THE FRAMEWORK FOR UNDERSTANDING ARRAY/GROUPING PRINCIPLES – Part 1

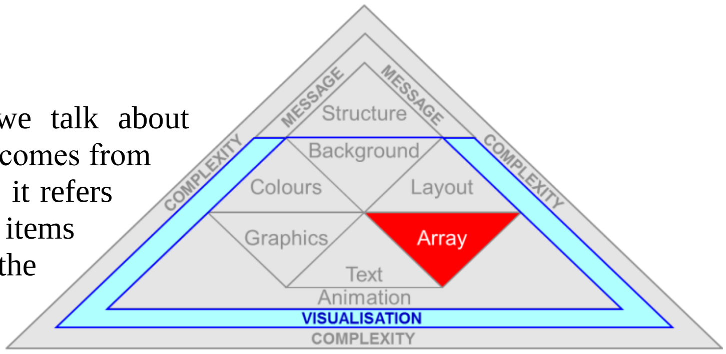
By Bruce Hilliard

WHAT'S THE POINT?

This handout:

- ✓ is an excerpt from Chapter 2 of my thesis *(hence why it refers to other parts of the thesis in the text)*;
- ✓ provides information that will be very important in the discussion of later design techniques, so it gives a very important foundation;
- ✓ is a little dry, because it just talks about the science behind perception, but if you take the time to understand this, it will help you to make sense of many other design aspects; and
- ✓ it therefore supplies information that can be used to optimise all types of presentation materials and visual displays.

1.1. Introduction



Firstly, what do we mean when we talk about 'array'? Array is simply a term that comes from psychophysics research. In essence, it refers to the way in which groups of visual items can be displayed, to optimise the communication of information to viewers. Most importantly, we can apply array techniques that are built on knowledge of the way in which our brains link and construct our understanding of visual objects. This is important, because once you understand how our brains do this, you can apply a set of key practises to optimise visual design.

Therefore, whereas the preceding handout addressed general layout principles *(which look at the general arrangement across the whole screen)*, array looks at the sub-components on the screen, and how they are perceived and mentally processed.

The concept of array therefore needs to be covered explicitly, because this aspect relates to the development of groups of visual elements within the overall structure of your presentation aids or web pages. Such grouping of sub-elements is fundamental to the generation of visual understanding and hierarchies (Vickery, 2008; Vickery & Jiang, 2009). Additionally, the delineation of array as an important sub-element of layout reflects the two stage processing described in Section 1.1 in the preceding layout handout(1). This separation of course visual analysis (e.g. gist) and fine visual analysis significantly affects content search and assessment (Over, Hooge, Vlaskamp, & Erkelens, 2007). It is therefore important to specifically address this second level of visual analysis in more detail.

1.2. What the research indicates

According to Tullis (1988) visual grouping (e.g. the number of groups and size of groups) is the most important display design factor. This importance is reflected by the fact that a significant amount of research has been conducted on the grouping of visual arrays (Wagemans et al., 2012) through the concept of perceptual organisation(2). The following sections in this and the following newsletter explain a perceptual and cognitive model for processing arrays, and identifies key factors that drive the mental generation of visual groups. These concepts are important, because array management is a critical factor in optimised design (Donderi, 2006).

1.2.1. How is Visual Grouping Achieved?

There has been considerable debate about the neurocognitive systems and methods utilised to generate perceptual organisation. For example, there are Representational, Connectionist, and Dynamic Systems Theory (DST) models(3) applied to explain these processes. Rather than address each of these approaches independently, a single model has been utilised in this thesis, which merges and aligns these three methodological paradigms. This model builds on the concepts defined by van der Helm (2012), and Figure 1 *(overleaf)* illustrates key concepts that were identified in his framework(4). To assist in the clarification of van der Helm's (2012)

1. See http://www.seahorses-consulting.com/DownloadableFiles/LayoutHandout.pdf .

2. *Perceptual organisation* 'refers to the neurocognitive process that takes the light in our eyes as input and enables us to perceive scenes as structured wholes consisting of objects arranged in space' (van der Helm, 2012, p. 14). Fundamental aspects of this processing are explained in Appendix 1 (see http://www.seahorses-consulting.com/DownloadableFiles/Appendix1.pdf).

