The Gestalt Principles of Similarity and Proximity Apply to Both the Haptic and Visual Grouping of Elements

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Abstract.

When designing multi-sensory displays it is necessary to consider human perceptual capabilities and understand how people find patterns and how they organise individual elements into structures and groups.

Gestalt theory, originally described in 1910, attempts to explain the way people perceive and recognise patterns. The early studies of Gestalt principles of grouping were predominantly concerned with visual perception, although more recently they have been investigated for auditory perception. This paper focuses on how individuals use the sense of touch (haptics) to group display elements using the Gestalt principles of similarity and proximity. A direct comparison is made with the visual grouping of elements using the same two principles of similarity and proximity.

The hypothesis of the experiment described in this paper is that people will use touch to group display elements in the same way they group elements visually. Overall we found that a significant number of subjects used texture or colour to group the elements when there was an equal spacing between the elements. This supports our hypothesis that the principle of similarity is equally applicable for both visual (colour) and haptic (texture) grouping. Similarly, when subjects perceived an unequal spacing between the elements they used spatial position to determine groupings. These results support our hypothesis that the principle of proximity is also applicable for both visual and haptic grouping.

Keywords: Gestalt principle of Similarity, Gestalt principle of Proximity, visual grouping, haptic grouping.

1 Introduction

Advanced computer interfaces provide new opportunities to develop more complex multi-sensory displays. One broad application of multi-sensory displays is to display abstract data using multiple senses in such a way that the user might detect useful patterns in the data. This can be thought of as ‘perceptual data mining’.

Unfortunately the design of multi-sensory displays is complex, as it is necessary to carefully consider the perceptual capabilities of humans. Indeed the understanding of how we perceive and process multi-sensory perceptions is still not well understood (Calvert, et. al., 2004). Because of the embryonic nature of this field the authors believe it is important to gather as much assistance as possible for designers of multi-sensory displays. Although low-level guidelines are useful for designers, the authors also believe that a higher-level framework should be defined to structure these guidelines. Well-structured guidelines can provide designers with both context and detail. This matches well with the top-down (high-level) and bottom-up (low-level) approach often described in software design (Pfleeger, 1998).

Gestalt theory is one of the well-known perceptual theories for perceptual organisation. Gestalt theory tries 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 multi-sensory display guidelines (Chang and Nesbitt, 2005).

Most early studies of perception have focused on the visual sense. This is also true for studies of Gestalt theory, where early works looked at principles for grouping and figure recognition in vision. For example, Coren and Girgus (1980) conducted experiments using Gestalt principles to explain perceptual organisation and spatial distortion and Gestalt principles were used as a foundation for instructional screen design (Fisher and Smith-Gratto, 1998-1999). This visual emphasis has also been evident when Gestalt principles have been used to improve the usability of multimedia applications (Chang, et. al., 2003-2004) or to assist in finding patterns in dynamic graph drawings (Nesbitt and Friedrich, 2002).

More recently the Gestalt theory has been applied to the study of auditory perception (Brattico and Sassanelli, 2000; Bregman, 1990; Moore, 2003; Williams, 1994). However, one finding from our previous studies is the lack of applied Gestalt research for the sense of touch (Chang and Nesbitt, 2005; Chang and Nesbitt, 2006). Therefore, one of the motivations for this paper is to study how humans group haptic elements and whether the Gestalt principles can be expected to work in a similar way for both the haptic and visual grouping of elements.

In the study of perception, it is important to understand how humans perceive elements (Goldstein, 1999). A number of researchers have examined the relationship between haptic and vision. For example, Sathian (2005) finds that the relationship between haptics and vision is close and that visually impaired people usually need to replace their visual sense with their haptic sense. Further, Newell, et. al (2005) investigates the application of visual, haptic and cross modal senses in recognising familiar objects.

Although there is little work in relation to haptic Gestalt principles, some researchers have studied the use of the touch to recognise 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 (Sathian, 1989). Kaitz (1992) examines how adults are able to recognise their partners by touch and shows that both the mother and the father can recognise their newborn children by touch (Kaitz, 994). Picard, et. al. (2003) uses different car-seat materials to investigate how people recognise different textures by touch.

