Developing Gestalt-based Design Guidelines for Multi-sensory Displays

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Abstract

Multi-sensory displays try to take advantage of a range of human senses, for example, displaying information visually and also with sound and haptic feedback. Designing multi-sensory displays is complex and needs to carefully consider human perceptual capabilities. Developing guidelines to support designers of multi-sensory displays is an important way to capture and communicate existing knowledge in this cross-discipline domain. However, the study of multi-sensory display is still an immature field and so work in this area is somewhat fragmented. Despite this many useful guidelines have been applied to visual, auditory and even haptic displays. Categorising these existing guidelines in a way to better support multi-sensory display and also developing guidelines explicitly concerned with multi-sensory design are the two overall aims of this research. One relevant area of study that has yet to be applied to multi-sensory design is Gestalt theory. Gestalt theory, originally described in 1910, can be used to explain the way we perceive and recognize patterns. Using Gestalt theory as a foundation, this paper develops a new framework to help categorise existing guidelines. This framework is also intended as a basis for developing new guidelines. The key feature of this framework is that it uses a few high-level Gestalt-based principles to help organise a large number of more detailed design guidelines.

Keywords: Gestalt principles, design guidelines, multi-sensory displays.

1 Introduction

Multi-sensory displays try to take advantage of a range of human senses, for example, displaying information visually and also with sound and haptic feedback. Designing multi-sensory displays is complex, and needs to carefully consider human perceptual capabilities. Guidelines to assist with the design of multi-sensory displays have been developed. For example, guidelines structured within temporal and spatial categories have been formulated (Nesbitt, 2003) and applied to the design of multi-sensory stock market displays (Nesbitt and Barrass, 2004). However, the study of multi-sensory displays is still immature. One relevant area of study that has yet to be applied to multi-sensory design is Gestalt theory.

This paper describes a framework that uses Gestalt theory as a basis for further developing and categorising both existing and new guidelines relevant to multi-sensory display. A brief introduction to Gestalt theory is followed by a description of the framework. The framework uses ten key Gestalt principles and the relevance of these principles to multi-sensory display is explained. The framework is further illustrated by providing some existing guidelines for visual, auditory and haptic display. These existing guidelines are reinterpreted in the context of the relevant Gestalt principle.

2 Gestalt Theory

Gestalt theory was originally described in 1910 (Behrens, 1998; 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, Wilson and Dooley, 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 is a German word and its meaning can be translated into English approximately as “form, shape, pattern” (Chambers English Dictionary, 1988). Gestalt theory states that “what is perceived by the individual is understood by the individual as a whole or gestalt, not as component parts” (Fisher and Smith-Gratto, 1998-99). 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. This is often stated as "the whole is greater than the sum of its parts". Gestalt theory develops principles that try to explain how we organise individual elements into groups. Thus it can be used to explain the way we perceive and recognize patterns.

Multi-sensory displays can of course be designed to satisfy many tasks. However, one important use of such displays is to help users find patterns in information. Since Gestalt theory explains how we organise individual elements into groups, it can also be used to explain the way we perceive and recognize patterns.

A number of researchers have used Gestalt principles to study pattern recognition in visual displays. For example, Gestalt principles have been used as a foundation for instructional screen design (Fisher and Smith-Gratto, 1998-1999) and more generally to improve the usability of multimedia applications (Chang, Wilson and Dooley, 2003-2004). The idea of applying these principles to assist with finding patterns in graph drawings has also been suggested (Nesbitt and Friedrich, 2002) although no empirical work has been reported in this area.

In terms of auditory display, Gestalt principles have been used to describe the recognition of objects in musical studies (Brattico and Sassanelli, 2000). Some researchers have used Gestalt principles as a theoretical framework for explaining perceptual organization of auditory signals (Bregman, 1990; Warren, 1999). Some studies also report on experiments designed to evaluate the influence of Gestalt principles on the way sounds are organised (Moore, 2003; Williams, 1994).

The authors are not aware of any work into the application of Gestalt principles for haptic displays. Furthermore Gestalt principles have not been applied to understanding the way patterns are perceived by multiple senses. One of the intended contributions for this research is to apply Gestalt principles to designing displays which are intended to be interpreted using a combination of sensory modes.

3 Principle and Guidelines

The authors distinguish between the idea of *design principles* and *design guidelines*. A *design principle* is considered to provide a higher level of advice for general design decisions. A design principle provides a "general recommendation on the process of design" (ISO 14915-1, 2002). A *design guideline* is a lower level instruction which provides designers with an exact design rule (Faulkner, 1998; Shneiderman and Plaisant, 2005). Therefore guidelines provide designers with detailed instructions during the design process.

