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DELIVERING A UNIFIED DESIGN MODEL (UDM) – TO ALIGN DESIGN TO THE WAY THE HUMAN BRAIN PROCESSES VISUAL INFORMATION

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Presentation tools like PowerPoint are used extensively (Park & Feigenson, 2013), but they are regularly criticised because poor application obfuscates the message (Schoeneborn, 2013). The project introduced in this paper focussed on developing a Unified Design Model (UDM) and an integrated set of research-based design principles, which would help users overcome identified weaknesses in the use of presentation aids. As a bi-product of the research, this project also addressed issues related to other computer-based visualisations. The first step taken to achieve this objective was to review research in neuroscience, biopsychology, and cognitive science. Collected information was used to develop an integrated understanding of the way the human brain processes information, and particularly visual content. This knowledge was then integrated with guidance and results from psychophysics and design related publications, to create a set of draft principles that holistically covered the key aspects of visual design. In all, the information from 1640 publications was used to develop these draft design principles. The validity of these draft principles was tested through an experimental program, which is explained in the PhD thesis at Hilliard (2016). In the interests of brevity, this paper only introduces the UDM framework. However, even this short introduction to the UDM gives important insights into the design of presentations, and other forms of computer-based visualisations, including web pages and e-learning material.

Keywords: Learning design, Psychophysics, Cognitive science, Presentation aids, Web design.

Introduction

Presentation software, such as Microsoft PowerPoint, is widely used in education (Brown, 2007; Coleman, 2009; James, Burke, & Hutchins, 2006; Parette, Blum, Boeckmann, & Watts, 2009), business (Mahin, 2004), and a range of other fields (Schoeneborn, 2013). This type of software is popular, because visual aids can be very effective in improving communication, by generating good comprehension, positive impressions, and viewer attention (Nouri & Shahid, 2005). However, there are also problems associated with its use. For example, authors like Tufte (2003), Aldrich (2008), Taylor (2013), and Thompson (2003) have strongly argued that visual aids such as PowerPoint are often misused, and can therefore be counterproductive in terms of facilitating communication.

Many books and articles have been published that aim to assist designers to improve presentation design. However, even a cursory review of existing ‘design’ books and articles demonstrates that different publications provide contradictory advice, and in many cases the empirical basis for the recommendations is unclear. This issue is borne out by Fritschi (2008, p. 6), who stated that design guidance ‘is still primarily based on the intuitive beliefs of designers instead of empirical evidence'. Consequently, some of the guidance in these design related sources may not be based on sound research. Additionally, as there is disagreement between design authors, it is unclear which set of advice is most appropriate.

On the other hand, there is extensive literature from psychology related fields (including educational psychology, psychophysics, biopsychology, neuroscience, and cognitive science). This material provides recommendations based on empirical research, which can be applied for the optimisation of visual design (Fritschi, 2008). However, the applicability of this work in managing visual design is typically restricted, because of the following limitations:

- The research often does not focus on the broader implications of the findings within a comprehensive design model. As an example, many psychophysical, biopsychological, and neuroscience related publications do not attempt to link the findings back to the optimisation of visual material. Consequently, it can be difficult for designers to apply this type of science-based understanding, to directly improve their visual aids, screen design, web pages, or e-learning systems.
- Most experimentation in these fields has a narrow research focus. For instance, the majority of experiments address singular, or small numbers of, visual attributes (design parameters). This means that the experiments typically do not take into account the complex interaction between different aspects (design factors) within the visualisation.

These limitations illustrate that many research based findings do not directly support the development of holistic design principles, which can be readily applied by designers to improve the quality and effectiveness of their visual material. Consequently, designers are left with a conundrum. On the one hand there has been a significant amount written about visual design, but the validity of the content is unclear. Alternately, there is a great deal of valid research information available, but this material is typically narrowly focussed and not readily usable for managing visual design.

Aim of the Research

A research project was initiated with the aim of helping overcome these problems, by developing a validated set of principles that can be used to optimise the effectiveness of presentations in particular, and visual design in general. In practice, this meant rigorously assessing the validity of design publications, by cross-matching the recommendations with science-based sources. To facilitate this endeavour a Unified Design Model (UDM) was created.

This document introduces the UDM and outlines the key design attributes within this framework. The paper also provides a short overview of the UDM development process, and it concludes with the hypotheses investigated to validate the draft principles.

The Unified Design Model

Laying the Foundation

It became obvious when assessing a wide range of design publications and research papers, that various authors use different nomenclature to categorise the visual attributes. The first step toward achieving the research objective was therefore to create a common framework for understanding the various visual attributes.

After investigating a range of options, Tufte's (1990) design advice was used as the foundation for the model. Tufte's (1990, 2006, 2007) research provided a sensible starting framework for categorising most of the visual attributes. Just as importantly, it seemed apposite to apply the research from one of PowerPoint's greatest critics, to help develop a set of design guidelines that would help to overcome the problems he identified.