3. The *Representational* model proposes that 'cognition relies on regularity extraction to create structured mental representations'(van der Helm, 2012, p. 15). In other words, according to Dilworth (2005) the Representational model constructs meaning by aggregating the visual content and mixing this with the viewer's knowledge. Alternatively, the *Connectionist* model posits that visual analysis is managed by linking activations in various parts of the brain (van der Helm, 2012, p. 15) to create a composite whole (Rueckl, 2010). Dynamic Systems Theory (DST) was developed by Marr (1982) to provide: (1) a computational level model for identifying how mental representations are created; (2) a set of algorithmic level methods for identifying the cognitive processes involved; and (3) an implementation level framework for categorising the neural structures being utilised.

4. This model was developed by the author, through the integration of information provided in: van der Helm (2012), Palmer and Rock (1994), Palmer, Brooks, and Nelson (2003), Clementz, Brahmbhatt, McDowell, Brown, and Sweeney (2007), and Fulton (2004). Additionally, the nomenclature has been aligned with the concepts specified in Appendix 1 of this thesis, to support consistency. The mathematical elements provided within van der Helm's (2012) model have not been included in this thesis, because they are unlikely to be of direct practical assistance for most developers. However, the general tenets of van der Helm's (2012) approach have been integrated into the model provided in Figure 1 and they are described in the following text.

concepts in this model, information provided by other appropriate publications has also been integrated.

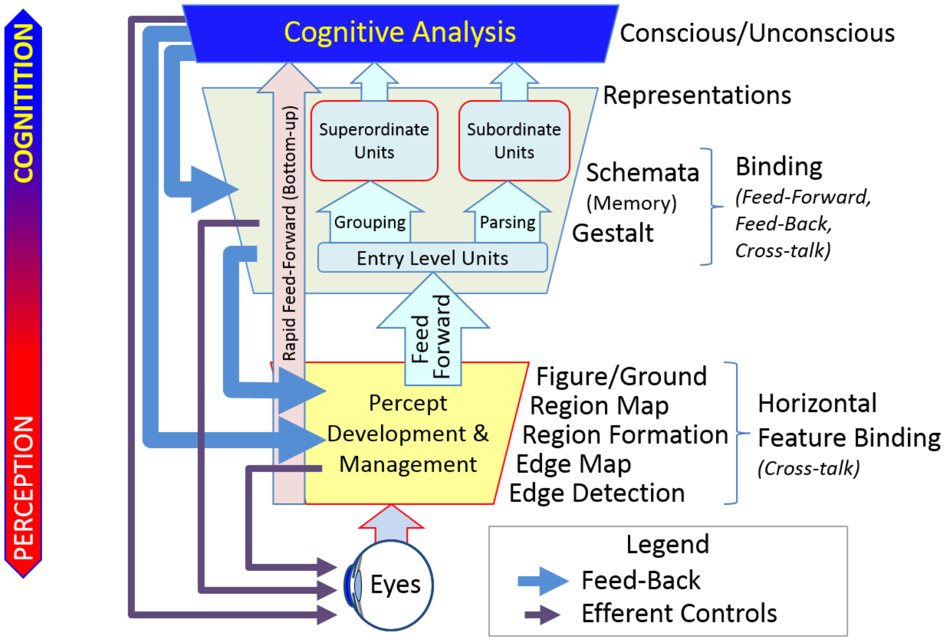
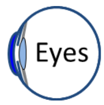
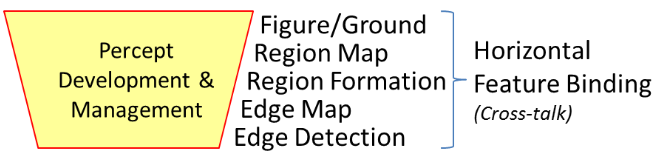


Figure 1: A Process for Understanding Perceptual Organisation of Arrays

The left hand side of this diagram roughly delineates the processes in terms of perception and cognition (which are defined in more detail in Sections 1.2.1 and 1.2.3 in Appendix 1). The colour gradient between these two levels of processing is aligned vertically with the other elements of the framework. However, the separation between these levels is purposely indefinite, to represent the ambiguity related to the level at which certain processes are carried out (Cavanagh, 2011; Todd & Reichel, 1989).



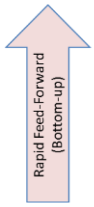
The eyes (as the receiver of the visual information) are represented at the bottom of Figure 1. The architecture of the retina (see Section 1.3.1 in Appendix 1) and the processing of information through the optic nerves (see Section 1.3.2 in Appendix 1) affects the clarity, accuracy, order, and speed at which the raw visual information is passed to the following parts of the brain. This very early processing affects the development of groupings, because of aspects such as salience (Vickery & Jiang, 2009).