In this paper, the principles of similarity and proximity have been selected for the experiment because they are two important and commonly-used Gestalt principles that have been identified as higher level principles for the design of multi-sensory displays (Chang and Nesbitt, 2006). The principle of similarity states that people tend to group similar elements together based on attributes such as colour or shape (Wertheimer, 1923). The principle of proximity states that elements that are located close to each other will be grouped together (Wertheimer, 1923).

Both the principle of similarity and proximity have frequently been described for the visual sense. The objective of this paper is to examine whether these principles can be adopted as higher-level design principles for haptic displays. Indeed the evaluation described here shows that similarity and proximity are indeed applicable for both the visual and haptic grouping of elements.

This paper begins with a brief introduction of Gestalt theory and describes the Gestalt principles of similarity and proximity. The paper then introduces the experimental evaluation, describing the methodology and results before discussing the outcomes in more detail.

2 Gestalt Theory

Gestalt theory was originally described in 1910 (Köhler, 1920; Wertheimer, 1924; Koffa, 1935). Initially, this theory was only studied in psychology (Wertherimer, 1924), but the concepts have influenced many research and study areas, such as image retrieval (Iqbal and Aggarwal, 2001; Wardhani, 2000), visual design (Chang, et. al., 2003–2004; Fisher and Smith-Gratto, 1998–1999; Moore and Fitz, 1993), graph drawing (Nesbitt and Friedrich, 2002), musical studies (Brattico and Sassanelli, 2000) and the design of auditory displays (Bregman, 1990; Moore, 2003; Warren, 1999; Williams, 1994). Gestalt theory has even been used to explain the psychological patterns of gamblers (Roney and Trick, 2003).

Gestalt is a German word and its meaning can be roughly translated into English as ‘form, shape, [or] pattern’ (Chambers English Dictionary, 1988). Every individual perceptual element has its own nature and characteristics, but 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. Gestalt ideas were a reaction against prevailing reductionist approaches of the time and the ideas are often stated as; "the whole is more than the sum of their parts" (Köhler, 1920, pp.17). This is interesting as recent developments in Complex Systems also seek to take a more holistic approach to understanding systems at many scales and also use the expression "whole is greater than the sum of its parts" (Bar-Yam, 2004). One criticism of Gestalt theory is that it only provides an explanatory tool and cannot be used to predict the outcome of design. It may be that Complex Systems research will provide the necessary mathematical framework to overcome this problem.

In summary, Gestalt theory developed principles that try to explain how we organize individual elements into groups. Thus it 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 allow users to find patterns. A number of principles were developed as part of Gestalt Theory and we will now discuss the two principles of similarity and proximity.

2.1 Similarity

Elements will tend to be grouped together if their attributes are perceived as related (Wertheimer, 1923; Goldstein, 1999). For example, visual display elements will be grouped together if their lightness (Figure 1), hue, size, orientations or shape are closely related with each other (Goldstein, 1999; Palmer, et al., 2003). With haptic perception, it is also possible to group similar shapes, forces, surface textures, weights and vibration. For example, visually disabled people are able to separate cutlery by the similarity in shapes; grouping knifes, forks and spoons into different groups.

2.2 Proximity

The principle of Proximity states that elements which are close to each other will be grouped together (Figure 2) (Wertheimer, 1923; Goldstein, 1999). With haptic perception, it is also possible to group elements into different groups if the elements are close to one another in location. For example, each character in Braille is made of a group of characters that are grouped together because they are close to one another.

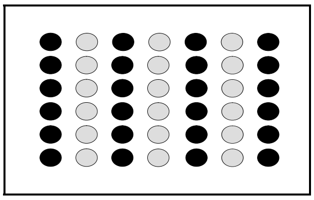

Figure 1: The elements in this figure are visually grouped by the similarity in lightness into four groups of black circles and three groups of grey circles.

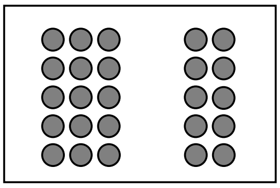

Figure 2: In this image we typically perceive two distinct groups based on their visual proximity.

3 Experimental Design

The hypothesis of this experiment is that the principles of similarity and proximity are used in the same way when people group elements either through their visual or haptic sense. We also attempt to evaluate, if for the Gestalt principle of similarity, the patterns found in visual grouping (by colour) are the same as those found in haptic grouping (by texture). This is shown in Figure 3. Furthermore for the Gestalt principle of proximity, we evaluate whether the patterns found with visual grouping (position) are the same as those found with haptic grouping (position). This is shown in Figure 4.