Tufte's (1990) framework of visual attributes included aspects such as complexity, colour, background, layout, arraying of the information, typography, and graphics. However, Tufte's (1990, 2006, 2007) design guidance was predominantly focussed on static elements, so animation was not a principal part of his design framework. Appropriate animations can, however, assist in generating comprehension, positive impressions (Kim, Yoon, Whang, Tversky, & Morrison, 2007; Rebetez, Bétrancourt, Sangin, & Dillenbourg, 2010), and attention (Dorr, Martinetz, Gegenfurtner, & Barth, 2010; Jamet, Gavota, & Quaireau, 2008). For this reason, animation has been added to the framework developed from Tuft's (1990, 2006, 2007) material. Finally, a key thrust of Tufte's (2003) argument against the use of PowerPoint is that the visualisation overwhelms the message structure and content. He therefore recommended that the message structure and content should take precedence.

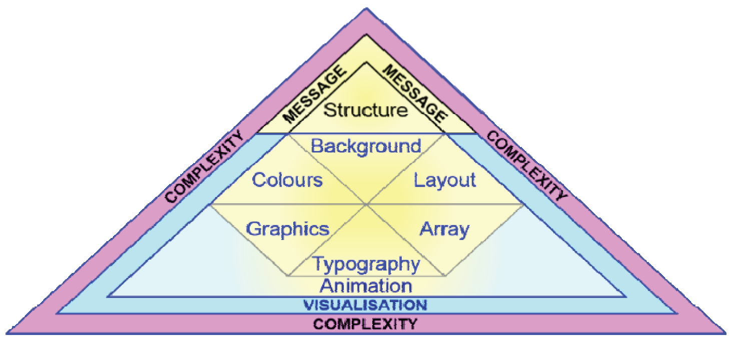


Figure 1. The attributes within the Unified Design Model

These attributes were then validated against other design and science literature, to ensure that the identified elements provided a suitable holistic framework. As a result of this extensive review, the UDM framework shown in Figure 1 was developed.

The attributes within this framework can be described as follows:

- ***Complexity.*** Within this context, complexity relates to 'the number of independent features of the stimuli and meaningfulness, that is to say, a factor related with the number and variability of the elements [on the screen and in the content], and a factor related with the overall structure of the elements' (Roberts, 2007, pp. 22-23). According to Tufte (1990), inappropriate use of complexity can adversely affect the communication of the pertinent information. For example, overly complex information imposes significant cognitive processing costs (Aksentijevic & Gibson, 2012), which can adversely affect learning and communication outcomes (Kyndt, Dochy, Sruyven, & Cascallar, 2011; Parks, Murray, Elfman, & Yonelinas, 2011), and create negative impressions about the content (Roberts, 2007). Alternately, low levels of complexity can also reduce the level of comprehension (McNamara, Kintsch, Songer, & Kintsch, 1996), attention (Geissler, Zinkhan, & Watson, 2006), and impressions (Balfanz, Herzog, & Mac Iver, 2007; Marks, 2000).
- ***Message content and structure.*** This attribute refers to the content being communicated through the presentation of the material. For instance, this covers the structure and amount of information to be processed by the audience. The message content and structure is an important source of complexity (Lang, Park, Sanders-Jackson, Wilson, & Wang, 2007), and can have a significant impact on comprehension (O'Keefe and McCornack, 1987; Peterson, 2011; Tennyson, 1980), impressions (Stoner, 2007; Whalen, 1996) and attention (Grosz and Sidner, 1986; Økland, 2011). Consequently, this attribute forms a fundamental element of the design.
- ***Visualisation attributes.*** The visualisation attributes formed the key focus of this research project, and include the following seven categories of variables:
  - ***Colour.*** The term colour refers to the application of hues, saturation, luminance and contrasts within the visual display. Colour is an important variable, because it can

significantly affect the communication of information (Hanke, 1998). For instance, colour can add reality, assist the viewer to discriminate between visual elements, focus attention on the important information (e.g. by using salience), code and link logically related elements, create impressions, and generate emotional responses (Jones, 1997; Kose, 2008; Pett & Wilson, 1996).

