard, et al. (2003) use different car seat materials to investigate how people recognise different textures by touch [21].

This paper studies how humans group haptic elements and whether the Gestalt principle of "Continuation" applies in a similar way for both the haptic and visual grouping of elements. The principle of continuation is often described in relation to the visual sense, and states that objects when connected, result in straight or smoothly curving lines, are seen as

Second Joint EuroHaptics Conference and Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems (WHC'07)
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belonging together, and the lines tend to be seen in such a way as to follow the smoothest path. In auditory display this is sometimes interpreted as temporal continuation rather than one in space. That is, we expect sound stobe continuous over time, and i fa soft sound is masked by a louder sound than we imagine the soft sound as continuous, even though it cannot be heard because of the louder sound. Accordingly this paper examines the question of whether the principle of continuation can be adopted as a higher-level design principle for haptic displays. The results of the evaluation indicate that the principle of continuation is indeed applicable for both the visual and haptic grouping of elements.

Before describing the evaluation, this paper begins with a brief introduction of Gestalt theory and describes the Gestalt principle of continuation. The paper then reports on the experiment and discusses the results in more detail.

2. Gestalt Theory

Gestalt theory was originally described in 1910 [16], [17], [30]. Initially, this theory was only studied in psychology [30], but the concepts have influenced many research and study areas, such as image retrieval [12], [27], visual design [8], [10], [18], graph drawing [20], musical studies [1] and the design of auditory displays [2], [19], [28], [31]. Gestalt theory has even been used to explain the psychological patterns of gamblers [22].

Gestalt is a German word which is roughly translated in to English as 'form, shape, [or] pattern' [9]. Whilst every individual perceptual element has its own nature and characteristics, the nature of individual elements alone cannot account for how a group of elements will be perceived. The essential point of Gestalt theory is that the perception of the whole pattern (or gestalt) cannot be explained from the sum of its parts.

In summary, Gestalt theory developed principles that attempt to explain how we organise individual elements into groups, and can be used to explain the way humans perceive and recognise patterns. This is of particular interest to the authors who are interested in the design of displays that help users to find patterns. A number of principles were developed as part of Gestalt Theory and we will now discuss the principle of continuation.

2.1. Continuation

People tend to perceive a smooth and continuous outline between points rather than lines with sudden or irregular changes in direction. Thus elements will be grouped together if a continuous pattern can be interpreted and this pattern will be assumed to continue even if some part are hidden [18].

For example, in a painting, if some object covers some part of a curving road, we still assume that the curving road continues beyond the smoke [11]. Similarly if a sound slowly changes in pitch, loudness or timbre in a very smooth manner then the sound will still be perceived as the one sound [19]. However, people will perceive different sounds if the timbre, the pitch or loudness changes abruptly. The intuition is that this principle also applies to touch. For example, when navigating along a wall by touch, we can perceive a continuous line of the wall and ignore irrelevant objects.

3. Experiment: Does the Gestalt principle of Continuation apply in the same way to both haptic and visual grouping of display elements?

The hypothesis of the experiment is that the principle of continuation is applicable to both visual and haptic grouping of display elements. That is, people tend to perceive a continuous line between points. For both visual and haptic displays it is expected that broken elements will be grouped together in a continuous way even though some part of the line are hidden. This is illustrated in Figure 1.

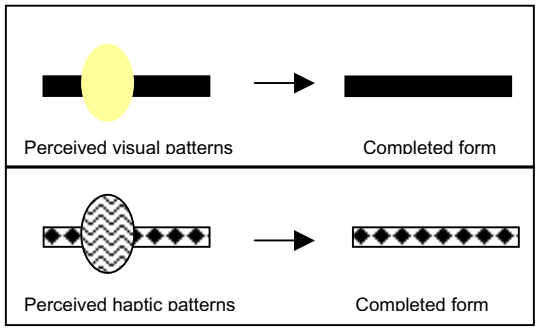

Figure 1. An example of the principle of continuation applied in both visual and haptic grouping of display elements.

3.1. Subjects

The subjects consisted of 20 female and 20 male subjects aged between 20 to 50 years. No subject

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suffered from any haptic impairment and all had normal or corrected-to-normal vision. Further, none of the subjects were especially trained to perceive elements through their visual or haptic sense.