For simple layouts, it is expected that either spatial position (proximity) or element properties (similarity) will result in non-ambiguous groupings. However, in more complex layouts, subjects may group the elements by either proximity or similarity or perhaps a mixture of both. This experiment provides a number of simple unambiguous layouts but also tries to evaluate how subjects will interpret more complex, ambiguous layouts. That is whether the patterns found with visual grouping (using colour and/or position) will be the same as those found with haptic grouping (texture and/or position). This is shown in Figure 5.

To help control for individual variations, the subjects of this experiment were asked to perform the task of inspecting a randomly ordered set of layouts using the two modes of sight and touch. In each mode the subjects were required to group elements in the layouts and to state the method applied in determining that grouping (position, colour or texture).

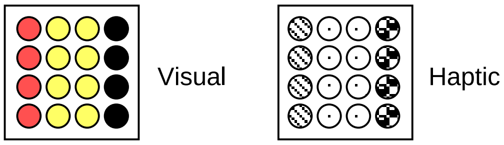

Figure 3: An example of how the principle of similarity is applied in the same way for both visual and haptic grouping of elements. Visually, elements are grouped by colour, while for haptic, it is expected surface texture will used to identify the same groups.

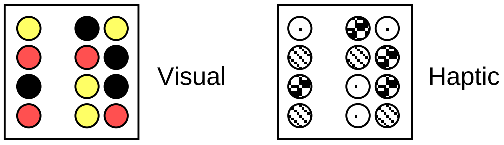

Figure 4: An example of how the principle of proximity is applied in the same way for both visual and haptic grouping of elements. In both cases it is expected that people will group the spatially close objects into the same groups.

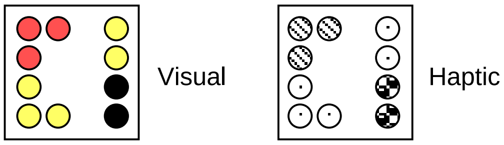

Figure 5: An example of how a mixture of both similarity and proximity can be applied in the same way for both visual and haptic grouping of elements. In both cases it is expected that people may use a combination of spatial location (proximity) and element properties (colour or texture) to make their groupings.

3.1 Subjects

Forty subjects took part in the experiment. There were 20 female and 20 male subjects aged between 20 to 50 years old. All subjects had normal or corrected-to-normal vision and none reported any haptic impairment. Further, none of the subjects were especially trained to perceive elements through their visual or haptic sense.

3.2 Materials

The stimulus set consisted of 16 different layouts (displays) that were designed and constructed using square shapes of the same size and thickness. For each layout, these square elements were positioned on an A4 piece of white paper. An example of a layout is illustrated in Figure 6. Each display layout consisted of between 7 to 16 elements measuring 2.5 by 2.5 centimetres. The 16 different layouts are shown in Figure 7.

To keep the displays as simple as possible it was decided to use only three distinct elements in the layouts. It was important that the three different elements would be distinguishable by both colour (visual) and surface texture (haptic). The elements were constructed using pieces of sandpaper and cardboard, which differed in both colour and the degree of surface texture. The three distinguishable elements are made from: yellow grit-280 sandpaper (medium texture); red grit-40 sandpaper (rough) and; black cardboard (smooth). The size, shape and thickness of each element was kept the same to rule out other grouping properties.

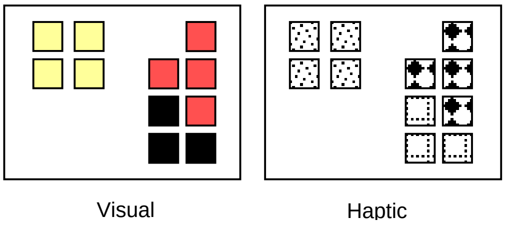

Figure 6: An example of the media used and a layout used in the experiment. Subjects apply visual perception to perceive the three colours (yellow, red and black) and haptic perception to perceive the three different textures (grit 280-medium, grit 40-rough and cardboard-smooth).