- ***Background.*** This attribute refers to the background colour, texture, and other visual elements on the screen that act as a backdrop, and their interaction with the foreground content. These background colours and visual elements can appreciably influence the effectiveness of the communication (Tufte, 1990). As an example, background clutter (Bravo & Farid, 2006), background content and context (e.g. gist information) (Epstein, 2005; Larson & Loschky, 2009; Otsuka & Kawaguchi, 2007), as well as background contrast, luminance (Engmann et al., 2009) and colour (Bedwell, Brown, & Orem, 2008) can all affect perception and cognition.
- ***Layout.*** Tufte (1990) refers to layout as the structuring of the entire visible content, which is processed holistically. Therefore, in the context of the UDM, the term layout refers to the general arrangement of objects over the entire expanse of the screen/slide. The layout of visual information can have a significant effect on viewer impressions (Altaboli & Lin, 2011) and comprehension (Wästlund, Norlander, & Archer, 2008). Additionally, good layout can shape attention, so the viewer processes the most important aspects of the information (Pralle, 2007).
- ***Array.*** The term array refers to the localised grouping, positioning, or conjoining of visual objects (Donderi, 2006). In other words, whereas layout addresses the entire screen arrangement, array signifies the grouping of sub-elements within the layout. This differentiation from layout is important, because visual material is processed at two levels (Sanocki, Michelet, Sellers, & Reynolds, 2006). Firstly, the entire gist of a scene (e.g. the entire screen/slide) is typically analysed as a whole entity by viewers once it is exposed (Henderson & Hollingworth, 1999; Henderson, Williams, Catstelhano, & Falk, 2003). Significant meaning is generated through this initial gist analysis of the layout (Tileagă, 2011; Wolfe, Võ, Evans, & Greene, 2011). For instance, object recognition within a scene is greatly influenced by the context generated by the gist analysis (Jiang, Sigstad, & Swallow, 2013; Wolfe et al., 2011). From the gist analysis, up to about 13 objects, or arrays of objects, can be assimilated (Sanocki, Sellers, Mittelstadt, & Sulman, 2010), and attention is then applied to process these (Betz, Kietzmann, Wilming, & König, 2010; Matsukura, Luck, & Vecera, 2007). It is this second layer of processing that is affected by the arraying of individual screen elements (Sanocki et al., 2006). Tufte (1990) identified that this arraying of the information within visual groupings is an important aspect of visual communication.
- ***Typography.*** This visual attribute relates to the way in which the words and sentences (text) are represented on the screen. As discussed in Sanocki and Dyson (2012), aspects such as the size, type, and the colour of the fonts used can directly affect comprehension of the textual information. Additionally, typography can influence emotions (Koch, 2011), and attention (Fondren, 2009).
- ***Graphics***. The term graphics covers pictures, graphs, and any form of pictorial element used within the display (i.e. anything that is not just text). The use of appropriate graphics can significantly enhance comprehension (Mayer, 2001), generate viewer attention (Tangen et al., 2011), and positively shape people's impressions (Gu, Liu, Van Dam, Hof, & Fan, 2013).
- ***Animation***. Within this UDM framework, animation means the utilisation of techniques to create transitions, changes, or movements of material on the screen. The application of appropriate animations can assist in generating comprehension and positive impressions (Kim et al., 2007; Rebetez et al., 2010). Additionally, motion or change within the visual field can attract attention to appropriate visual elements (Dorr et al., 2010; Jamet et al., 2008), or interfere with the communication of the material if the animations are poorly applied (Lowe & Boucheix, 2011)

The UDM also illustrates key interactions between the various attributes. For instance, colour, background, layout, array, typography, and graphical elements all interact (Tufte, 1990). Additionally, the application of animation can affect each of the other attributes (de Koning, Tabbers, Rikers, & Paas, 2007). Visualisation attributes also interact with the message and structure (Medley & Haddad, 2011). As an example, complex message content can be made more or less understandable, dependent on the way it is visualised (Chaiken & Eagly, 1976).

Lastly, as shown in Figure 1, complexity encompasses all of the other attributes. This is because all of these other attributes interact to generate complexity. For instance, the colour combinations used (Cummings & Tsonis, 2006; Pathiavadi, 2009), pictorial/graphical design techniques applied (De Westelinck, Valcke, De Craene, & Kirschner, 2005; Makaramanee, 1985; Moreno & Mayer, 1999), the typography utilised (Green, 1981; Rayner, Reichle, Stroud, Williams, & Pollatsek, 2006), and the animations that are implemented (Huff & Schwan, 2011; Mineo, Peischl, & Pennington, 2008; Schnotz & Rasch, 2005) directly influence viewer assessments of complexity.

Applying the UDM

The UDM framework was used as a foundation for rationalising and amalgamating information in diverse research and design publications. The full listing of the 1640 publications used for this analysis is provided in Hilliard (2016). However, the various documents can be broadly grouped as explained in the following subsections.

Neuroscience, Biopsychology and Cognitive Science Publications

More than 600 neuroscience, biopsychology and cognitive science papers were assessed in the literature review, and key information from these was integrated to develop an understanding of perceptual and cognitive processes. In particular, the following key models were developed:

- An end-to-end visual processing model was created, which integrated available research on neural physiology and the behaviours and roles of key structures in the eyes and brain. This reverse engineering of the neural systems allowed the likely effects of different aspects of the visual elements to be determined.
- As the concepts of attention and awareness were critical to understanding how visual content is processed; Attention and Continuum of Awareness models were created. These integrated models provide a useful holistic framework for understanding how differences in the visualisation affect perception and cognition at a fundamental level.
- A model that explains visual grouping was also developed, and applied to understand the optimisation of layouts and arrays.
- Information related to other key processes (e.g. reading and motion tracking) was also collated, so this material could be applied to determine likely effects of different visual treatments.