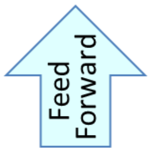
The initial processing of visual information is conducted within neural components within the interbrain (see Section 1.3.3 in Appendix 1), midbrain (see Section 1.3.4 in Appendix 1) and occipital lobes (see Section 1.3.4 in Appendix 1). It is within these regions (and particularly the occipital lobes) that the percepts[5] are developed and managed. These percepts appear to

5. A percept is a blended construct of visual stimuli, which allows the brain to handle congruent or incomplete information (Crick & Koch, 2003; Navarra, Alsius, Soto-Faraco, & Spence, 2010). Percepts are explained in more detail Footnote 6 (on Page 12) in Appendix 1.

be created by aggregating basic features[6] like colour, luminance and orientation[7] (Palmer & Rock, 1994). Such features may then be utilised to detect edges and create edge maps, which are applied to distinguish regions within the field of view (Palmer & Rock, 1994). This type of regional differentiation may also be applied to assist in determining figure-ground distinctions (Palmer et al., 2003). Each of these processes appear to be conducted in what van der Helm (2012) nominates as horizontal feature binding[8], because they utilise neural synchronisation[9] (e.g. cross-talk[10] connectivity within similar regions of the brain[11]).



Another characteristic of the process detailed by van der Helm (2012) is the early and rapid feed-forward[12] created by the bottom-up processing of salient stimuli (see Section 1.2.2 in Appendix 1 for more information)[13]. This rapid feed-forward helps to explain why salience issues can play such an important part in creating attention and shaping perceptual organisation (e.g. object recognition) (Humphreys & Forde, 2001).



Appropriate percepts (e.g. ones to which top-down or bottom-up attention are applied) are then forwarded through the ventral (see Section 1.4.1 in Appendix 1) and/or dorsal (see Section 1.4.2 in Appendix 1) streams. According to Palmer and Rock (1994) the more advanced percepts created by this stage of the process may be equated to an entry level unit (e.g. a basic shape or background element).

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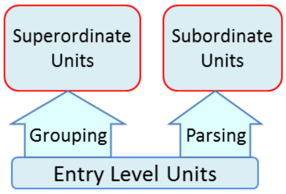
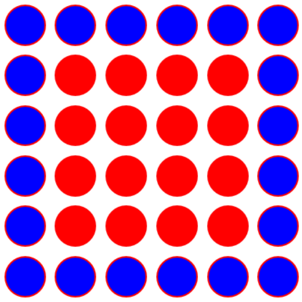
6. There are a range of theories applied to this type of conjunction, which include the Feature Integration Theory (FIT) (Treisman & Gelade, 1980), Hierarchical Interactive Theory (HIT) (Humphreys & Forde, 2001), and Dual-Process Theory (Wixted, 2007). These theories are discussed in more detail in Appendix 1.
7. For more information on these features, see Section 2.1 in http://www.seahorses-consulting.com/DownloadableFiles/ShapingAttentionHandout.pdf.
8. Binding is the process related to combining the sensory information that belongs to an object (McGovern, Hancock, & Peirce, 2011).
9. Synchronisation relates to gamma-band interconnectivity within transient neural assemblies within the brain (van der Helm, 2012).
10. Cross-talk refers to the utilisation of reciprocal communication between parts of the brain during similar levels within the visual analysis process (Felleman & Van Essen, 1991; Verhoef, Vogels, & Janssen, 2011), and in this context it refers to how it is applied to support perceptual organisation (e.g. object recognition) (Farivar, 2009). Cross-talk is explained in more detail in Section 1.4.4.1 in Appendix 1.
11. A good example of this neural relationship is provided in Figure 1.18 (on Page 37) within Appendix 1. As shown in that diagram, regions such as V4 and V5 exchange information to assist in percept development.
12. Feed-forward refers to the typically rapid forwarding of stimuli information to higher areas of processing within the brain (Foxe & Simpson, 2002). See Sections 1.4.4.1 and 1.2.3.2 in Appendix 1 for more information on feed-forward.
13. It appears that many of these aspects of feed-forward are passed rapidly through the dorsal stream (see Section 1.4.2 in Appendix 1) and through the interbrain and midbrain regions (see Sections 1.3.3 and 1.3.4 in Appendix 1) to shape top-down attention and cognitive processing.