3.3 Layout Design

The layouts used in the experiment are shown in Figure 7. Eight of the layouts (1-8) were each designed to be simple and unambiguous. It was expected that most subjects would interpret these by using the same principle. Four of these simple layouts were designed using similarity (1-4) and the other four were designed using proximity (5-8). The other eight layouts (9-16) were designed to be more ambiguous with the expectation that some subjects might use a combination of similarity and proximity to make their groupings. To control variations expected from ordering, the layouts were presented in random order for both the visual and haptic modes. The 16 layouts were presented one at a time and subjects were told to take as much time as they required for the task.

Because each of the elements in the layouts differed in both colour and surface texture the same set of layouts could be used for both the visual and haptic modes of the evaluation. In total, 20 of the 40 subjects undertook the visual grouping exercise followed by the haptic grouping exercise (Visual-Haptic). The remaining 20 subjects undertook the haptic grouping exercise followed by the visual grouping exercise (Haptic-Visual). Subjects were allocated randomly to each group.

3.4 Procedure

Subjects were individually tested in a normal room with normal lighting. Each subject was seated in front of a table and positioned directly in front of the layouts. Some minimal training was conducted with each subject. The training exposed the subjects to six haptic and visual layouts, allowing them the opportunity to distinguish between the three colours and textures and to practice the grouping task. No feedback was given to the subjects to indicate that answers were in any sense right or wrong. The subjects did not proceed with the experiment if they were unable to distinguish between the textures and colours at this stage.

During the visual grouping part of the experiment, the subjects were asked to use their visual sense only to group the elements in the layout into groups. Given the influence haptic senses have over perception (Violentyev, et. al., 2005), the subjects were instructed to not touch the layouts during this part of the experiment.

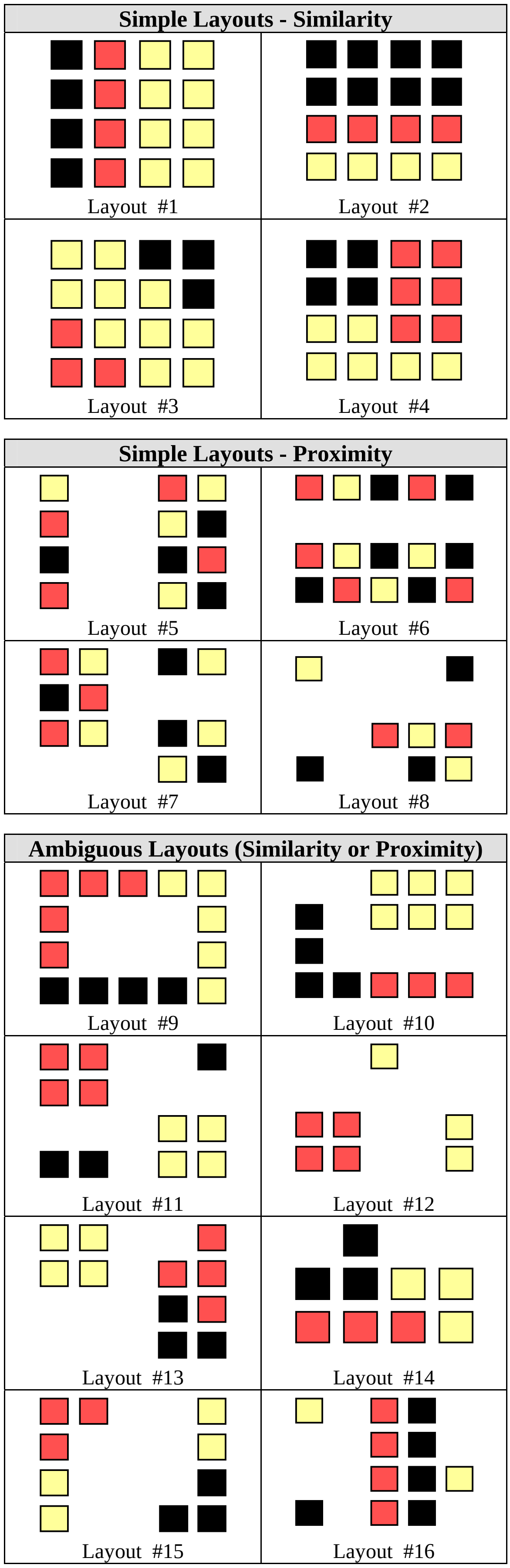

Figure 7: The 16 layouts used in the experiment. Layouts 1-4 have been designed so that we expect subjects to group based on similarity. Layouts5-8 we expect to be interpreting using proximity. Layouts 9-16) use a more ambiguous arrangement and may be grouped using either similarity or proximity.