Presentation Design Publications

There has been so much design material published that it would have been impossible to assess all of it in detail. Consequently, it was decided to focus on suitable representatives of this material. After analysing numerous presentation design publications, five books were selected as exemplars. This selection was also simplified by leveraging expert advice on the most influential books within this domain. The five publications used in this project were identified in Gabrielle and Alvarez (2012), who ‘asked 7 of the top presentation experts in the world to tell us what books most inspired them to be better presenters’. In this survey, each expert was asked to evaluate widely used and popular books in terms of their coverage of content development, design, and delivery techniques. The top five visual design publications that they selected are shown in Table 1.

Table 1. Selected publications for presentation design analysis

Title	Panel Rating	Author/Reference
Slide:ology	#1 for design	Duarte (2008)
Presentation Zen	#2 for design	Reynolds (2012)
Presentation Zen Design	#3 for design	Reynolds (2010)
Speaking PowerPoint	#4 for design	Gabrielle (2010)
Clear and to the Point	#5 for design	Kosslyn (2007)

This group of publications was representative, because it demonstrated the gamut between philosophically design-focussed and more science-defined publications. For example, Reynolds (2010, 2012) predominantly concentrated on aesthetic design concepts based on the Zen philosophy. Conversely, Kosslyn (2007), and to a lesser extent Gabrielle (2010) and then Duarte (2008), appeared to found more of their recommendations on science-based research. Consequently, these five publications were likely to provide advice that represented the range of design publications available. The selected publications were reviewed in detail, to identify common and divergent recommendations that could then be assessed in relation to the psychology related research.

Psychophysics Related Publications

Psychophysics ‘studies the relationships between stimulus characteristics and the perception of those stimuli’ (Matsumoto, 2009, p. 412). In relation to this project, the term psychophysics refers to research and findings examining different visualisation attributes. Information from more than 1000 psychophysics related publications was integrated within this literature review, to help assimilate design recommendations and create a set of science-based draft principles. These publications typically covered narrowly focussed experiments, so they needed to be assessed in terms of the UDM and other papers covering similar topics. Additionally, the psychophysics material was cross-linked to the models and frameworks created through the neuroscience, biopsychology and cognitive science research review, to help determine low level relationships between outcomes and likely causation.

As a direct result of this analysis a range of additional models were developed to facilitate understanding of key design issues. These models included developing a Complexity Curve (discussed below), a Colour Salience Model (which identified fundamental colour prominence measures), a Gestalt Interaction Model (that delivers a framework for understanding the relationship between various Gestalt and aesthetic design principles), a font size readability calculator (to determine optimal point sizes for different fonts, so they could be applied effectively to promote legibility and/or readability), a rigorous process for graphics selection, and a clear methodology for identifying optimal animation strategies. Each of these models is explained in more detail within Hilliard (2016).

The information from the psychophysics publications was applied to:

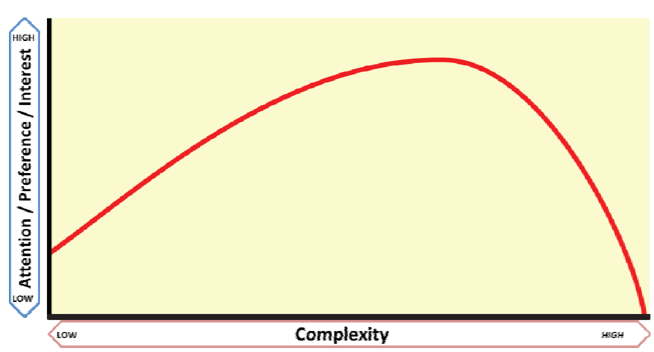
- validate recommendations made in the design publications;
- identify other design principles that had not been expounded in the presentation design publications; and
- identify areas of ambiguity that required further investigation, to ratify the design principles.

This last point was of particular import, because it facilitated the development of hypotheses that were most applicable for investigation within the framework of this research.

Identified Ambiguities

The key ambiguities identified through the literature review are shown in Table 2. Each of these ambiguities reflect situations in which empirical research on these issues was not available, or conflicting information had been identified in the literature review.

