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Optimising Visual Layout for Training and Learning Technologies

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Optimising Visual Layout for Training and Learning Technologies

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Abstract

The layout and arraying of information in electronic aids used for training can affect viewer comprehension and impressions. This paper explains existing layout guidance, and defines an integrated design model for applying these recommendations. To test the efficacy of this model, experiments were conducted under Murdoch University Human Research Ethics Committee (HREC) approval 2010/012. In these experiments two similar presentations were created, which contained the same content. However, one of these presentations applied the integrated design model to shape the positioning of the visual content, and a variant was developed that flipped the layout, so it did not conform to this design approach. The experimental results demonstrated that developing layouts that bias the important visual material to the top and left positively influenced viewer impressions. These results will have design implications for predominantly text-based material (e.g. presentations, web-pages, e-learning systems); particularly when the content is being delivered to people who typically read from left to right and top to bottom.

Keywords learning design, presentation aids, web-page, visual design, psychophysics.

1 INTRODUCTION

Bateman et al. (2001) identified that the layout of presented information can directly impact on a viewer's comprehension and impressions. To optimise layouts, publications such as Bradley (2013), Duarte (2008) and Gabrielle (2010) recommend that material laid out in electronic visual aids should be aligned to standard patterns of visual scanning. These authors cited patterns defined as the Gutenberg Diagram, Z-Pattern, Zig-Zag Pattern, and F-Pattern. The scan patterns are explained below. Eldesouky (2013) indicated that in some cases the application of visual layouts that reflect these patterns can facilitate understanding of a visual hierarchy, which can aid comprehension of the material. According to Mohler and Duff (2000), facilitating this standard flow of the viewer's eye across the material reduces the number of eye movements required to handle the content, and consequently helps to improve the efficiency of mental processing.

However, these types of layout may not always be ideal. For instance, Plocher et al. (2012) identified that such scan pattern based layouts are not appropriate for some cultures, and Suvorov (2013) showed that the scanning techniques employed by screen viewers are context dependent.

This paper investigates whether advice on applying the Gutenberg Diagram, Z-Pattern, Zig-Zag Pattern, or F-Pattern for screen design is appropriate. As this paper is focussed on the application of these scan patterns to aid learning through the use of information technology (e.g. slideware, web-pages and e-learning systems), the analysis relates to the implications in terms of comprehension and learner impressions about the visual material. To achieve this objective, the paper explains the outcomes from an experiment that was one element of a larger project presented in Hilliard (2016). Therefore, the experiment reflects research within a more extensive design framework, which is discussed below.

2 FRAMEWORK FOR THE ASSESSMENT

Whereas much of the previous research on visual design has addressed individual visual attributes, the project discussed in this paper began by developing a Unified Design Model (UDM). The intent of this model was to provide a framework that could be applied to assess individual attributes of visualisations, and their interactions with other visual characteristics. The key attributes within this model include colours, background, layout, array, typography, graphics, animation and complexity. A detailed description of all of the attributes is beyond the scope of this paper, as the focus is on the highlighted elements illustrated in Figure 1.

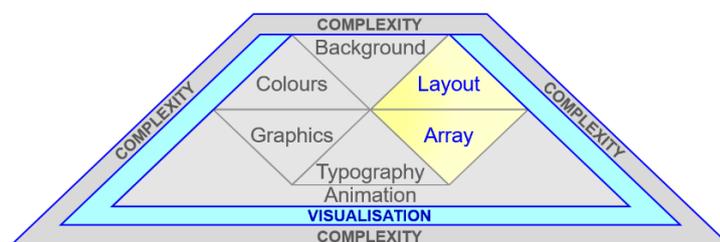


Figure 1: The Unified Design Model (UDM), with the Layout and Array attributes highlighted

As shown in Figure 1, two highlighted terms have been applied within the UDM, and both refer to the positioning of information on the screen. These two terms are:

- **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. The layout of visual information can have a significant effect on viewer impressions (Altaboli and Lin 2011) and comprehension (Wästlund et al. 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 et al. 2006). Firstly, the entire gist of a scene (e.g. the entire screen) is typically analysed as a whole entity by viewers once it is exposed (Henderson and Hollingworth 1999; Henderson et al. 2003). Significant meaning is generated through this initial gist analysis of the layout (Tileagă 2011; Wolfe et al. 2011). For instance, object recognition within a

scene is greatly influenced by the context generated by the gist analysis (Jiang et al. 2013; Wolfe et al. 2011). From the gist analysis, up to about 13 objects, or arrays of objects, can be assimilated (Sanocki et al. 2010), and attention is then applied to process these (Betz et al. 2010; Matsukura et al. 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.

Optimal positioning of content within the screen should therefore facilitate processing at both levels, to aid perception, cognition (Cavanagh 2011), and the generation of attention (Pettersson 2010; Wolfe et al. 2011). Additionally, the layout should also be designed to be rich and appealing, so the gist can help to generate positive attitudes (Agarwal and Karahanna 2000).

One technique recommended to achieve this objective is to position the material, so that it conforms to standard eye scanning patterns (Bradley 2011). An overview of these patterns is provided in the following section.

3 AN OVERVIEW OF THE IDENTIFIED EYE SCAN PATTERNS

3.1 The Gutenberg Diagram

The Gutenberg Diagram was espoused by Arnold (1978), who aimed to characterise the general flow of the eye across homogenous material like a text filled newspaper page. However, this scan pattern has also been identified as being appropriate for a full screen of text (Hanington 2006). The premise of the Gutenberg diagram is illustrated in Figure 2. This diagram indicates that readers from western cultures will typically scan from the top left (the Primary Optical Area (POA)) and gravitate toward the bottom right (the Terminal Area (TA)), by reading the content through a series of horizontal movements along the axis of orientation (e.g. reading lines of text from left to right and from top to bottom). The Gutenberg Diagram also splits the readable area into four quadrants, and indicates that the viewer is likely to pay less attention to the fallow areas (Arnold 1978). However, in this layout concept the viewer is likely to pay more attention to the strong fallow area (top right corner) than to the weak fallow area (bottom left corner) (Bradley 2013).

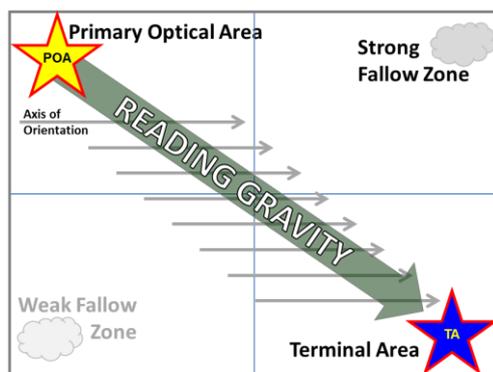


Figure 2: The Gutenberg Diagram

3.2 Z-Pattern and Zig-Zag Pattern

The Z-Pattern method of scanning has been reported by various authors over many years. For instance, Schroeder and Holland (1969) identified this pattern in vigilance activities. Later researchers such as Cooke (2005) identified the applicability of this pattern for web-pages. Additionally, authors such as Campbell (2002) recommend the direct applicability of this pattern when developing presentations.

The Z-Pattern indicates that viewers will begin scanning in the top left, move horizontally to the top right, and then diagonally to the bottom left, before gravitating horizontally to the bottom right of the screen (Bradley 2013). The left hand diagram in Figure 3 illustrates this concept. According to Bradley (2013) the Z-Pattern is a useful representation of standard eye scanning paths for simple designs, but for more complex content the Zig-Zag pattern (shown to the right in Figure 3) may provide a better representation. This second visual search model has many similarities with the Gutenberg Diagram, because each horizontal path represents the axis of orientation, and the general scanning gravity is from the top left to the bottom right. Research by Holmqvist et al. (2003) identified that this pattern was

particularly clear for screen based newspaper presentations, where the content was predominantly text, but the columns also contained some graphical content.

