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# Navigating the narrative: An eye-tracking study of readers' strategies when Reading comic page layouts

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## Abstract

In multimedia stimuli (e.g., comics), the reader must follow a narrative in which text and image both contribute information, and artists may use more irregular layouts which must still be followed correctly. While previous work has found that the external structure (outlines) of panels is a major contributor to navigation decisions in comics, other studies have shown that panel content can affect reading order. The present studies use eye-tracking to investigate these contributions further. In Experiment 1, the reading behaviors on six layout variations were compared. The influence of the external structure was replicated, but an effect of text location was also found for one layout type. Experiment 2 focused on variations of this particular layout, manipulating the location of text within critical panels. Panel content was a consistent effect for all variations. While most navigation decisions are made using the external structure, content becomes key when resolving ambiguous layouts.

KEYWORDS
attention, comic structure, eye-tracking, reading, word-image combination

## 1 | INTRODUCTION

The order in which viewers choose to look at the components of an image is not particularly strict. Unlike text, where readers predominantly move from one word to another in a single reading direction, viewing order of image regions depends on several factors, such as task setting, the viewers' own interest in particular image regions, and low-level features such as brightness or line orientation that may grab attention.

In multimedia stimuli, such as comics, images play an important role, contributing much information alongside text (or, in the case of textless comics, all the information). Perhaps due to the role of images in this medium, initial theories of comic reading suggested that the viewing process would not be particularly structured, as images communicated "largely without rules" (Postema, 2013). Tracking the eyes of someone reading a comic would, it was thought, provide a rather erratic pattern, as the reader gathered information holistically from the page (Barber, 2002). However, this interpretation is debated, with a growing number of studies showing that, when reading comics, readers follow the narrative sequence of the panels, in a fashion that is similar to reading text (Foulsham et al., 2016; Kirtley et al., 2018). Indeed, disruptions to the panel order, either by mixing up or deleting certain items have clear effects on viewing behavior (Foulsham et al., 2016; Cohn, 2013), slowing reading speed and increasing the amount of regressive saccades and re-fixations on the disordered items. This work has shown that, when reading comics, readers are following the sequential narrative provided by the text and images.

As with text, comics mostly follow the typical reading order of the culture in which they were written: Western comics tend to be written to read left-to-right, Japanese manga are written right-to-left (Bongco, 2000; Duncan, 2000). The standard reading order is to follow the line of panels from one side of the page to the other, and upon reaching the end, drop down by one line and return to the start to begin again, also known as the Z-path (Cohn, 2013). However,

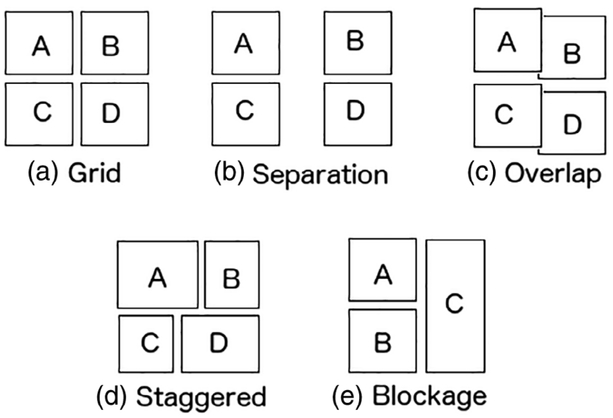


**FIGURE 1** Examples of the five layout types used by Cohn (2013). Letters indicate reading order. (a) Grid; (b) Separation; (c) Overlap; (d) Staggered; (e) Overlap