Table 2. Ambiguities selected for investigation in this project

Attribute (Code)	***Description of the Ambiguity***
Colour & Background (RCB1)	***The effects of warm and cool colours.*** Warm hues like yellow are highly stimulating colours, which may promote arousal, memory, perception, awareness (Massachusetts General Hospital, 2009), and attention (Berman, 2007). However large areas of full hue warm colours are often disliked (Berman, 2007), and overuse of these hues appear to cause over-stimulation that can induce psychological stress (Daggett, Cobble, & Gertel, 2008). Alternatively, as identified by Mehta and Zhu (2009) cool colours like blue can enhance cognition and performance, and blue light with higher luminance levels may also enhance arousal (Lehrl et al., 2007). Conversely, cool colours are also reported as being calming (Madden, Hewett, & Roth, 2000), which appears counter-intuitive noting the arousal these hues can create. Therefore, variations have been identified in the effects of warm and cool colours, but earlier research had not defined where the extent and characteristics associated with warm and cool colours transition from one effect to the other.
Layout/ Array (RLA1)	***Conforming to standard scanning patterns.*** Design publications such as Duarte (2008) and Gabrielle (2010) recommend that the layout of slide elements should take into account the viewer's expected scan path. However, identified standard scan paths (e.g. Gutenberg, F, Z, or Zig-Zag patterns) were defined for text heavy content viewed by people from western cultures (Bradley, 2011). Consequently, these layouts are unlikely to be as appropriate for people from non-western cultures (Abed, 1991; Brockman, 1991; Plocher, Rau, & Choong, 2012). Additionally, non-text layouts may be processed in very different ways (Bindemann, 2010; Engmann et al., 2009; Suvorov, 2013). From the literature assessed in this project, it was unclear where differing scan paths would be appropriate, and what the effects would be if various layout approaches applied.
Layout/ Array (RLA2)	***Slide titles.*** Gabrielle (2010) provided clear design advice on separating the slide title from the body text. Consequently, the draft principles included recommendations on creating this type of separation. However, no definitive research could be identified to validate these recommendations. This design advice therefore needed to be substantiated through an empirical assessment.
Complexity (RX1)	***Defining the peak of the complexity curve.*** Information from Vitz (1966), Wang, Yang, Liu, Cao, and Ma (2014), Berlyne (1970), Day (1967), Hillyard (1979), Roberts (2007), Thorson, Reeves, and Schleuder (1985), McNamara, Kintsch, Songer, and Kintsch (1996), Surenda, Nikunj, and Spears (2005), Geissler, Zinkhand, and Watson (2006), Granger (2012), Schnotz and Kurschner (2007), and Schnotz and Rasch (2005) was coalesced to develop a framework for selecting optimal complexity. A key element of this approach was applied within the Complexity Curve, which is illustrated in Figure 2.  **Figure 2.** The Complexity Curve – Illustrating the generalised relationship between complexity and attention, preference and interest

Attribute (Code)	***Description of the Ambiguity***
	This curve indicates that moderate complexity provides the optimal balance for visual aid design. However, the literature review used to develop this Complexity Curve model identified that there was a paucity of readily usable material that could be applied to quantify moderate complexity. For instance, Cognitive Load Theory (CLT) provides a general framework for understanding the complexity issues and their interaction (Schnotz & Kurschner, 2007), but it does not directly support the definitive identification of the peak for the Complexity Curve. This fundamental aspect of complexity was therefore unclear and required additional investigation.
Typography (RT1)	***Serif and sans serif fonts.*** According to many researchers (e.g. Mackiewicz (2007); Earnest (2003); Beymer, Russell, and Orton (2008)) there may not be a significant difference between serif and san serif fonts for supporting readability. However, as discussed in more detail within Hilliard (2016), it was possible that some characteristics of serif fonts (such as Times New Roman) may positively affect readability and comprehension. This aspect therefore required further investigation, because it was possible that some of the preceding research may not have appropriately isolated causative factors from confounding variables, to isolate differences in experimental outcomes.
Typography (RT2)	***Rotated text.*** Although a substantial amount of research has been conducted into the utilisation of rotated text (e.g. Koriat and Norman (1985); Yu, Park, Gerold, and Legge (2010)), it was unclear from these experiments what effects this font modification would have in a complex visual environment. For example, it was possible that this change would reduce readability, or that the disfluency created by this change might actually improve comprehension.
Typography (RT3)	***Bullet effects.*** Authors such as Gabrielle (2010) and Kosslyn (2007) propose the utilisation of bullets to clarify and reinforce the message. Other authors such as Aspillaga (1996), and Hilligoss and Howard (2002), recommend the specific use of meaningful icons as bullets (e.g. ✓). Bachfischer, Robertson, and Agnieszka (2007) suggest that using these types of iconic bullet points can generate semiotic benefits (e.g. creating inferred meanings). However, a detailed investigation conducted for the literature review identified a paucity of specific empirical experimentation that would support these propositions. Further research was therefore required.
Graphics (RG1)	***The effects of graphics in titles.*** According to Horton (1993) the provision of graphical content that is directly associated with the text, can assist in generating universal understanding. However, the literature review conducted for this project found no advice that advocated utilising graphics in the title area, to facilitate viewer understanding. The absence of such recommendations does not align to the possible benefits that could be generated by utilising text and graphics in the title, to support multimodal communication. Therefore, this aspect required additional investigation.
Animation (RN1)	***The effects of text clearing.*** The concept of text clearing was defined in this project, as an approach that could help to manage visual complexity in slideware, by removing or greying-out text and graphics after moving on to the next point. However, there appeared to be a lack of detailed science-based evidence to support the efficacy of this approach within a complex visual environment, like a PowerPoint presentation.
Animation (RN2)	***Multiple cueing.*** The term multiple cueing relates to an approach that may be of assistance in generating attention by providing multiple visual stimuli simultaneously or in sequence. However, researchers such as Alvarez and Franconeri (2007) indicated that when used incorrectly, these techniques may create perceptual inhibitions that could suppress processing of the visual information. This aspect therefore required additional investigation to determine the optimal utilisation of these techniques.
Animation (RN3)	***Animation fly-over.*** Research by Moore, Mordkoff, and Enns (2007) found that the perception of moving visual elements was influenced by (and influences) the background over which the object moves. It was therefore assumed that moving animated objects over existing visual elements on the screen could possibly interfere with accurate perception. However, an extensive investigation of existing research did not disclose any experiments into the practical