There are many general principles which can be applied for designing any human computer interaction (Faulkner, 1998; Dix, Finlay, Abowd and Beale, 2004; Shneiderman and Plaisant, 2005). There are also some design principles for designers to use in specific area, for example, there are detailed principles for multimedia user interfaces (ISO 14915-1, 2002; ISO 14915-2, 2003), general user interface design principles for educational applications (Najjar, 1998), detailed user interface principles for web-based context and detailed design principles for multi-sensory displays (Nesbitt, 2003).

Consistency is an example of a commonly used design principle. This principle provides some general advice for designers that the user-interface should always be designed to seem consistent. This can be interpreted in many ways. For example, the designer should ensure that the user enters commands in a consistent way and receives output in a consistent manner (Faulkner, 1998; Shneiderman and Plaisant, 2005). It can also be interpreted more precisely to imply that any text used in the interface maintains a consistency with regard to character size, spacing, punctuation and colours (ISO 14915-2, 2003; Ozok and Slvendy, 2004).

Flexibility is another common design principle has been suggested for user interface design. Once again, flexibility is a general suggestion that remind designers to provide various methods for the user to operate the system (Dix, Finlay, Abowd and Beale, 2004). For example, the system should be able to maximize the user's performance by allowing the user to modify the way commands are entered. This might allow the user to change the font size or create personal short cut keys (Faulkner, 1998).

The described principles of consistency and flexibility are general and can be interpreted in many ways. Such principles contrast with guidelines, where the design advice is more precise. For example, a design guideline to help with the screen design of a user interface might stipulate that the date entry format must be DD-MM-YY in Australia (Preece, 1994). Another example might be to always have a 'confirm' message box appeared, to the user, in the centre of the window before quitting the system (Brown, 1988; ETSI EG 2002 048, 2002).

Although the distinction between, "what is a principle" and, "what is a guideline", is somewhat blurred, the two levels of advice are useful for categorising design support. Principles tend to be few in number and also widely applicable which makes them more accessible to designers. Unfortunately their generality can also lead to problems of misinterpretation. Guidelines are more precise in nature, but this can make them less broadly applicable. This lack of generality, means that collections of guidelines tend to be large in an effort to cover all scenarios. Having a large body of guidelines can lead to problems with locating the correct one when it is needed. The pragmatic approach we take is to develop a framework that groups precise, low-level guidelines by more general, high-level principles. The principles then act as both useful general advice but also an index for designers into the large collection of more precise guidelines.

4 Framework for Existing Guidelines

One important focus of our research is the design of multi-sensory displays that allow users to find patterns in abstract data. Since Gestalt theory is concerned with how we group and consequently separate information elements

in a display is used as a basis for a framework which is used to structure existing guidelines.

The first step of this research was to identify some of the commonly used Gestalt principles from the existing literature that apply to the visual, auditory and haptic senses (Table 1). These Gestalt principles provide general advice for designers of multi-sensory displays and also provide useful categories to arrange lower level and more detailed design guidelines.

Gestalt Principles		
1	Similarity	(section 4.1)
2	Continuation	(section 4.2)
3	Focal Point	(section 4.3)
4	Figure-Ground	(section 4.4)
5	Belongingness	(section 4.5)
6	Balance	(section 4.6)
7	Proximity	(section 4.7)
8	Common Fate	(section 4.8)
9	Closure	(section 4.9)

Table 1: Shows the selected Gestalt principles.

Many guidelines for designing displays have already been developed (Apple Computer Inc., 1995; Brown, 1988; Brewster, Wright and Edwards, 1992; ETSI EG 2002 048, 2002; ISO 14915-3, 2002; Nesbitt, 2003; Ngo, Teo and Byrne, 2000; Ozok and Slvendy, 2004; Patterson, 1982; Shneiderman and Plaisant, 2005). Our next step is to analyse these existing guidelines and then categorise them according to the relevant Gestalt principle. A further grouping is then made according to whether the guidelines apply to the visual, auditory or haptic sense (Table 2).

Gestalt Principle e.g. Focal Point		
Visual Guidelines (for Focal Point)	**Auditory Guidelines** (for Focal Point)	**Haptic Guidelines** (for Focal Point)
visual guideline 1 visual guideline 2 visual guideline 3	auditory guideline 1 auditory guideline 2 auditory guideline 3	haptic guideline 1 haptic guideline 2 haptic guideline 3 .....

Table 2: Shows how Gestalt principles and sensory categories are used to categorise existing guidelines.