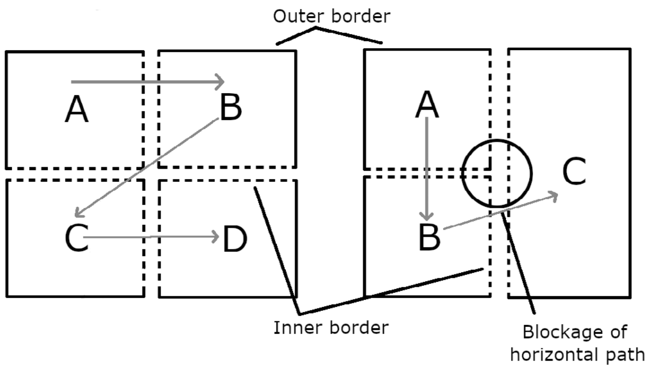


**FIGURE 2** Correct reading order for Grid layouts (L) and Blocked layouts (R)

within comics there is much more scope for varying panel layouts beyond a simple grid shape. Artists and writers may choose to use a variety of panel layouts, such as basing the pages around a circle or more irregular shapes or superimposing smaller images on a larger background to draw attention to them. However the panels are laid out, they should still serve the reader, and allow them to navigate successfully through the sequence. Mistakes in this aspect of comic creation can result in readers failing to follow the narrative, or losing interest in the story itself (McCloud, 1993).

The first investigations into comic page navigation were conducted by Cohn and colleagues (Cohn, 2013; Cohn & Campbell, 2015). In these studies, the focus was on the contribution of the panels' spatial arrangement, rather than their content. Cohn (2013) suggested layout alone could be a strong contributor to navigation, noting that it was possible to re-arrange comic strips into different layouts without affecting the information within the panels. To this end, participants were presented with blank comic pages, showing only the outlines of empty panels. Participants were required to number the panels in the order they thought they would read them if the panels contained information.

Five manipulations of layout in particular were examined, all created by changing the spatial relationships between the panels in question (shown in Figure 1). The baseline type was the typical Grid pattern (Figure 1a), the arrangement which could be considered the closest to the organization of rows of text, and the manipulations included increasing the distance between panels (Separation, Figure 1b) or reducing it so that panels overlapped (Overlap, Figure 1c). The Staggered pattern (Figure 1d) is an adjustment of the Grid pattern where either the vertical or horizontal gutters are no longer continuous. All these layout types are used in published comics today (Cohn, 2013). The final manipulation (Blockage, Figure 1e) is a more extreme version of the Staggered layout, where one panel effectively blocks the horizontal gutter of the neighboring panels. The Blockage layout has also been mentioned in other works, with comic theorists and creators pointing out that this is one of the more potentially misleading layouts that can be used (e.g., McCloud, 2006; Abel & Madden, 2008), due to uncertainty as to whether the reader should read across or down.

When labeling the empty panels, readers showed a strong tendency to follow the Z path in the Grid layout. While slight deviations were found, participants were also more likely to follow this path for Separation and Staggered layouts. For the Overlap layout, however, readers were more likely to follow the direction indicated by the overlapping panels: thus, if the arrangement indicated a Z-path pattern, readers would follow this, while if the overlap suggested a Blockage pattern, readers would use this path. Finally, when labeling the Blockage panel, readers were significantly more likely to break from the standard Z-path—as is necessary to follow the narrative in this layout—and follow a vertical pathway (from A to B, then across to C). This tendency was enhanced for readers who scored highly on measures of comic expertise: participants who were less familiar with comics and did not read as many were more likely to follow the Z-path (A–C) even on the blockage layouts, where this path is not what was intended by the artist in order to follow the narrative.

Based on these findings, Cohn (2013) proposed a set of rules for detailing how the external compositional structure (ECS) of comic panels influenced readers' navigational choices in selecting which panel to move to next from their current position. These rules suggest that readers will try to maintain a grouping between panels, preferring smooth paths to broken ones, something that the borders (both internal and external) of the panels indicate. Readers will also usually attempt to follow a Z-path, moving to the right, and then returning to the left a line down, unless a downwards movement is indicated by the borders (as in the Blockage layout). Less expert readers, Cohn notes, may stick to the Z-path whatever the panel arrangement, due to their lack of familiarity with the more varied comic layouts. As a last catch-all, readers will finally examine any panel which has not yet been viewed, to ensure no details have been lost.