Similarly, because vision influences haptic perception (Klatzky, et. al., 1987; Schaefer, et. al., 2005; Tipper, et. al., 1998), the subjects were blindfolded during the haptic grouping part of the experiment. The hand is often acknowledged as the primary organ of the tactile sense. (Sathian, 1989). 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 verbally express the number of groups they perceived, and the reason they drew that conclusion. The evaluator was present at all times during the experiment to manually record the number of groups detected in each layout and the grouping technique used in each case (position, colour or texture). The time taken to complete each layout was also recorded, although the subjects were not aware they were being timed for each task and measuring performance was not a primary goal of the experiment.

4 Results

The experiment is designed to measure whether the subjects use the same principle; either similarity (colour/texture) or proximity (position) when grouping elements using their visual and haptic senses.

There are four possible outcomes for each layout used in the experiment where the visual observation is followed by the haptic observation: the subject may group by similarity using both the visual and haptic sense (SV-SH); the subject may group by proximity using both the visual and haptic sense (PV-PH); the subject may group using similarity with the visual sense and proximity with the haptic sense (SV-PH) and; the subject may group using proximity with the visual sense and similarity with the haptic sense (PV-SH). These four possible outcomes for each layout are shown in Table 1 and the actual results for each layout are shown in Table 2.

	Mode	
Outcome	**Visual**	**Haptic**
SV-SH	Similarity (colour)	Similarity (surface texture)
PV-PH	Proximity (visual position)	Proximity (haptic position)
SV-PH	Similarity (colour)	Proximity (haptic position)
PV-SH	Proximity (visual position)	Similarity (surface texture)

Table 1: The four possible outcomes for each layout when a single subject groups elements in the visual and haptic modes.

First, a Chi-squared test of independence was performed on all the responses. The null hypothesis:

> H_0: The responses are independent (the visual response is independent of the haptic response and vice versa),
>
> was tested against an alternative hypothesis:
>
> H_a: The responses are not independent (the visual response is related to the haptic response).

	Layout Number							
Outcome	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
SV-SH	32	30	29	31	7	7	6	7
PV-PH	6	7	8	5	31	31	30	31
SV-PH	1	0	1	1	1	0	1	0
PV-SH	1	3	2	3	1	2	3	2
Outcome	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
SV-SH	15	15	6	17	10	26	8	6
PV-PH	13	19	30	20	22	9	30	30
SV-PH	5	3	1	2	3	2	0	1
PV-SH	7	3	3	1	5	3	2	3

Table 2: Shows how many times each of the four possible outcomes occurred for the 16 different layouts.

On the basis of the test statistic (Q^2 = 355) the null hypothesis was rejected (pvalue = 0.000). From this we draw the conclusion that the visual and haptic responses are not independent. This is what we would expect if subjects are using the principles of similarity and proximity in the same way to determine both visual and haptic groups. Using a 99% confidence interval we found that we could expect subjects responses to be the same for both visual (SV-PV) and haptic (PV-PH) grouping between 87-93% of the time (CI 99% (p) = (0.93, 0.87)).

We expected that some memory of layouts from the first task may influence subjects responses in the second task. To check for ordering effects, between the visual and haptic modes the number of different responses (SV-PH or PV-SH) was determined for the subjects that attempted the visual task before the haptic task and then again for subjects who performed the haptic task before the visual task. Although a discrepancy was found between the average difference rate of Visual-Haptic (2.2) and Haptic-Visual (1.1) groups, a t-test indicates that there was no significant difference between the groups ($t(39) = 1.83$, $p > 0.05$).

A t-test was also used to analyse for possible gender differences in the outcomes. However, no significant differences between male and female responses were found ($t(39) = 0.31$, $p > 0.5$).

Haptic grouping normally uses more working memory than visual grouping (Bliss and Hamalainen, 2005). Therefore we were not surprised to find considerable difference in completion times for the haptic and visual grouping tasks. All 40 subjects took less time in the visual grouping part of the experiment. The average completion time was 3.86 seconds for the visual task and 25.48 seconds for the haptic task (Paired $t(39) = -10.32$, p value = 0.0000).