Below we introduce the relevant Gestalt principles (Table 1) and describe how they apply to grouping information in the visual, auditory and haptic senses. To illustrate the framework we also provide some examples of existing guidelines for each of the principles.

One intention of this work is to leverage from existing knowledge and reframe it in terms of the Gestalt principles. There is an assumption made that the Gestalt principles provide sensible and useful categories for a framework. However this analysis also serves to investigate questions such as, "how well can existing guidelines be grouped by the Gestalt principles?", "which Gestalt principles are the most applicable for describing multi-sensory displays?", and "which Gestalt principles are poorly covered by existing guidelines?".

4.1 Similarity

Elements will tend to be grouped together if their attributes are perceived as related (Goldstein, 1999; Moore, 2003). For example, with visual displays elements will be grouped together, if the lightness (Figure 1), hue, size, orientations or shape are closely related with each other (Goldstein, 1999; Palmer, Brooks and Nelson, 2003). People also group similar sounds together if the timbre, pitch, subjective location or loudness is closely related to each other (Bregman, 1990). For example, people may group string instruments together within an orchestra, because they have similar timbres. With haptic perception, it is also possible to group similar shapes, forces, surface textures, weights and vibrations. For example, visually disabled people are able to separate cutlery by similar shapes, for example grouping forks and spoons into two different groups. An example of an existing guideline for this principle is shown in Table 3.

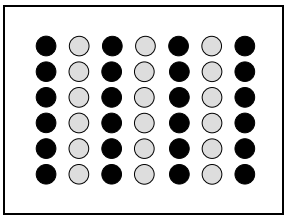


Figure 1: The elements in this figure are visually grouped by the similar lightness into four groups of black circles and three groups of grey circles.

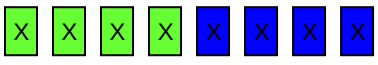
Similarity Principle
Visual Guidelines for Similarity
"Provide consistent visual appearance within icon sets" (ETSI EG 2002 048, 2002) In screen design, the designers should keep graphical style consistently for the same icon set. This is because users will naturally group icons if the icons are similar. For example, elements with the same colour and the same size can be used to keep icons consistently within the same icon group (Palmer, Brooks and Nelson, 2003).    *Two distinct groups of icons are shown. Similar colour icons form a group.*

Table 3: Shows an example of a visual guideline grouped by the similarity principle.

4.2 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 parts are hidden (Moore and Fitz, 1993)

For example, in a painting, if smoke covers some part of a curving road on the mountain, we still assume the curving road continues and will reach the top of the mountain (Goldstein, 1999). 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 (Moore, 2003). However, people will perceive different sounds if the timbre, the pitch or loudness changes abruptly. When we use the sense of touch we tend to perceive a smooth and continuous outline even though some parts are hidden with unfamiliar patterns. This explains how people possibly can exit a completed dark room by touching the walls. People can perceive the surface texture of the walls and ignore irrelevant objects. An example of an existing auditory guideline for this principle is shown in Table 4.

Figure 2: The continuous edge of the path is broken by shadow but the path is perceived to continue in a smooth and regular pattern.

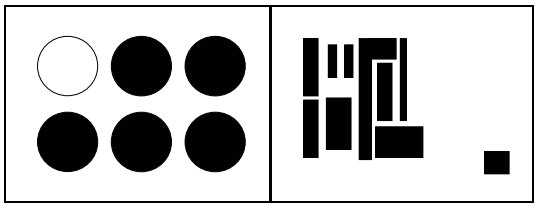


Figure 3: The white circle may be seen as the focal point in the left image because it is different. In the right image the eye is drawn to the separated element.

Continuation Principle
Auditory Guidelines for Continuation
To prevent users connecting unrelated auditory icons put a gap between consecutive auditory icons (ETSI EG 2002 048, 2002) People will tend to perceive a continuous auditory signal and ignore small gaps between consecutive auditory icons. Designers should use an appropriate gap (0.1 seconds) to ensure people perceive separate sound events (Brewster, Wright and Edwards, 1992).

Table 4: An example of an existing auditory guideline for the Continuation principle.

4.3 Focal Point

The principle of Focal Point refers to elements in a display that catch a person's attention (Lauer, 1979). People will perceive the elements as focal points if the attributes of those elements are significantly different from others. In visual displays, there are many methods to create a focal point, for example by using differences in colour, relative position or shape (Figure 3). The colour red is often used in Western cultures to create a visual focal point and draw attention to some form danger. Sound is also often used to draw attention, for example with fire alarms. At many train stations, the passengers attention is drawn by the tactile marks near the of platform edge (Figure 4). Some examples of existing visual guidelines for the principle of Focal Point are shown in Table 5.