Figure 2 provides an example of the proposed navigation decisions in Grid and Blocked layouts. In the Grid pattern, the reader begins in Panel A, and, since both inner and outer borders are continuous, they prefer to move to the right, into Panel B. Once in B, there are no more rightwards panels, so they follow the Z-path to move into C, before repeating the same process to move from C to D. In the

Blocked layout, the vertical inner border is continuous, while the horizontal inner border is blocked by Panel C. Thus, rightward movement from A to C is blocked, and so the reader moves from A to B, violating the Z-path, but following the narrative.

While Cohn's (2013) findings suggest a major role for the layout alone in guiding navigation, there is evidence that the content of the panel also makes some contribution. Text as a feature of comic panels is a strong attractor of attention: Laubrock et al. (2018) found that text within comic panels drew significantly more fixations than images, despite the fact that text regions typically occupied a much smaller area of a panel than images. Text also appears to be identified as a target for future fixations: Laubrock et al. (2018) found readers used preview information more for text than images; on a similar note, Kirtley et al. (2018) found that the presence of text within a panel increased the likelihood of readers visiting that panel, while textless panels were more likely to be skipped in first pass reading. The position of text within an upcoming panel can also influence the incidences of fixation within the region (Kirtley et al., 2018; Ishii et al., 2004). However, there is currently no work examining how content might contribute to readers' navigation, in conjunction with the panel layout.

The overall aim of the current studies, therefore, is to explore the contributions of panel content and panel layout on the behavior of participants reading short comic stories. By adding content to the layout types suggested by Cohn (2013) we create a situation in which there are right and wrong ways to follow the story. By using comics created for the purpose of this study, we were able to control for the narrative and visual content of panels across the different types of layouts studied here. Furthermore, by using eye tracking to record the gaze and viewing behavior of the participants, we can obtain more details on the participants' decision making during the reading process. Rather than only seeing the final outcome of participants' direction choices, the eye-tracking allows us to trace any cases in which participants make errors which they then correct, thus providing a clearer understanding of the processes participants go through to make their decisions about the order in which to read the panels.

It is predicted that readers will show differences in how they read the same content across the different layout types, with measures such as regressions (returns to panels that are earlier in the narrative sequence) and skips indicating where readers make more errors in the reading order. Second, the content of the layouts, in particular the presence of text within the panels, will contribute to how readers choose to navigate the layouts presented. These findings will add to the understanding of page navigation in sequential art and expand upon Cohn's (2013) initial proposal.

## 2 | EXPERIMENT 1

### 2.1 | Method

#### 2.1.1 | Participants

Twenty-nine participants (2 males, $M_{age} = 21.03$, $SD = 5.29$) were recruited from the Psychology undergraduate population at the University of Aberdeen. They received course credits in return for their participation in the study. A measure of comic expertise, the Visual Language Fluency Index (VLFI; Cohn, 2014) was administered, and the mean score for participants was 7.27 ($SD = 4.03$), indicating readers were not highly experienced comic readers. All participants had normal or corrected-to-normal vision. The study was approved by the local ethics committee (reference PEC/3625/2017/4) and was in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki).

#### 2.1.2 | Stimuli and apparatus

*Stimulus comics*

Six comics were created for the purposes of this study. These comics portrayed a range of art styles, genres and use of color or black and white, and ranged in length from 3–8 pages. Table 1 summarizes further information about the six comics, including the breakdown of panel content. A panel was considered to contain text if it presented words in speech or sound effects. Character-focused panels were those in which the focus was on a human character central to the story.