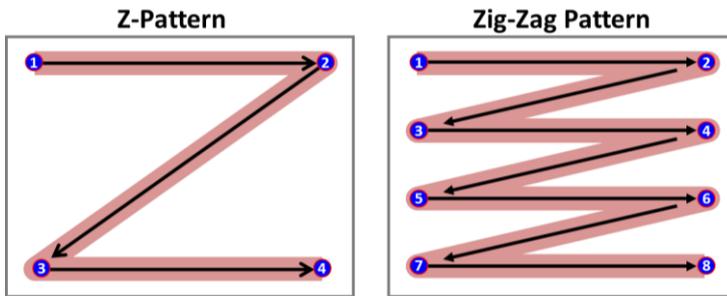


Figure 3: The Z-Pattern and Zig-Zag Pattern diagrams

3.3 F-Pattern

Nielson (2006) conducted research into the standard methods for visually scanning text based web-pages, and used these experiments to identify the so-called F-Pattern, which is illustrated in Figure 4. The F-Pattern concept posits that the eye will typically begin in the top left hand corner and then move across and down the screen through a series of horizontal sweeps, which typically remain progressively closer to the left hand margin, as the scan proceeds down the screen. Experiments by Shrestha and Owens (2009) indicated that this strong bias for giving priority to content on the top and left of the screen for web-pages was a strong driver for visual processing, and was applicable to both text-based and icon-heavy screens.

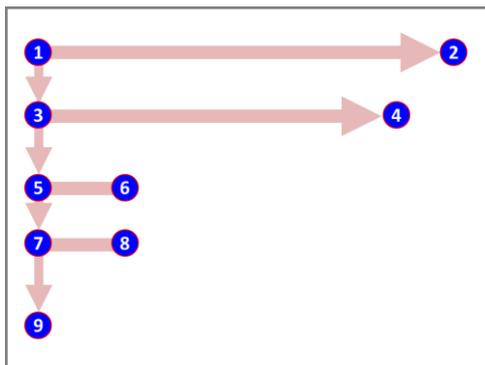


Figure 4: The F-Pattern diagram

3.4 Creating an integrated layout model

As illustrated in the preceding sections, there are similarities between these identified scan patterns. The research reported within Hilliard (2016) integrated these similarities, to create the type of layout model illustrated in Figure 5.

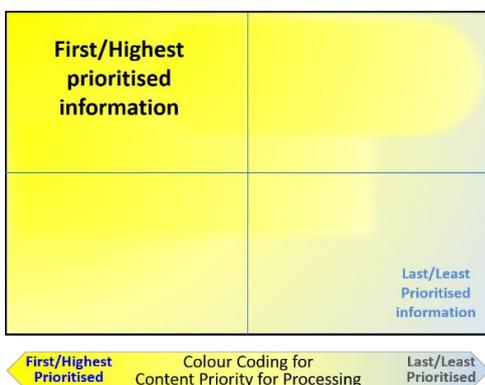


Figure 5: An integrated model that combines the common elements of the patterns

This diagram, is colour coded as shown at the bottom of the model. Consequently, in this integrated model, content toward the top and left of the screen would typically be prioritised for processing, and this should shape the order in which the content is managed by the viewer.

However, as specified by Bradley (2011), each of the scanning patterns used to develop this integrated model are predicated on viewing relatively homogenous information, such as a full page of text. Each of the preceding models is also defined in terms of cultures where people read from left to right and scan from top to bottom, so this design framework may not be applicable in situations where different reading techniques are applied (Plocher et al. 2012). Additionally, even relatively old research results, such as those described in Noton and Stark (1971), Stark and Ellis (1981) and Groner et al. (1984), identified that different scanning techniques are applied when viewing various types of visual material (e.g. the way a viewer scans text may be different from the way in which they scan a picture).