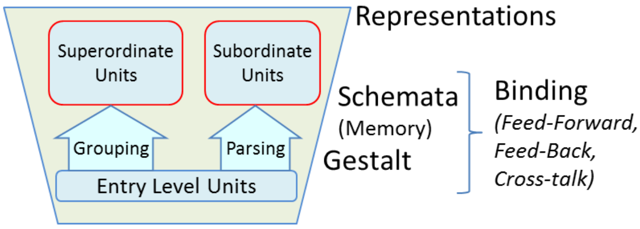
Two parallel approaches may then be applied to these entry level units (Palmer et al., 2003). Firstly, parsing can be employed to delineate complex shapes into subordinate units that help the viewer to create understanding (Palmer & Rock, 1994). For example, parsing of the two lines in a Gestalt continuation example, such as the one provided in Figure 7 (on Page 11 of the layout handout), is likely to be achieved at this level of processing (Palmer & Rock, 1994). Grouping may also take place to aggregate entry level units (e.g. basic shapes and objects) into superordinate units (Palmer & Rock, 1994). Figure 2 provides an example of this concept.



EXPLANATION

In the diagram to the left thirty-six coloured circles are presented. Although each circle could be equated to an entry level unit, the viewer is also likely to create additional levels of perceptual organisation. For example, they are likely to identify a square shape, which is created as a superordinate object by grouping the dots. Additionally, because of the different colouration of the circles, two squares (an inner red square, and an outer blue square or frame) may be identified. In other words complex grouping is implemented to identify a range of superordinate objects from simpler entry level units.

Figure 2: An example of superordinate unit development by grouping



According to the framework espoused by van der Helm (2012), these activities are managed through another level of feature binding that utilises Gestalt related principles. To codify this approach, van der Helm (2012) utilised Structural Information Theory (SIT)[14]. A central tenet of SIT is that the 'visual system selects the most simple interpretation of a given stimulus' (van der Helm, 2012, p. 21). Such selection and interpretation is based on Gestalt related analysis of visual regularities[15] (Palmer et al., 2003; van der Helm, 2012).

In particular, the concept of Prägnanz (good form) is important in interpreting the simplest configuration of the content, because the viewer's mind is aiming to identify a relatively stable understanding of the visual elements (van der Helm, 2012)[16]. However, it is also important

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14. The *Structural Information Theory* (SIT) was originally proposed by Leeuwenberg (1968), and has been expanded in a range of following publications that include: Leeuwenberg (1969); Leeuwenberg (1971); Buffart, Leeuwenberg, and Restle (1981); Leeuwenberg and Buffart (1984); van der Helm and Leeuwenberg (1991); Palmer (1999); Palmer et al. (2003). 'Nowadays, it is probably the most elaborated representational approach to perceptual organisation' (van der Helm, 2012, p. 21).

15. *Regularity* is created by uniformity of identifiable visual factors (e.g. features and spatial positioning) (Ngo, Teo, & Byrne, 2002). As an example of the import of regularity, aspects like symmetry provide visual regularity that is processed with priority, and it becomes highly salient (van der Helm & Leeuwenberg, 1996). Regularity issues are discussed in more detail in the layout handout.

16. This aspect also has implications in relation to the field of phenomenology (Siegel, 2006), because of its effect on holistic perception, which is more than just the synthesis of perceptual material (McClamrock, 2013). For the purpose of brevity the implications of phenomenology

to understand that this assessment of good form is often influenced by the viewer's knowledge (van der Helm, 1994). In other words, the interpretation draws on memory schemas[17] (Intraub, Bender, & Mangels, 1992). As an example, Silveri and Ciccarelli (2009) identified that object recognition is highly dependent on the semantic memory of the viewer[18]. Additionally, the level of familiarity with the configuration of the visual elements can directly affect the way in which they are interpreted, and can even interfere with valid interpretation (Anaki & Bentin, 2009) (e.g. we see what we expect to see, based on identifiable feature analysis). This stage is therefore where the percepts effectively transition to become representations[19], because they are mixed with schema information.

Conscious and unconscious[20] cognition can then be applied appropriately to the representations or percepts (e.g. those forwarded through the dorsal stream as a part of bottom-up attentional processes), which are forwarded to the frontal cortex. In practical terms, this is where the viewer analyses and assesses the groups that have been identified (see Section 1.4.3 in Appendix 1).

There is another key aspect of this model that is illustrated toward the left of the main elements within Figure 1. This aspect relates to the provision of feed-back[21]. Van der Helm (2012) identifies this feed-back as an important element in the network based processing utilised within the brain, as it supports data fitting. For instance, cognition can create top-down attention, which then shapes the way in which the percept or representation is managed or processed[22] (see Section 1.2.3.2 in Appendix 1).

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were not expounded within this thesis. However, a deeper investigation of aspects of phenomenology may be very productive in following research.