Within each comic, a set of four panels was selected to be manipulated into the following chosen layouts (examples of these layouts for one of the comics is shown in Figure 3). Table 2 summarizes the panel content for the four critical panels in each comic. It is important to note that the critical panels did not occupy the entire page of any comic. Rather they were a subset of panels on one of the pages and their position within the page—and indeed whether

**TABLE 1** Summary details for the six stimulus comic stories

| Comic | Pages | Mean panels per page | Text present (%) | Character focused (%) | Mean words per panel |
|---|---|---|---|---|---|
| Alpha | 4 | 5.5 | 68.18 | 88.89 | 34.38 |
| Autobiography | 3 | 6 | 100 | 81.82 | 5.27 |
| Alpha Girl | 4 | 3.75 | 86.67 | 100 | 10.53 |
| Dan | 8 | 5.25 | 80.95 | 92.31 | 6.94 |
| Pop! Goes the Art World | 7 | 5.86 | 73.17 | 97.56 | 8.41 |
| The Sentinels | 6 | 6.83 | 68.29 | 90.24 | 7.71 |


**FIGURE 3** Examples of the six layout styles used in Experiment 1; (L-R, T-B): Grid, Grid Overlap, Staggered, Staggered Overlap, Blocked and Blocked Overlap

**TABLE 2** Summary details for the four critical panels in each comic

| Comic | Text present (%) | Character focused (%) | Mean words per panel |
|---|---|---|---|
| Alpha | 100 | 100 | 8.25 |
| Autobiography | 100 | 75 | 32.75 |
| Alpha Girl | 100 | 100 | 10.25 |
| Dan | 75 | 75 | 6.5 |
| Pop! Goes the Art World | 75 | 100 | 2.75 |
| The Sentinels | 75 | 100 | 2.5 |

they were on the right or left hand page of each double-page spread (see below)— varied between comics.

*Grid.* The basic layout: the panels were arranged in a 2 × 2 square. Correct reading order required the reader to use the standard *Z* path to move left to right and then down the line.

*Overlap Grid.* The same grid layout, with panels overlapping so that Panel 1 (P1) overlapped P2 and P3 overlapped P4.

*Staggered.* The size of the panels in the grid layout was adapted, so that there was no longer a clear grid between the panels. Panels were manipulated horizontally for all items. Correct reading order required the reader to use the standard *Z* path to move left to right and then down to the line below.

*Overlap Staggered.* The same staggered layout was used, with panels arranged so that Panel 1 overlapped P3 and P2 overlapped P4.

*Blocked.* One of the four panels was removed (care was taken to ensure that the narrative was not disrupted by this removal, and no text was removed from the story). The third panel was increased in size, with the content adjusted to fit it. Correct reading order for such panels was the typical blocked pattern of moving down from 1 to 2, then across to 3.

*Overlap Blocked.* Panel A of the blocked layout was extended so it overlapped with Panel C. Figure 3 shows the six examples of layout for one of the stories. In each case, the numbers 1–4 indicate the correct reading order.

Stimulus presentation and response collection was controlled by the Experiment Builder software from SR Research. The comics were displayed to the participants on a BenQXL2420Z monitor at a resolution of 1024 × 768 pixels, and with a refresh rate of 60 Hz. Participants viewed the screen from a distance of 72 cm, at which the screen subtended 40.6° horizontally and 23.5° vertically, with the image subtending 31.0° horizontally and 23.5° vertically. All comics used were established to be easily readable by participants with normal/corrected-to-normal vision at this distance/size.

*Eye-Tracking*

Participants' eye movements were monitored and recorded on the EyeLink 1000+ eye-tracker, set to the participants' dominant eye. Eye dominance was determined using a variant of the Miles test (Miles, 1928). A 9-point calibration grid, followed by a 9-point validation grid was used to fit and test the spatial accuracy of the eye-tracker at the start of the experiment. If the validation procedure showed a mean spatial accuracy worse than 0.5°, or a maximum spatial accuracy worse than 1 degree, calibration and set up were repeated. Saccades were detected using the default cognitive setting for the SR Research algorithm, whereby saccades are detected if both the velocity threshold of $30^\circ\ s^{-1}$ and acceleration threshold of $8000^\circ\ s^{-2}$ were exceeded for two consecutive samples.