Consequently, this research project investigated whether the integrated model holds true when utilising other types of less homogeneously text intensive visual material (e.g. learning material featuring both text and salient graphics). To determine the wider applicability of the integrated scan pattern, an experiment was conducted using the approach discussed in the following section. This set of experiments was designed to test the hypothesis (H₁) that: *the application of layouts and arrays that conform to standard scanning patterns would positively affect viewer comprehension and impressions.*

4 METHODOLOGY

4.1 Experimental Materials

The research process is discussed in detail within Hilliard (2016), but the following points provide a broad outline of the experimental approach that was utilised.

Firstly, as a result of an extensive literature review, information from 1640 visual design, psychophysics, biopsychology and cognitive science publications was integrated, to create a set of draft design principles. These included the application of the integrated model shown at Figure 5. These draft principles were then used to develop a Control Presentation (CP). The CP contained 33 slides that explained the application of empirical methods, to resolve probability questions. An example of one of the slides within the CP used in the experiment is shown to the left of Figure 6. This screen shot shows that the material was structured from top to bottom, with the most important content on the top and left.

A variant of this presentation was then developed. An example slide from this Variant Presentation (VP) is shown on the right of Figure 6. As demonstrated in this screenshot, the learnable content within both presentations was the same, but in the VP the title area was placed at the bottom of the slides, vertical positioning of the material flowed from bottom to top, the horizontal positioning was flipped (to place the most important elements on the right and the least important on the left), and the university logo was positioned in the top right-hand corner of each content slide.

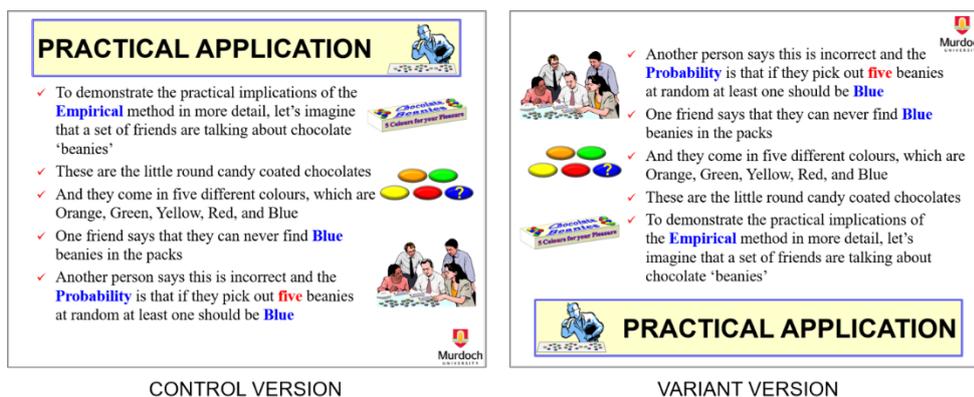


Figure 6: Example slide from the control and variant versions

In each presentation, the points and the associated reinforcing graphic flew in (i.e. from left or right, so the graphics and text did not pass over the other item) on each successive mouse click. It was this animation which ensured that the flow of the information was maintained in the VP, even though the static screenshot demonstrates that the points were not in the standard top-to-bottom reading order.

In addition to developing the presentations, two tests related to the content were created. Each test contained seven similar but different questions, which directly related to specific coverage within the presentation. One of these tests was randomly allocated as a Diagnostic (i.e. to determine the participant's pre-existing subject knowledge), and the second was taken by each participant after viewing either the CP or VP.

Additionally, an instrument was created to measure participant impressions about the CP or VP they viewed. The first 10 questions in this survey collected responses using a Likert Scale (e.g. Strongly Disagree (1) to Strongly Agree (5)). Additionally, two qualitative questions (Questions 11 and 12) were included, to find out what the participants liked most or least about the presentation they had viewed.