Figure 4: The tactile marking (mat) is a haptic focal point to draw attention to possible danger.

Focal Point Principle
Visual Guidelines for Focal Point
"Avoid capitals" (ETSI EG 2002 048, 2002) Capital letters in text attract the user's focal point. Avoid excessive use or capitals. For example, avoid using all capital letters for text display, to prevent the user's vision being distracted. "Use more than colour coding alone" (ETSI EG 2002 048, 2002) Strong colour attracts the user's focal point. If a screen contains many colours it may be necessary to use more than colour coding to attract the user's attention, for example, put a border for each colour block (Shneiderman and Plaisant, 2005). Designers should avoid using just colour as the only informative element to distinguish between images or icons.

Table 5: Show some examples of some existing visual guidelines for the Focal Point principle.

4.4 Figure-Ground

It is natural for humans to distinguish between foreground and background when they receive information (Arnheim, 1970). The figure is more visible than ground, and the ground seems to be an unformed material that is always behind the figure (Fisher and Smith-Gratto, 1998-1999). For example, people can read text from the newspaper because background paper colour seems to be behind the text; therefore people perceive text as figure and the other

as ground (Goldstein, 1999). Also, when we are listening a symphony, different sounds emerge from various instruments. We will tend to separate primary streams (figure) from background harmony (ground) (Moore, 2003). Braille is a form of writing for the visually impaired that relies on haptic perception and the Figure-Ground principle to allow characters to be distinguished (Figure 6). An example of existing visual guidelines for the principle of Figure-Ground is shown in Table 6.

Figure 6: Braille letters are perceived as figures against the ground.

Figure-Ground Principle
Visual Guidelines for Figure-Ground
"Use a high contrast" (ETSI EG 2002 048, 2002) It is important to use sufficient contrast for the text and background in visual displays (Fisher and Smith-Gratto, 1998-1999). Designers need to make sure to use light colours for text displays and dark colours for background displays. For example, use white colour for text and black colour as background.

Table 6: An existing visual guideline for the Figure-Ground principle.

4.5 Belongingness

The principle of Belongingness allows that a single element can only belonged to one source at a time (Moore, 2003). For example when we perceive clouds in the sky they will belong to a single cloud. If they become separated by sky then they are seen as belonging to separate clouds. With auditory streams, a single component in a sound can only belong to one source (Williams, 1994). For example, in music when instruments are used to play different parts they are interpreted as separate streams. When feeling objects a change in surface texture or hardness may be interpreted as a new object. An example of an existing auditory guideline for the principle of Belongingness is shown in Table 7.

Belongingness Principle
Auditory Guidelines for Belongingness
"Use different voices for different interface elements" (ETSI EG 2002 048, 2002) "Different auditory interface elements should be distinguished by using different voices" (ETSI EG 2002 048, 2002). For example, if the sound of 'beep' is used to indicate warning, the 'beep' sound cannot be used to represent other commands within the system. This is because 'Beep' sound is perceived to belong to warning information.

Table 7: An example of an existing auditory guideline for the Belongingness principle.

4.6 Balance

The principle of Balance is also known as the principle of 'Symmetry'. People tend to feel more comfortable with a 'sense of equilibrium' when seeing, hearing or touching (Lauer, 1979). The idea of the principle of Balance is to achieve an 'equal weighting' of attributes when elements are displayed (Boring, 1942).

There are two ways to achieve balance: symmetric balance and asymmetric balance. Symmetric balance is sometimes known as formal balance and asymmetric balance as informal balance. For example, in visual displays, symmetric balance occurs when the elements are evenly spaced around a centre point of the image (Figure 7). Asymmetric balance occurs when the elements are not evenly placed around the centre point, but some other weighting of the elements, such as their size, are perceived as equal (Figure 8). When listening we tend to perceive sounds that have the same properties in both ears and may even feel disoriented, unsteady or woozy when this balance is impaired.

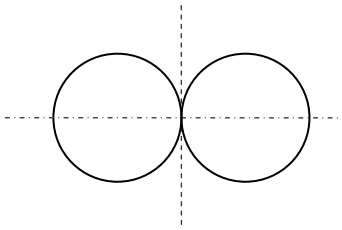


Figure 7: An example of symmetric balance: people perceive the two circles are evenly placed both vertically and horizontally.