*Expertise questionnaire*

Participants' familiarity with comics as a medium was assessed using the Visual Language Fluency Index (Cohn, 2014). This questionnaire asks participants to rate, on a scale of 1–7, the frequency with which they read different types of comics, both currently and during childhood (aged 16 or younger). They are also asked to rate their proficiency in drawing both currently and during childhood, and how fluent they consider themselves to be in comic reading. The VLFI score ranges from 1 to 52.5, with higher numbers indicating greater comic fluency.

#### 2.1.3 | Procedure

Participants were asked to read the full stories, while their eye movements were tracked. Stories were presented as in sets of two pages per screen, in order to mimic natural comic reading. Readers were able to "turn" to a new pair of pages using the left and right arrow keys on the keyboard. An information screen was presented at the end of each story, allowing the reader to either turn back to previous pages, or move on to a new story. Reading was self-paced, and the study typically took less than 30 min to complete. Each participant saw each of the six layout types, counterbalanced across the stories. After reading the stories, participants were given the VLFI to complete on a laptop computer.

#### 2.1.4 | Analysis

To analyze the various possible influences on reading behaviors in comics, linear mixed models (LMM) were run for analyses involving continuous variables (viewing time, saccade progression), while

**TABLE 3** Mean viewing time in ms per panel for the six panel layouts in Experiment 1

| | Layout type | | | | | |
|---|---|---|---|---|---|---|
| Panel | Grid *M* (SD) | Blocked *M* (SD) | Overlap Blocked *M* (SD) | Overlap Grid *M* (SD) | Staggered *M* (SD) | Overlap Staggered *M* (SD) |
| 1 | 3212.55 (2358.23) | 3282.31 (2314.50) | 2846.90 (2213.90) | 2815.41 (2212.84) | 2554.07 (1768.68) | 2760.59 (1713.81) |
| 2 | 2428.03 (1635.21) | 2283.45 (1189.66) | 2256.31 (1572.64) | 2206.73 (1311.48) | 2258.17 (1501.01) | 2829.929 (1693.39) |
| 3 | 4835.31 (4283.61) | 4746.28 (3618.80) | 4851.17 (3760.64) | 4415.96 (3911.58) | 4655.10 (4789.44) | 4911.00 (4815.19) |
| 4 | 2843.69 (2988.59) | – | – | 3076.33 (3248.69) | 3284.54 (3896.55) | 3327.71 (4030.79) |

generalized linear models (gLMM) were used for categorical variables (skipping and regression). Both were run using the lme4 package (Bates et al., 2013) in the R statistical programming environment (R Core Team, 2016). To meet the assumptions of normal distribution required for LMMs, the dependent eye movement measures were adjusted using log transformations if required. *p*-Values were generated using the lmerTest library (Kuznetsova et al., 2015). When an interaction was significant, we ran follow-up models to explore it. Data plots were created using the ggplot2 package (Wickham, 2016).

The main concern of the experiment was how the reading behavior of participants changed, and how both panel layout and panel content (presence of text) affected this. Four key measures are presented, each looking at the level of the individual panels within the critical set. These were the viewing time per panel (the summed duration of all fixations on a panel); the likelihood of each panel being skipped over and fixated out of sequence; the likelihood of each panel being returned to via a regressive saccade, and the proportion of saccades progressing from one panel to another. The measures of skipping, regression and progression between panels are likely to be related—for example, if all panels were looked at once then the number of first pass skips should correlate strongly with the number of regressions to go back and inspect these panels that were initially missed. However, given that reading in comics is not a strictly linear ordered process, these measures need not be overly related. For example, skips may happen without regressions and regressions may happen without skips. This set of measures was selected in order to offer an overview of key aspects of stimulus inspection, with particular focus on reading order, and tendency to re-read, as an indication of confusion or uncertainty on the part of the participant, each offering a slightly different insight into how people read comics and respond to challenging panel layouts.