A short demographic questionnaire was also developed. This questionnaire collected responses in relation to each participant's gender; age group (e.g. 18-30, 31-50, >50); whether English was their first language (EFL), (to determine possible cultural and language comprehension variations); if they had any vision problems that could affect their ability to see the presentations properly; and whether they were colour blind.

4.2 Participants

Two hundred and seventy-three volunteers (who were mostly students, but also included staff, from Murdoch University) participated in the experiment. They were separated into two groups using stratified random allocation techniques, to help balance key demographic attributes and numeracy skill levels across the groups. Although randomly allocated to the groups, this approach distributed participants with different demographic characteristics relatively evenly, as illustrated in *Table 1*.

Group	n	n by Gender (Male / Female)	n by Age Group (18-30 / 31-50 / >50)	n by English as First Language (Yes / No)	n by Vision Problems (Yes / No)	n by Colour Blindness (Yes / No)
1	110	37 / 73	85 / 22 / 3	95 / 15	7 / 103	1 / 109
2	163	40 / 123	137 / 22 / 4	141 / 22	5 / 158	1 / 162

Table 1: Distribution of demographic characteristics across the groups

4.3 Procedures

The participants accessed the experimental materials online through the university's Learning Management System (LMS), so they could carry out the experimental procedures at their own pace, and at a time that was convenient for them. Prior to commencing the experiment, each participant was asked to answer the questions in the demographic questionnaire. The experiment included the following steps:

- **Step 1.** Prior to them viewing the presentation, each participant completed a standard Diagnostic Test (DT), to determine their pre-existing level of knowledge related to the subject being covered.
- **Step 2.** After completing the DT, each person was asked to view the presentation. The CP or VP that they viewed was controlled by the LMS, so everyone in each group viewed the same version of the presentation. On average, it took the participants 12 minutes and 24 seconds to validly read the numeracy module.
- **Step 3.** As soon as possible after finishing Step 2, each participant was prompted to complete the associated Post Test (PT), to assess their knowledge after viewing the presentation. The difference in time between finishing the viewing of the module, and commencing the PT was only a few minutes.
- **Step 4.** The participants were then asked to answer the questions in the impressions survey as soon as possible after completing the PT.

5 RESULTS

The collected data was validated and assessed through the techniques discussed in Hilliard (2016). To specifically test the hypothesis, the collected comprehension and impressions data was used as follows. To measure comprehension related to the CP or VP viewed, the differences in each participant's DT and PT scores were used. This measure was defined as Comprehension Related Change (CRC). In relation to the assessment of impressions, each participant's mean Likert score for the first ten survey questions

was utilised as one key measure (identified as the Mean Impressions Outcomes (MIO)). Additionally, Likert score responses to Question 4 in the survey (I found the layout of the information easy to follow) were utilised as an additional measure of the effects.

The data was then analysed using descriptive statistics and Univariate General Linear Model (UGLM) analysis. These UGLM analyses took into account the influence of differences in the visualisation, as well as affects attributable to the various demographic characteristics that were identified above. As the presentations contained the same content, effects could be attributed to differences in the visualisation. For the sake of brevity, *Table 2* only shows the UGLM results for the difference in visualisation characteristics.

Test Type	Control Presentation Results (Group 1)		Variant Presentation Results (Group 2)		UGLM Results for Visualisation Differences			Effect Size			
	n	Mean CRC/MIO	SD	n	Mean CRC/MIO	SD	Mean Square	F	p	Cohen's d	Partial Eta Squared
Comprehension	110	1.890	1.052	163	1.860	1.281	0.002	0.969	0.026	0.056	
Impressions		3.666	0.425		3.482	0.580	2.270	9.030	0.003	0.361	0.033

Table 2: Comparison of comprehension and impressions between the CP and VP groups

Table 2 shows that there were no significant differences in comprehension between the two groups, so it appeared that the variant treatment had not influenced learning outcomes. Conversely, the group who viewed the VP produced significantly lower MIO scores, so the treatment that flipped the scan patterns was less liked, but the Cohen's d and Partial Eta Squared effect size was small. The hypothesis was therefore partially supported.