Attribute (Code)	*Description of the Ambiguity*
	implications of this effect during presentations. This aspect therefore required additional exploration, to determine the practical consequences of animation fly-over.
Animation (RN4)	***Vertical fly-in.*** The default direction for fly-in animations within PowerPoint is from the bottom. However, this approach does not accord with the advice provided by Ke, Lam, Pai, and Spering (2013) and Tatler, Hayhoe, Land, and Ballard (2011), who indicated that horizontal visual tracking is superior to vertical tracking. Just as importantly, Ke et al. (2013) identified that upward vertical tracking (which is what is induced by fly-in from bottom animations) is very poorly handled by the human perception systems. It therefore appeared apropos to investigate whether the PowerPoint default was the most suitable approach, or whether this form of animation is suboptimal.

Hypotheses

The 12 ambiguities identified for investigation can be aligned to the UDM as illustrated in Figure 3, which applies the same coding used in Table 2.

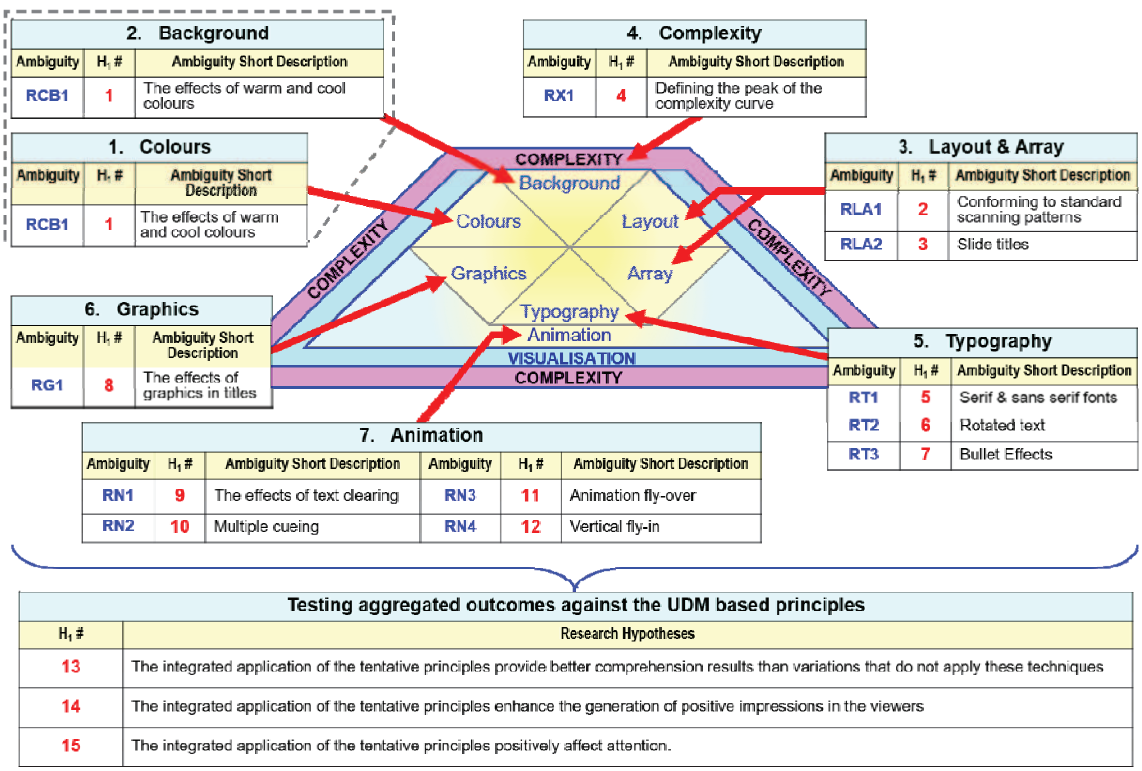


Figure 3. Mapping the ambiguities and hypotheses to the UDM

This figure also shows the 15 research hypotheses selected for assessment. The first 12 of these hypotheses aimed to directly investigate the identified ambiguities. Hypotheses H_1#13 to H_1#15 focussed on assessing the aggregated outcomes of the different experiments. This integrated assessment was intended to help determine whether previous narrowly-focussed research could be effectively integrated to create detailed design principles, and therefore fulfil the primary aim of this research project. Table 3 outlines the hypotheses in more detail.