Three key factors were considered as possible influences on these measures of reading behavior: the layout in which a panel was set (the six versions); the readers' prior experience of comic reading (as measured by their VLFI score), and the panel content. For these studies, panel content concentrated on the presence, amount and location of text within the critical panels. While earlier work has indicated that the presence of character is also important, the comics used in these studies had very little variation in character presence, with most panels focusing on main characters. By using LMMs, it could be determined whether effects of these measures arose independently of each other.

In the models that follow, any predictor with only two levels was coded using deviation coding. The predictor for layout type had six levels, and was coded using simple coding, with the Grid type as the reference level. This was chosen as the simplest of the layout types with the clearest reading order.

Where interactions were found between layout type and other factors, these were broken down by comparing each of the six layout types to a level of the other predictor. In all models, the score for each participant on the VLFI was included as a fixed effect, in order to consider whether any aspects of reading order were influenced by prior experience. Other potentially confounding factors were included as fixed effects where necessary and described in the following sections. Model structures can be viewed in Appendix A, and full results tables for Experiment 1 can be seen in Appendix B.

## 2.2 | Results

### 2.2.1 | Viewing time

We investigated whether differences in layout might affect how long readers took to explore the individual panels within the critical panel groups: layouts which readers found more complex might be expected to increase the participants' viewing time per panel compared to simple layout types (Model 1.1).

Table 3 shows the average total viewing times per panel on the critical panel groups for each of the three layouts. Comparing these showed that participants spent longer on the panels in the critical panel group for blocked layouts than grid layouts, $\beta = 0.073$, SE $= 0.033$, $t = 2.21$, $p = 0.028$.[1] No other layouts differed from the simple grid layout. The number of words within a panel influenced viewing time, $\beta = 0.018$, SE $= 0.001$, $t = 18.83$, $p < 0.001$, with more words being associated with increased panel viewing time. Reader's expertise did not influence panel viewing time.

### 2.2.2 | Skips and regressions within a layout

To explore whether changes to layout contributed to more disordered reading, we examined skipping and regression behaviors. Both measures are used within reading research to determine how closely readers follow the set/intended reading order. Skipping a word (or in the present study, a panel) indicate that the reader has deviated from the intended reading order and moved to a panel later in the sequence. Regressions (moving back to earlier panels in the sequence) indicate re-reading of previously inspected panels or returns to panels that were originally skipped.

*First pass skipping*

For the current study, we looked only at first pass skips (where a panel is not read in sequence, but the reader returns to it later), because full skips (where a panel was not fixated at all) were very rare, occurring in only 0.8% of instances while the critical panels were read.

Closer examination of the skipping patterns showed that navigation of the panels was more erratic than would be seen for reading text alone, resulting in a high proportion of skips (43.7%). However, these skips could be divided into two distinct types: brief "look-aheads," where the reader would make a single fixation to a panel later in the sequence, but then return to the current position to continue reading, and longer deviations from the order, where the participant would continue to fixate on the later panel, exploring the image and reading the text out of sequence. As the focus of this study was readers tendency to be misled when reading, we focus only on this second category of skips, which occurred at a lower frequency (13.1%).[2]

For two of the comic layouts, the critical layout began at the top of the left-hand page. Since pages were displayed to participants after a central fixation, readers would begin at the center and progress to the first panel on the left-hand page (Panel 1 of the critical layout these comics). When moving from the center to the top-left of the page, participants would often make a single fixation elsewhere on the page before moving to Panel 1. These early fixations were not counted as skips. However, if the participant made more than one fixation on later panels before reaching Panel 1, it was considered that they were focusing more on the content, and they were recorded as having read out of sequence, and therefore skipped Panel 1.