Additionally, the UGLM results showed that gender had been a significant factor in shaping the MIO results (MS = 2.073, F = 8.245, p = .004). A separate UGLM assessing the effects between the groups in relation to Question 4 in the impressions survey (I found the layout of the information easy to follow) also showed that the differences between the CP and VP groups was significant (MS = 25.845, F = 47.333, p < .001), with the control being preferred. This UGLM calculation also identified that gender (MS = 2.217, F = 4.060, p = .045) was a significant factor influencing the outcome, with males' impressions appearing to be more adversely affected by the variant treatment.

6 DISCUSSION

These results therefore indicate that the application of the integrated model (which took into account the Gutenberg Diagram, Z-Pattern, Zig-Zag Pattern, and F-Pattern scans) was preferred. Consequently, placing the priority content towards the top and left of the screen (as illustrated in Figure 5) is appropriate when utilising mixed text and graphic layouts.

Interestingly, individuals appear to have adapted to the unusual layout in different ways. For example, Participant 896 complained about 'how things came out in an odd order', Participant 1730 did not like the 'funny layout', and Participant 2453 disliked 'the way things were upside down'. Alternately, some participants were more positive. For instance, Participant 2344 identified that 'the layout was unusual but understandable', Participant 875 indicated that 'the layout was unusual, but I got used to it', and Participant 901 felt that 'it was strangely laid out', but 'it was easy to read'. Consequently, at least some individuals appear to be able to adapt to the layout differences, and in these cases their response scores were not as adversely impacted.

Additionally, the results showed that males appeared to be affected more adversely by the change in the layout than females. This is borne out by the group averages and standard deviations for MIO and the responses to Question 4 in the impressions survey. As shown in *Table 3*, the differences between males and females across the two groups were larger in the variant group, and differences for males were particularly marked in the responses to Question 4.

Group	Male		Female		Male		Female	
	MIO	SD	MIO	SD	Mean Q4	SD	Mean Q4	SD
Control (Group 1)	3.61	0.46	3.70	0.41	3.84	0.65	3.88	0.55
Variant (Group 2)	3.32	0.65	3.53	0.55	2.90	0.84	3.40	0.78

Table 3: Gender comparison for impressions scores

Consequently, this experiment partially supports the practical application of the integrated model to arrange layouts, and this aligns to the results in the preceding experiments cited in Section 3. However, it is the limitations and generalisability of the results that may have just as much impact on the practical application of the integrated model. These aspects are discussed in the following section.

6.1 Limitations and Generalisability

Although these results demonstrated some significant differences, the generalisability of these outcomes is limited for the following reasons:

- **Western Culture Sample.** As illustrated by the results shown for the English as First language demographic column within *Table 1*, the vast majority of the participants were native English speakers. Many of the others who nominated that English was not their first language also came from cultures where they read from left to right and top to bottom. Consequently, the sample is aligned to those used to develop the Gutenberg Diagram, Z-Pattern, Zig-Zag Pattern, or F-Pattern models. However, these scan paths may only be appropriate to languages where the viewer has learned to scan from left to right and move line by line from the top to the bottom (Schuett et al. 2008). Different cultures learn other standard scanning techniques (Abed 1991; Brockman 1991). For example, Chang et al. (2005) identified that when a Chinese reader identifies vertical Chinese characters they will start reading in the top right corner and scan vertically through the column and then move to the left for successive lines (this can be defined as a reverse N-Pattern). On the other hand, Chang et al. (2005) showed that when a Chinese reader finds horizontal lines of text characters (e.g. headings) these will typically be scanned automatically from left to right. Alternately, Abed (1991) found that Hebrew readers tend to focus initially on the top right when reading text. Similar scan paths define the standard technique for reading Arabic script (George et al. 2011). This text scanning is defined as a reverse-Z-Pattern, because it is the mirror image of the Z-Pattern (starting in the top right corner, moving across the top, then diagonally toward the bottom right corner, and then horizontally to the bottom left corner) (George et al. 2011). Consequently, although the findings in this paper reinforce the efficacy of the layout diagram specified in Figure 5, the results may only be applicable for people who have learnt to read from left to right and top to bottom.
- **Predominantly text based slides.** The slides tested in this experiment were predominantly text-based, with some graphical content included. These mainly text-based slides therefore create a viewing environment that generally reflects conditions utilised to define the standard scan patterns utilised to build the model in Figure 5. The results may therefore have conformed to the expectations for the scan pattern layouts, because of the attention processes applied when reading. When literate viewers encounter text, they apply top-down attention processes which influence their scanning techniques (Schuett et al. 2008). The term top-down refers to goal directed processes in the viewer's brain, which drive their allocation of attention. For instance, when a person is highly focussed on reading text, they may not be attracted by other visualisation factors such as salient pictures (Intraub et al. 2006). These top-down scanning strategies therefore affect the order of processing, because the reader applies their learned reading techniques to process the visual material. Alternatively, when viewing highly graphical material, other types of visual scanning techniques are applied (Myers 2007; Noton and Stark 1971; Rayner 1998). As an example, Bindemann (2010) identified that there is a strong bias toward beginning the scan around the centre of the screen when viewing graphical scenes. Engmann et al. (2009) also showed that scanning of graphical content was typically biased to begin just to the left of the screen centre, and the scanning was then predisposed toward salient regions (e.g. areas of high luminance and colour contrasts). Consequently, although this experiment illustrated that flipping the content (so it did not conform to the standard scan patterns) produced significant impressions differences, the results may only reflect situations in which the visual material is predominantly textual.
- **Application of point-by-point animations.** As discussed earlier in this paper, each point was brought out through fly-in animations, to ensure that the flow of the material was readily comprehensible, even though the content was exposed from the bottom to the top. This salient exposure of each point in sequence is likely to explain why there was no significant comprehension difference between the CP and VP groups. It is likely that if the participants were required to make sense of the static bottom-to-top layout without each animated point ordering the presentation, they may have had greater problems following and comprehending

the material. Consequently, the animation attribute within the UDM framework is also likely to have affected the outcome.

Within the constraints of the preceding limitations, these results may be generalisable to presentation, web-page, and screen design, where the content is predominantly textual, and the viewers are expected to read from left to right and top to bottom. In these cases, the same layout may also be appropriate when icons or graphical arrays are provided on the screen. As an example, when showing shapes in a row, the standard reading order can determine the order of processing (Abed 1991). Additionally, as demonstrated in the research conducted by Shrestha and Owens (2009), the material on the left is prioritised for scanning even when more iconic content is displayed.

6.2 Future Research

Following research should address the following:

- Causation for the gender differences identified in this research should be identified. In particular, eye tracking should be utilised to determine possible differences in the scanning techniques utilised. Additionally, biometric arousal data could be assessed, or tools such as fMRI could be applied to determine differences in neural processes.
- The same types of experiments should be conducted utilising presentations that are predominantly graphical, to determine if the flipping of different scanning strategies would affect comprehension and impressions.
- Similar experiments should be conducted using a larger sample of participants who do not naturally read from left to right and top to bottom.

7 CONCLUSION

This paper addressed just one of the experiments conducted as a part of a larger project. The results illustrate that the application of layouts that place the most important content to the top and left of the slide can positively influence viewer impressions. However, these results should only be generalised to situations in which the viewers are likely to prefer reading from left to right and top to bottom. Additionally, although the type of layout prioritisation illustrated in Figure 5 is focussed on predominantly text-based presentations and web-pages, it may have wider applicability in mixed displays.

However, as pointed out in Eldesouky (2013), the effects of layout and arraying are also influenced by a range of other factors. These factors are defined in the broader Unified Design Model.

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