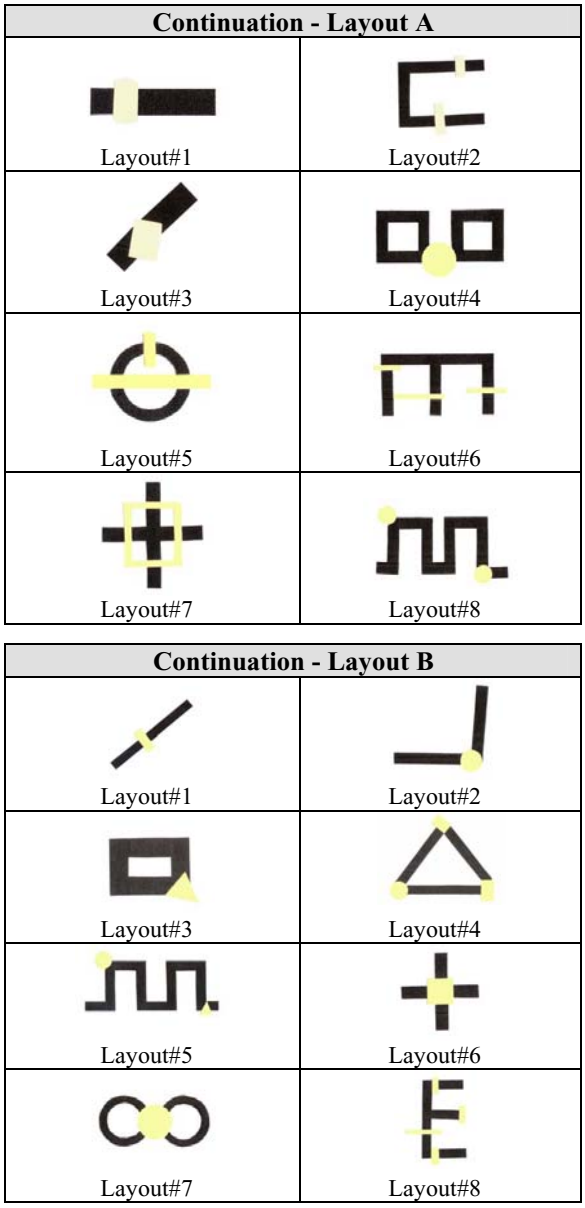

Figure 2. There are two sets of layouts used in the experiment. Both sets have been designed according to the principle of continuation.

3.2. Materials

The materials consisted of two stimulus sets of eight layouts (displays). Each set consists of eight different layouts of simple shapes and familiar objects. The elements were designed and constructed to be the same thickness and use the same surface texture. This helps to rule out other object properties, apart from spatial location that could result in grouping. Each layout was positioned on a piece of white paper with size measuring 15 by 10.5 centimetres. The 16 different layouts are shown in Figure 2.

Two materials were used to construct the elements that are used in the layouts. To ensure the elements would be distinguishable from the white paper (background) the elements in the layout were of different colours (visual) and surface textures (haptic). The two distinguishable elements are made from: black colour of sandpaper with the grit value of 120 (rough) and yellow cardboard (smooth).

3.3. Layout Design

There are two layout sets (Layout A and Layout B) used in the experiment (Figure 2). Each layout was designed to be used in either the haptic or visual mode. Our intuition was that subjects would group the elements together in order to complete a continuous pattern even though some part of the patterns were masked by other elements. We expected subjects would interpret the forms in the same way for both visual and haptic modes. The layouts were presented one at a time and the subjects were allowed to take as much time as they required for the task. To help control for variation between genders, half of the subjects were male and half female. To control further possible variations from learning and the differences between the two layout sets, the order of the visual and haptic tests under taken was reversed.

A total of forty subjects undertook the experiment. The twenty males and twenty females were randomly assigned to their experimental groups. The subjects were divided into two equal lysized groups (ten female and ten male): the first group conducted the visual test before the haptic test and the second group conducted the haptic test before the visual test. Furthermore, each group were divided into two equal lysized subgroups (five female and five male): the first subgroup conducted the tests using layout A before using layout B. The remaining subjects (five female and five male) using the layout B before the layout A.

3.4. Procedure

Subjects were individually tested in a normal room with normal lighting. Each subject was seated in front of a table and position eddirectly with the centre of the layouts. Subjects were free to use their own grouping methods and were able to take as long as they required

completing each task. Some minimal training was conducted with each subject. The training exposed the subjects to two haptic and visual layouts, allowing them to become familiar with the grouping task. No feedback was given to indicate the correctness or otherwise of the subjects' answers.

The visual grouping part of the experiment required the subjects to only use their visual sense to interpret the elements in the layout. Given the influence haptic senses have over perception [26], the subjects were instructed not to touch the layouts.

Similarly, during the haptic grouping part of the experiment, and given vision influences haptic perception [15], [24], [25], the subjects were instructed to place their hands inside a box which prevented the viewing of each layout (Figure 3). In the haptic case the subjects were only allowed to explore the layouts and group the elements using their hands and fingers.