We looked initially at the proportion of skipping in all panels in the critical layout set, before looking at the panels on an individual basis. Panels were numbered 1–4, in accordance with the correct reading order.[3] As well as the layout in which the panel was set, we considered the influence of text content: specifically, the number of words present. Full tables for the models run for each panel can be viewed in Appendix C, here, we consider only the significant findings. Table 4 shows the average proportion of first pass skips occurring per panel in the first three panels of the critical layouts once saccades classified as "look-aheads" have been removed.

For first pass skipping behavior, it was found that there was a strong effect of layout, with both the Blocked and Overlap Blocked layouts showing significantly more skipping across all panels, compared to the Grid (Blocked: $\beta = 1.21$, SE $= 0.390$, $t = 3.11$, $p = 0.002$; Overlap Blocked: $\beta = 0.96$, SE $= 0.399$, $t = 2.40$, $p = 0.017$). No effects of other factors were found.

Layout, word number and expertise had no influence on skipping in Panel 1 of the critical panels (Model 2.2). These factors also had no effect on skipping Panels 3 (Model 2.4) and 4 (Model 2.5). However,

**TABLE 4** Average skip proportions per individual panel across the six layout types in Experiment 1

| | Panel number | | | |
|---|---|---|---|---|
| Layout | 1 | 2 | 3 | 4 |
| Grid | 0.035 | 0.138 | 0.103 | 0.138 |
| Overlap Grid | 0.037 | 0.115 | 0.0 | 0.111 |
| Staggered | 0.0 | 0.036 | 0.069 | 0.107 |
| Overlap Staggered | 0.034 | 0.172 | 0.103 | 0.142 |
| Blocked | 0.103 | 0.621 | 0.103 | – |
| Overlap Blocked | 0.069 | 0.586 | 0.034 | – |

significant effects of layout were found for Panel 2 (Model 2.3). Readers were found to be more likely to skip the second panel (Panel B in Figure 1e) of the Blocked $\beta = 2.36$, SE $= 0.664$, $t = 3.55$, $p < 0.001$, and Overlap Blocked layouts, $\beta = 2.20$, SE $= 0.661$, $t = 3.33$, $p < 0.001$, compared to the Grid layout. No other panel types differed in terms of skipping the second panel, and neither the number of words not expertise had an influence on this measure either.

*Regressions to earlier panels*

Regressions were defined as saccades that began in one panel and ended in a sequentially earlier panel. Within the study, 37.2% of saccades between panels in the critical layouts were regressions—this is high in comparison to regressions in text-only reading, but comparable to similar findings by Foulsham et al. (2016) with 35%. Returning to previous panels seems to be a more common reading practice for comics.

Given the findings regarding skipping, it appeared that Panel 2 was the most likely to be skipped within the critical panel set, at least for Blocked and Overlap Blocked layouts. To examine regressions, we therefore explored whether this skipping was also associated with regressive saccades into Panel 2, which might indicate that readers were returning to the previously skipped panel (Model 3.1). If readers are skipping Panel 2 and moving to Panel 3 earlier, then such corrective regressions might be more expected specifically between Panels 3 and 2. Looking only at regressive saccades within the critical layouts, we examined what proportion of these regressions were from Panel 3 to Panel 2, in each of the six layouts.

Significantly more of these saccades occurred in the Blocked layout ($M = 0.508$, SD $= 0.504$), $\beta = 1.87$, SE $= 0.485$, $z = 3.85$, $p < 0.001$ and in the Overlap Blocked layout, ($M = 0.596$, SD $= 0.496$), $\beta = 2.24$, SE $= 0.503$, $z = 4.45$, $p < 0.001$ than the standard Grid pattern ($M = 0.134$, SD $= 0.345$). No other layouts differed from grid layout in the proportion of regressions made toward Panel 2 in the critical panel group. Similarly, neither expertise nor the number of words in Panel 2 were significant predictors of this behavior.