17. A *schema* is 'a kind of mental framework' which contains a wide range of different types of memory, and they are 'used by humans to make sense of what they see' (Pathiavadi, 2009, p. 22). In other words, they are groups of memories held in long term storage within the brain, which are called upon to interact with new information in working memory, so the viewer can make sense of the world around them.

18. This mixing appears to be carried out predominantly through the ventral stream, and in particular within the Perirhinal cortex (Murray, Bussey, & Saksida, 2007).

19. Representations are higher level (Crick & Koch, 2003; Pugh et al., 2000) mental constructs (Wu, 2011), which are based on feature conjunctions (e.g. percepts) that can then be linked to previous knowledge (Becker & Horstmann, 2009; Lewis, Borst, & Kosslyn, 2011). More information on representations Appendix 1.

20. Consciousness can be classified as the level of neural activity, which generates 'awareness of the sensations, thoughts, and feelings being experienced at a given moment. Consciousness is our subjective understanding of both the environment around us and our private internal world' (Feldman, 2005, p. 148). The term unconscious refers 'to those mental processes of which the individual is not aware while they occur' (Borchert, 2006, p. 570). See Section 1.2.3.1.2 in Appendix 1 for a more detailed definition of consciousness and unconsciousness.

21. Feed-back relates to the transmission of information from higher processing regions within the brain to lower levels of processing (Laycock, Crewther, Fitzgerald, & Crewther, 2009). Feed-back is explained in more detail in Section 1.4.4.1 in Appendix 1.

22. Bottom-up and top-down attention shaping is explained in more detail http://www.seahorses-consulting.com/DownloadableFiles/ShapingAttentionHandout.pdf.

Additionally, efferent systems[23] can be triggered to generate saccades (Clementz et al., 2007; McDowell, Dyckman, Austin, & Clementz, 2008), or smooth pursuits (Missal & Heinen, 2004)[24]. In practice these eye movements create overt attention, which can then shape how the visual elements are assessed in detail (Loschky, McConkie, Yang, & Miller, 2005). This concept is demonstrated in Figure 3.

EXPLANATION

In the top group to the left, the salient yellow and high contrast black outline are likely to draw the viewer's attention first, and these features appear to 'pop out' of the group. It is therefore most likely that a viewer would assess this as a group of objects trailing down and to the right. Alternatively, in the bottom example to the left, the highly salient square at the bottom right is likely to be analysed with precedence, and therefore the group is liable to be assessed as trailing up and to the left.

Such differences are important in drawing viewer attention to the most salient items and then shaping their cognitive processes.

Figure 3: Modifying Perceptual Organisation due to Changes in Saccade Order

The model provided in Figure 1 therefore demonstrates the linkage between three critical factors for grouping information. These factors are:

- ***Salience.*** Salience factors such as colour can directly affect perceptual organisation (Ziemkiewicz, 2010). Such factors should therefore be taken into account within the design, as discussed within other newsletters.
- ***Schema Mixing.*** Groups of visual elements which are familiar can assist in the aggregation and delineation of the content (Anaki & Bentin, 2009; Honda, Abe, Matsuka, & Yamagishi, 2011), trigger unconscious inferences, and support more rapid perceptual processing (Whittlesea, 1993). Therefore, visual design should implement arrays that help the viewer to leverage their existing knowledge (Aspillaga, 1996).
- ***Gestalt Principles.*** The development of superordinate and subordinate visual units leverage methods that align with the Gestalt principles. This important factor is explained in the following newsletter. Most importantly, this following newsletter discloses a really useful set of insights into the practical utilisation of the mechanics of visual analysis, so you can apply this to enhance all forms of visual design.

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23. Van der Helm (2012) does not include efferent aspects within his model, but they have been included by the author, because of the important role these play in shaping overt attention, and hence perceptual organisation.

24. Smooth pursuit eye movements support continual clear vision of objects, which are moving within the visual environment. (Leigh & Zee, 1999). In this form of eye movement the fovea is aligned to the object on which the person is focussing their attention, and the eye then tracks the movement (Lisberger, 2010). Smooth pursuits are described more extensively in Section 1.6.2 in Appendix 1.

End of Array Part 1

Although this newsletter is a little '*sciencey*', it is well worth your while to understand the concepts that are explained here. The next newsletter and the following ones will illustrate just how important these concepts are, because once you understand the mechanics, you can actually control your presentation designs much more effectively.

You can find the second part, which provides an innovative model for applying Gestalt principles to optimise grouping, at the following web address:

http://www.seahorses-consulting.com/DownloadableFiles/ArrayHandout-Part2.pdf

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