In both parts of the experiment, the subjects were asked to draw the lines of the layout (shapes) they perceived on the provided answer sheet (Figure 4). The subjects did not have visual and haptic access to the actual layout when they were required to draw their response. Unknown to the subject, the time taken to complete each layout, for each mode, was also recorded. The subjects were not aware of this and measuring completion time was not a primary goal of the experiment.

Figure 3. Photographs showing the experiment setup for haptic grouping. Subjects took the haptic grouping task inside a box to prevent viewing the layouts.

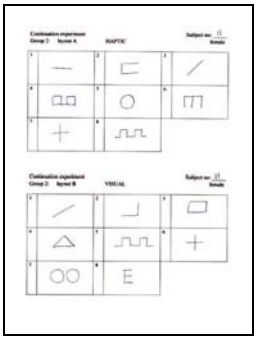

Figure 4. An example of a completed answer sheet used in the experiment.

3.5. Results

The experiment is designed to measure whether the subjects perceive continuous forms and ignore hidden parts in order to complete the form. Our hypothesis is that subject s grouper cei ved haptic or visual elements as continuous in the same way using both vision and haptic.

Table 1. The actual outcomes obtained from the 40 subjects.

Layout A - Visual			Layout A - Haptic		
no.	**actual outcome**	**no. of subjects**	**no.**	**actual outcome**	**no. of subjects**
1		20	1		20
2		20	2		20
3		20	3		20
4a		15	4a		17
4b		5	4b		3
5		20	5		20
6		20	6a		19
			6b		1
7		20	7a		19
			7b		1
8		20	8		20

Layout B - Visual			Layout B - Haptic		
no.	**actual outcome**	**no. of subjects**	**no.**	**actual outcome**	**no. of subjects**
1		20	1		20
2		20	2		20
3		20	3		20

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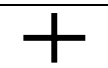
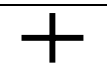
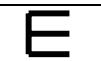
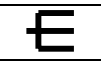
4		20	4		20
5		20	5a		19
			5b		1
6		20	6		20
7a		13	7a		12
7b		7	7b		8
8		20	8a		19
			8b		1

3.5.1. Types of response. The actual outcomes obtained from the 40 subjects are detailed in Table 1. The majority of responses were the simple closed forms expected from the continuation principle. There was almost no difference between haptic and visual modes. Of the 320 possible responses from the 40 subjects, 308 were of this form in the visual mode and 305 were of this form in the haptic mode. There were no identifiable differences in the response due to gender, the different sets (layout A and layout B) and the ordering of the visual and haptic modes. Furthermore, there was no interaction between these variables.

3.5.2. Timing of responses. Haptic grouping normally uses more working memory than visual grouping [3]. It is thus not surprising that there were considerable differences in the completion times between the haptic and visual grouping tasks. An analysis of variance was run on the total time data as subjects took each of the 8 task sin a layout set.

The results reveals a significant difference between the time taken to complete the task s haptically and visually (*p value = 0.0000*).

All 40 subjects took less time in the visual grouping part of the experiment. On average the visual tasks took only 14.28 seconds to complete where as the haptic tasks took 177.78 seconds to complete (Table 2). There appears to be generally no difference between the total time taken by subjects to complete the task (*p value = 0.2444*). Moreover, closer examination reveals the order of the visual tasks undertaken (eg whether the visual task was undertaken first or last) did not affect the time taken to complete the task (*p value = 0.2982*). Similarly, the order in which layout sets A and B were used did not affect the time taken to complete the task (*p value = 0.5019*). However, a significant difference in the time taken by gender is observable in the haptic mode, as males generally took longer to respond than females.

Table 2. Response time from the 40 subjects.

Response Time (seconds)	Visual	Haptic
Female	14.75	142.50
Male	13.80	213.05
Average	14.28	177.78

4. Conclusion

The early works surrounding Gestalt theory explore the principles for grouping elements and figure recognition in vision. More recent works have been applied to the study of auditory perception. However, there currently appears to be a lack of research applying the Gestalt theory in the haptic domain.

This paper examines whether the Gestalt principle of continuation is applicable in the same way to both haptic and visual grouping in order to determine whether continuation is an appropriate high level principle for structuring haptic displays guidelines.

The results indicate that the principle of continuation does apply in the same way to both the visual and haptic grouping of elements. These findings indicate that the designers of haptic and multisensory displays can confidently conclude users will complete forms for both visual and haptic elements in the same way. Designers also need to be aware that haptic grouping tasks require significantly more time than visual grouping and that performance variations may occur between genders.

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