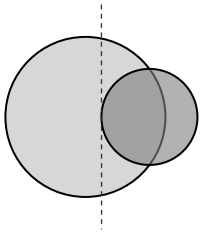


Figure 8: An example of asymmetric balance: people perceive that the two circles of different sizes are not evenly placed around a central axis, but the visual weight is still equally distributed on both sides.

4.7 Proximity principle

The principle of Proximity states that elements that are close to each other will be grouped together (Figure 9) (Fisher and Smith-Gratto, 1998-1999; Goldstein, 1999). Sound events are also grouped together if the sounds are related to one another in time (Bergman, 1990). For example, three flute sounds playing the same melody at the same time that are close together temporally will be grouped together. If they were to play the melody in an unsynchronised way then the three flutes would form separate groups. An example of existing visual guideline for the principle of Proximity is in Table 8.

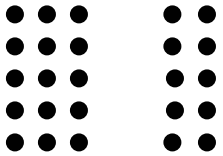


Figure 9: In this image we typically perceive two distinct groups based on their visual proximity.

Proximity Principle
Visual Guidelines for Proximity
"Arrange data to make relationships clear" (Brown, 1988) Designers need to take care when arranging elements in space. For example, put related displayed data next to each other as people tend to group elements based on their location to each other (Fisher and Smith-Gratto, 1998-1999).

Table 8: An example of an existing guideline for the Proximity principle.

4.8 Common Fate

The principle of Common Fate suggests that display elements that change at the same time or move in a similar way will be grouped together (Goldstein, 1999). For example, animated visual elements that move in the same direction, with the same speed will be seen as related (Figure 10). In auditory displays, people tend to group sounds together if they change in pitch in a similar way. Sounds that begin and finish at the same time are also likely to be perceived as related (Moore, 2003). If you turn a door handle and feel the door handle on the other side of the door also turn then you can perceive their common fate. An example of an existing guideline for the principle of Common Fate is shown in Table 9.

Common Fate Principle
Visual Guidelines for Common Fate
"Use only two levels of blink coding (flashing)" (Brown, 1988) Blink coding is often to be used for indicating waning displays. Designers need to be aware that do not use different blink level for the same visual displays, because different blink level will confuse people. Use only blinking and not blinking for blink coding (Brown, 1988). People grouped the blink together when their flashing speeds are the same.

Table 9: An example of an existing visual guideline for the Common Fate principle.

4.9 Closure

The principle of Closure describes our natural tendancy to fill in missing information when a signal is perceived. To complete unfinished forms, people will ignore gaps, filling in the missing parts with a familiar pattern in order to complete the form (Fisher and Smith-Gratto, 1998-1999). Once again this principle applies to visual, auditory or haptic perception. The principle of Closure is useful as it allows people to ignore missing information and use their experience to group disconnected, but related, objects together (Figure 11). For example, when we are listening to music, and a continuous sound track is interrupted by noise, the original sound track will still be perceived as continuous despite being occluded by the noise (Moore, 2003; Williams, 1994).

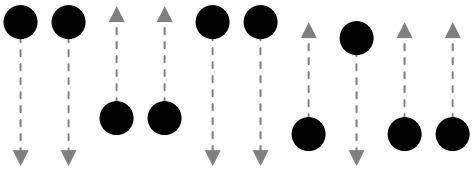


Figure 10: if you can imagine these visual elements moving as indicated by the arrows you will group the elements based on their common fate.

Figure 11: People will tend to fill in the empty spaces for each letter and so form familiar patterns.

5 Discussion

We have presented a framework designed for categorising guidelines to assist designers of multi-sensory displays. The framework is based on Gestalt principles. These well-known principles are used to create high-level categories that act as general advice for designers but also provide a novel way of structuring existing guidelines.

We describe guidelines as lower level more detail instructions that display designers can use. Although many such guidelines have been proposed they have not previously been organised using Gestalt principles. Indeed many guidelines have little structure but are simply collections of related knowledge. In this paper we have merely provided examples of how the proposed framework will be used to structure existing guidelines. Early investigations indicate that few guidelines related to Gestalt principles exist. This may not be surprising given the more embryonic nature of haptic display.

We have also found that some of Gestalt principles are closely related and may even be organised into hierarchies. For example the principle of Similarity and principle of Proximity, both deal with grouping elements by similar attributes, although one has to do with appearance and the other with location. The principle of Similarity is concerned with what items look like and the principle of

Proximity is more concerned with where items are placed in space. The principle of Continuation is also related to the Similarity, Proximity and Closure.

Future work will involve categorisation of a much larger collections of guidelines and also the development of new guidelines explicitly for multi-sensory display. It is proposed to perform experimental evaluations to validate these new guidelines.

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