5 Discussion

As described above, there were 16 layouts in the experiment and we divided them into two main groups, Simple Group-1 and Ambiguous Group-2. Simple

Group-1 consisted of the 4 layouts designed according to the single principle of similarity and the 4 layouts designed using the single principle of proximity. For example, when using these layouts we expected most subjects to identify grouping techniques such as, "I grouped close elements together" (proximity), or, "I grouped elements together because they were all the same colour/texture" (similarity). Ambiguous Group-2 used a mixture of both similarity and proximity. We expected the subjects approaches to grouping in these cases to be more varied.

We then compared the grouping methods applied by the subjects between the two groups. In the Simple Group 1 layouts, 26 subjects used the same method (SV-SH or PV-PH) for both their haptic and visual grouping and 14 subjects applied at least one different method in the two modes (SV-PH or PV-SH). As expected for Ambiguous Group 2 layouts only 15 subjects used a consistent method (SV-SH or PV-PH) between modes while 25 subjects changed methods between modes (SV-PH or PV-SH).

Figure 7 shows all cases where subjects changed grouping methods between modes. For the Simple Group-1, 9 subjects changed modes for 1 layout, while in the Ambiguous Group-2, 13 subjects changed grouping methods between modes. For the Simple Group-1, 3 subjects changed modes for 2 layouts, while in the Ambiguous Group-2, 9 subjects changed grouping methods between modes. For the both the Simple Group-1 and Ambiguous Group-2, only a single subject changed modes for 3 or 4 layouts.

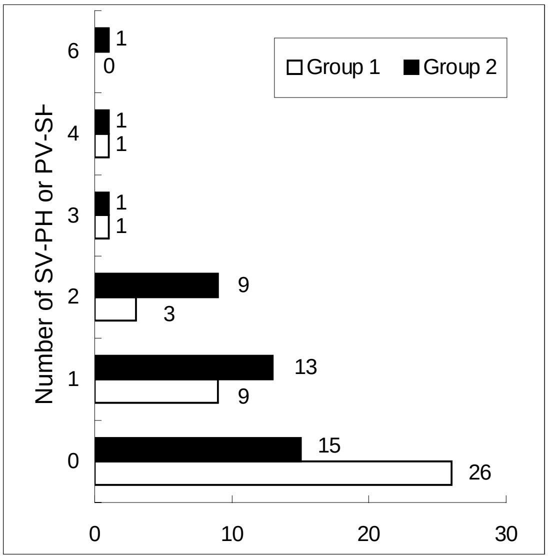

Figure 7: The number of subjects who applied different grouping methods (SV-PH or PV-SH) across the different modes for Simple Group-1 and Ambiguous Goup-2 layouts. More subjects used a consistent method for the simple layouts and more subjects changed grouping methods when interpreting the ambiguous layouts.

The results indicate that subjects are more likely to apply different grouping methods when working with the more complex patterns of the Group-2 layouts. It could be argued that some of the subjects confused the mixed designed layouts when conducting the perceptual grouping, or that some subjects inherently apply different Gestalt principles for visual and haptic grouping more complex arrangements. This could be due to the more memory intensive nature of detecting haptic similarity (texture) and proximity (position). Further cause may lie with the different spatial resolutions of each sense. For example, we might expect proximity to be more accurate with the higher spatial resolution of the visual sense.

The results in Figure 8 show that the vast majority of subjects used colour or texture (SV-SH) as the grouping method on the Similarity layouts and used position (PV-PH) as the grouping method on the Proximity layouts.

Even on the remaining 8 more complex layouts the same methods were chosen by subjects in a majority of cases (SV-SH or PV-PH). None of layouts used caused the subjects to systematically change the grouping method used between the visual and haptic displays. The authors conclude that the subjects tend to apply the same methods for both visual and haptic grouping.