Table 3. The research hypotheses

Ambiguity Investigated	Research Hypothesis (H_1) Number	Research Hypothesis
RCB1	H_1# 1	The amount, and presence or absence, of warm or cool colours affects viewer comprehension and impressions.
RLA1	H_1# 2	The application of layouts and arrays that conform to standard scanning patterns (as listed in the draft principles) positively affects viewer comprehension and impressions.
RLA2	H_1# 3	Removing the separation and highlighting from the content slide titles affects viewer comprehension and impressions.
RX1	H_1# 4	Moderate complexity (as achieved through the application of the identified draft principles) enhances viewer comprehension and impressions.
RT1	H_1# 5	Utilising serif fonts affects viewer comprehension and impressions, when compared with sans serif fonts.
RT2	H_1# 6	The application of rotated text in a complex visual environment affects viewer comprehension and impressions.
RT3	H_1# 7	The use of bullets, and particularly connoting bullets, affects viewer comprehension and impressions.
RG1	H_1# 8	The presence or absence of graphics in the content slide titles affects viewer comprehension and impressions.
RN1	H_1# 9	The application of text clearing (by greying-out the text as specified in the draft principles) affects viewer comprehension and impressions.
RN2	H_1# 10	The use of multiple cueing and synchronous symmetrical animation (as specified in the draft principles) affects viewer comprehension and impressions.
RN3	H_1# 11	Animation of objects over extant visual content affects viewer comprehension and impressions.
RN4	H_1# 12	Vertical fly-in of content affects viewer comprehension and impressions.
Holistic Issues	H_1# 13	The integrated application of the draft principles generate better comprehension for viewers than variations that do not apply these principles.
	H_1# 14	The integrated application of the draft principles generate more positive impressions for viewers than variations that do not apply these principles.
	H_1# 15	The integrated application of the draft principles generate more positive attention for viewers than variations that do not apply these principles.

As illustrated in the preceding table, many of these hypotheses are relatively broad, and hence required a range of different experiments to adequately test them. Consequently, the complex hypotheses were further delineated into sets of Key Testable Propositions (KTPs). A total of 25 KTPs were identified and these are mapped to the ambiguities, hypotheses and UDM, as illustrated in Figure 4. This diagram shows that some KTPs just map to one hypothesis, while other hypotheses use many KTPs. For instance, KTPs 1.A., 1.B., 1.C., 2.A., 2.B., 2.C., and 2.D. were used to support the investigation of H_1 # 1.

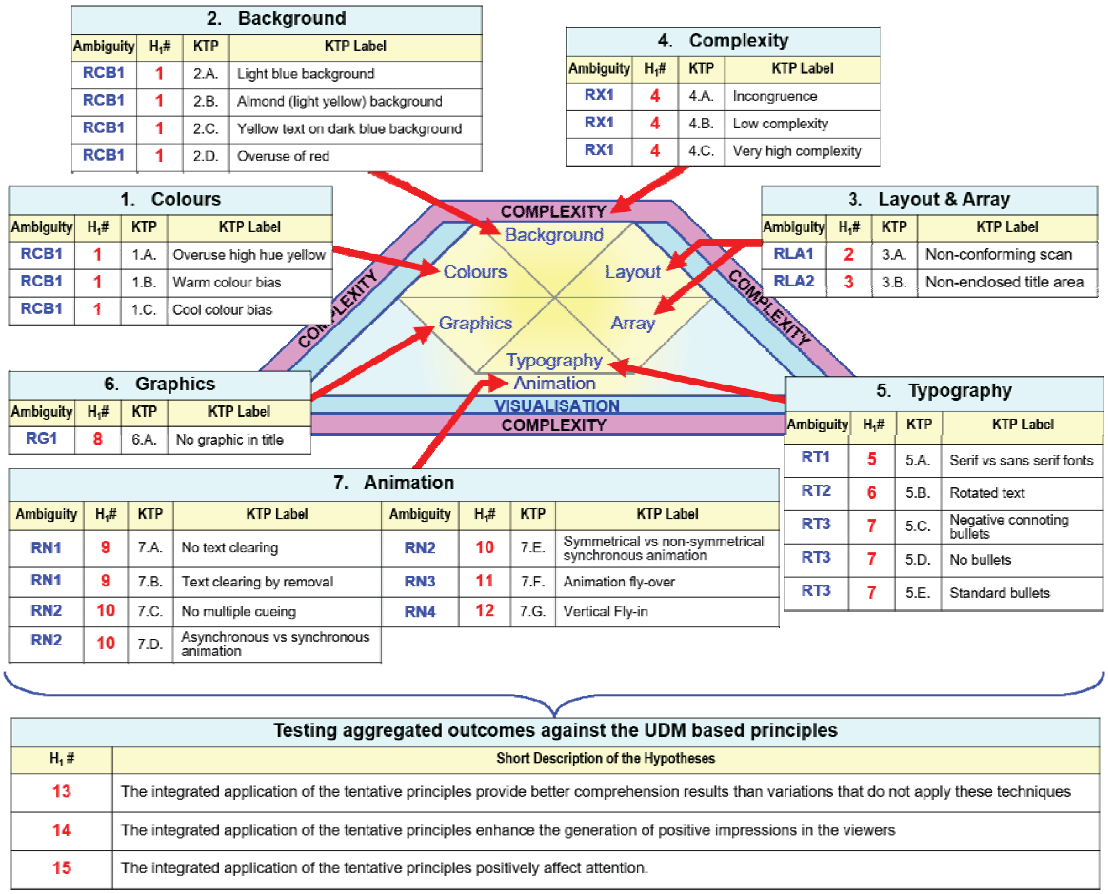


Figure 4. Mapping the KTPs to the ambiguities, hypotheses and the UDM

The first step in testing these hypotheses was to apply the draft principles to develop experimental presentations and associated materials. As these presentations directly reflected the aggregation of design and science-based recommendations, the effectiveness of the draft principle integration could be investigated holistically. These presentations were defined as the controls. Variations of these principles-based control presentations were then created. Each of these variant presentations covered the same material as the associated control, but the slideshow was modified in line with the KTPs being investigated. Comprehension, impressions and attention data were then captured in the experiments, and assessed to investigate:

- each of the ambiguities; and
- whether the integration of previously narrowly focussed research could be applied effectively within a holistic design model.

These aspects, and the methodologies applied to conduct the investigation detailed in Hilliard (2016) will be discussed in future papers.

Research Implications

The UDM, models, and principles developed through this project provide a framework that can assist designers by:

- leveraging a wide range of science-based research and practical design advice, which helps to separate the fact from fiction in the implementation of visual design;

- investigating identified ambiguities, to resolve gaps and uncertainties related to existing research; and
- providing this information within an integrated design methodology that addresses each of the visual attributes individually and holistically.

The research introduced in this paper can therefore provide guidance that may be used to enhance visual design, and also provide a consolidated framework to facilitate future science-based exploration of this topic. The results of this project can therefore have direct implications for a range of different fields, which include:

- ***Education.*** As illustrated in Hilliard (2016), the application of the UDM and principles can definitively improve comprehension, impressions, and attention outcomes in educational situations. Consequently, the developed guidance may be applied to enhance instructional presentations. Additionally, as a bi-product of this research, these design principles are also likely to be useful in the creation of e-learning systems.
- ***Other types of presentations.*** These models and principles are based on elemental psychophysical, neuroscience, cognitive, and biopsychological research. The recommendations are therefore focussed on optimising the design, to conform with fundamental human processing methods for visual information. As a result, the developed principles may be very broadly generalisable, which means that they can be applied to most types of presentations and visualisation tools. The research may therefore be of use to anyone developing presentations for business, marketing, sales, or any other form of structured communication that applies visual aids.
- ***Wider visual design.*** As discussed in the preceding point, the guidelines leveraged fundamental aspects of human visual processing to identify methods for enhancing design. Consequently, the resulting recommendations may also be applied to many other situations. For example, similar techniques are likely to be applicable when designing and implementing web pages, or other types of Graphic User Interface (GUI).
- ***Psychology.*** By integrating diverse psychological research material and then testing the outcomes, the project provided many useful insights for research in psychology, and the associated sub-disciplines used in this research. In particular, assimilative frameworks such as the Attention Model, Continuum of Awareness, Complexity Curve, and Gestalt Interaction Model developed for this project provide a constructive theoretical foundation for understanding these issues.

Conclusion

A primary aim of this research project was to integrate diverse multidiscipline material to create a Unified Design Model aligned to the way people process visual information. This article just introduced the UDM, which integrates aspects related to colour, background, layout, array, typography, graphics, animation, message structure and content, and complexity within a holistic framework.

The introduction of the UDM in this paper has also laid the foundation for the discussion of the experiments, which will be explained in following papers. These following papers will flesh out the concepts, to give guidance on developing presentations, web pages, or e-learning platforms. Additionally, these frameworks can assist future researchers to develop experiments that better manage attribute interaction.

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