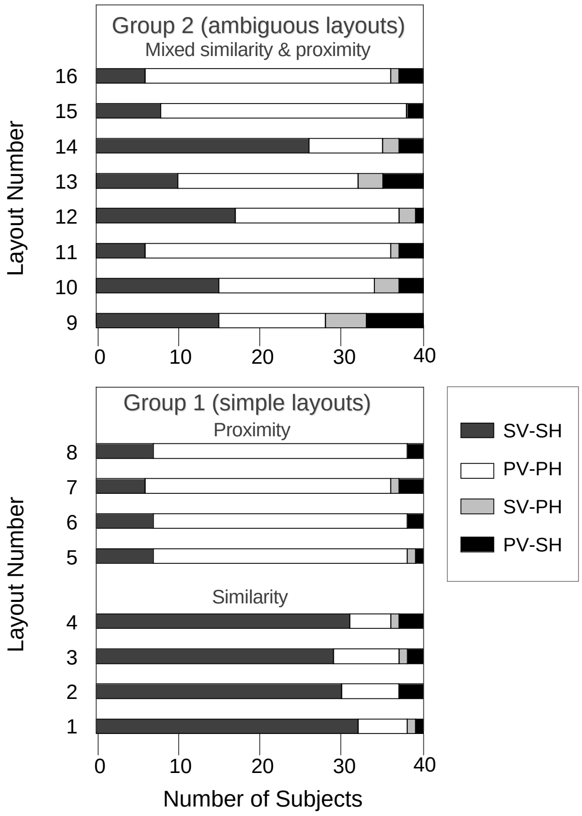

Figure 8: The results suggest that in most layouts, subjects use the same method (either similarity or proximity) for both visual and haptic grouping. Layout 9 shows the most variation between haptic and visual grouping techniques (SV-PH or PV-SV).

6 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.

One of the motivations for this research is to examine whether the Gestalt principles of similarity and proximity are applicable in the same way to both haptic and visual grouping in order to determine the utility of the principles of similarity and proximity as high-level principles for structuring haptic display guidelines.

The results in this paper indicate that the principles of similarity and proximity do apply in the same way to both the visual and haptic grouping of elements. In ninety per cent of the cases, subjects applied texture or colour to group the elements when they perceived an equal spacing between the elements. Further, when they perceived an unequal spacing between the elements, the subjects grouped on closeness, rather than the colour or texture differences of the elements.

These findings are useful for designers of haptic or indeed multi-sensory displays who can confidently expect users will group both visual and haptic elements in the same way.

7 References

Brattico, E. and Sassanelli, F. (2000): Perception and Musical Preferences in Wishart's Work, *Journal of New Music Research*, **29** (2): 107-119

Bar-Yam, Y. (2004): *Making Things Work: Solving Complex Problems in a Complex World*, Knowledge Press, 2004.

Bregman, A. (1990): *Auditory Scene Analysis: the perceptual organization of sound*. Massachusetts, The MIT Press.

Bliss, I. and Hamalainen, H. (2005): Different working memory capacity in normal young adults for visual and tactile letter recognition task. *Scandinavian Journal of Psychology*, **46**: 247-251.

Calvert, G. A., Spence, C. and Stein, B. E. (2004): Introduction. *The Handbook of Multisensory Processes*. Massachusetts: MIT Press Cambridge, xi-xvii.

Chang, D., Wilson, C. and Dooley, L. (2003–2004): Toward Criteria for Visual Layout of Instructional Multimedia Interfaces. *Journal of Educational Technology Systems*, **32** (1): 3-29.

Chang, D. and Nesbitt, K. (2006): Identifying Commonly-Used Gestalt Principles as a Design Framework for Multi-Sensory Displays, *Proceedings of 2006 IEEE international conference on SMC*, Taipei, Taiwan, 8-11 October 2006.

Chang, D. and Nesbitt, K. (2005): Developing Gestalt-based Design Guidelines for Multi-sensory Displays. *The Proceedings of NICTA-HCSNet Multimodal User Interaction Workshop, the ACS Conferences in Research and Practice in Information Technology*, CRPIT, **57**: 9-16.

Chambers English Dictionary (1988): 7th edition, W & R Chambers Limited and Cambridge University Press: 595.

Coren, S. and J. Girgus (1980): Principles of Perceptual Organization and Spatial Distortion: The Gestalt Illusions. *Journal of Experimental Psychology: Human Perception and Performance*, **6**(3): 404-412.

Fisher, M. and Smith-Gratto, K. (1998–1999): Gestalt Theory: a foundation for instructional screen design. *Journal of Education Technology Systems,* **27**(4): 361-371.

Goldstein, E. B. (1999): *Sensation and Perception*. Pacific Grove, Brooks/Cole.

Iqbal, Q. and Aggarwal, J. K. (2001): Applying perceptual grouping to content-based image retrieval: Building images. *Third IEEE Computer Society Workshop on Perceptual Organization in Computer Vision*: 19-1 - 19-4.

Kaitz, M. (1992): Recognition of Familiar Individuals by Touch. *Physiology & Behavior*, **22**: 565-567.

Kaitz, M., Shiri, S., Danziger, S., Hershko, Z. and Eidelman, A. (1994): Fathers Can Also Recognize Their Newborns by Touch. *Infant Behavior and Development*, **17**: 205-207.

Klatzky, R., Lederman, S. and Reed, C. (1987): There's more to touch than meets the eye: the salience of object attributes for haptics with and without vision. *Journal of experimental psychology*, **116** (4): 356-369.

Koffa, K. (1935): *Principles of Gestalt Psychology*. London, Routledge & Kegan Paul Ltd.

Köhler, W. (1920): *Physical Gestalten (Die Physischen Gestalten in Ruhe und im stationaren Zustand)*. Erlangen: Eine naturphilosophische Untersuchung: ix-259. [Ellis, W. D. (Ed.) (1938): *A sourcebook of Gestalt psychology*. London: Routledge & Kegan Paul: 17-54].

Moore, P. and Fitz, C. (1993): Gestalt Theory and Instructional Design**.** *Journal of Technical Writing and Communication*, **23** (2): 137-157.

Moore, B. (2003): *An introduction to the psychology of hearing*. 5th ed. London: Academic Press.

Nesbitt, K. and Friedrich, C. (2002): Applying Gestalt Principles to Animated Visualizations of Network Data. *Proceedings of the sixth international Conference on Information Visualisation*, London, IEEE Computer Society, 737-743.

Newell, F. N., Woods, A. T., Mernagh, M. and Bulthoff, H. H. (2005): Visual, haptic and crossmodal recognition of scenes. *Experimental Brian Research*, **161**: 233-242.

Palmer, S. E., Brooks, J. L. and Nelson, R. (2003): When does grouping happen? *Acta Psychologica*, **114**: 311-330.

Pfleeger, S. L. (1998): *Software Engineering: Theory and Practice*. New Jersey: Prentice Hall.

Picard, D., Dacremont, C., Valentin, D. and Giboreau, A. (2003): Perceptual dimensions of tactile textures. *Acta Psychologica*, **114**: 165-184.

Roney, C. J. R. and Trick, L. M. (2003): Grouping and Gambling: A Gestalt approach to understanding the gambler's fallacy, *Canadian J. of Experimental Psychology,* **57**(2): 69-75.

Sathian, K. (2005): Visual Cortical Activity during Tactile Perception in the Sighted and the Visually Deprived. *Developmental Psychobiology*. **46** (3): 279-286.

Sathian, K. (1989): Tactile sensing of surface features. *Trends in Neurosciences*, **12** (12): 513-519.

Schaefer, M., Heinze, H. and Rotte, M. (2005): Viewing touch improves tactile sensory threshold. *NeuroReport*, **16** (4): 367-370.

Tipper, S., Lloyd, D., Shorland, B., Dancer, C., Howard, L. A. and McGlone, F. (1998): Vision influences tactile perception without proprioceptive orienting. *NeuroReport*, **9**: 1741-1744.

Violentyev, A., Shimojo, S. and Shams, L. (2005): Touch-induced visual illusion, *NeuroReport*, **16** (10): 1107-1110.

Wardhani, A. (2000): *Application of Psychological Principles to Automatic Object Identification for Content Based Image Retrieval*. PhD thesis, School of Information Technology, Griffith University, Australia.

Warren, R. (1999): *Auditory Perception: A new analysis and synthesis*. Cambridge, Cambridge University Press.

Wertheimer, M. (1923): Laws of organization in perceptual forms (Untersuchungen zur Lehre von der Gestalt), *II Psychologische Forschung*, **4**: 310-350. [Ellis, W. D. (Ed.) (1938): *A sourcebook of Gestalt psychology.* London: Routledge & Kegan Paul: 71- 88].

Wertherimer, M. (1924) *Gestalt Theory* (Uber Gestalttheorie): 39-59, [Ellis, W. D. (Ed.) (1938): *A sourcebook of Gestalt psychology.* London: Routledge & Kegan Paul: 1-11].

Williams, S. (1994): Perceptual principles in sound grouping, *Auditory Display*, *SFI Studies in the Sciences of Complexity, Proc. Vol. XVIII*, 95-125, Addison-Wesley.