Taking the skipping and regression together, it appears that readers had more difficulty in inspecting panels in the intended order with layout types that included blocked panels. Initially, it seems they missed out the second panel and went directly to the third, before realizing their mistake and regressing back to the second.

*Proportion of progressive saccades*

In order to explore this further, we considered what proportion of saccades that started from P1 and progressed to a later panel in the comic ended in either P2 (correctly moving to the next panel in the narrative) or P3 (incorrect progression in the narrative), and how this might be influenced by panel contents. For these analyses, saccades which began and ended within the same panel were excluded, as were regressive saccades in which readers moved back to an earlier panel. Thus, we focus only on progressive saccades, starting in one panel and ending in a sequentially later one, which might be P2 or P3 in the critical panel or a later panel in the comic.

Our previous analyses showed consistently that the readers behaved similarly when viewing the Grid, Overlap Grid, Staggered and Overlap Staggered layouts. However, Blocked and Overlap Block layout differed from these four layouts. In order to maximize our ability to detect any differences in these analyses, the layout types were re-classified into three groups. These were the Grid-Based layouts (Grid, Overlap Grid, Staggered, Overlap Staggered), the Blocked layout and the Overlap Block layout, with the fixed effect of layout being entered into models with these three levels.

As previous work has shown readers will often direct saccades to text in upcoming panels (e.g., Kirtley et al., 2018; Laubrock et al., 2018), the location of text in Panels 1 and 2 was used as a fixed effect in the LMMs that follow in order to assess whether reading order was influenced by text placement within panels. Each stimulus comic was assigned to one of two categories: those in which the text in Panel 2 was closest to Panel 1, or those in which the Panel 3 text was closest to Panel 1. To determine which comics fell into which category, distance was measured from the center of Panel 1 to the center of the text region in each of panels 2 and 3. Half of the comics had closer text in Panel 2, and half had closer text in Panel 3.

Examining the proportion of correct-order saccades (Panel 1 to Panel 2, Model 4.1), it was found that readers made fewer sequentially correct saccades in the Overlap Block layout, compared to the Grid-Based Types, $\beta = -1.66$, SE $= 0.56$, $t = -2.97$, $p = 0.003$. While overall the proportion within the Blocked layout did not differ from Grid-Based layouts, $\beta = -0.18$, SE $= 0.26$, $t = -0.71$, $p = 0.475$, this contrast interacted with the location of the nearest text in Panels 2 and 3, $\beta = 0.56$, SE $= 0.255$, $t = 2.12$, $p = 0.027$. Breaking down this interaction showed readers were marginally more likely to saccade to Panel 2 when the closest text was in this region, $t(60) = 1.80$, $p = 0.077$. Figure 4a illustrates this interaction. No such interaction between layout and text location was found for the comparison between Overlap Block and Grid layouts.

A model to predict the proportion of progressive saccades made to the incorrect panel for the narrative sequence (Panel 1 to Panel 3, Model 4.2) showed that readers were significantly more likely to make incorrectly ordered saccades within the Blocked layout, $\beta = 0.77$, SE $= 0.36$, $t = 2.12$, $p = 0.034$, and the Overlap Block layout, $\beta = 1.65$, SE $= 0.29$, $t = 5.60$, $p < 0.001$, than the Grid-Based layouts. There was an overall effect of text location in Panels 2 and 3, $\beta = -0.31$, SE $= 0.15$, $t = -2.13$, $p = 0.034$, with more saccades toward Panel 3 when text was closer in Panel 3 ($M = 0.15$, SD $= 0.36$) than when text was closer in Panel 2 ($M = 0.07$, SD $= 0.26$). Text location and panel layout did not interact (see Figure 4b).

## 2.3 | Discussion

Experiment 1 investigated how readers navigated comic panel layouts, in which the content remained identical, but the spatial relations

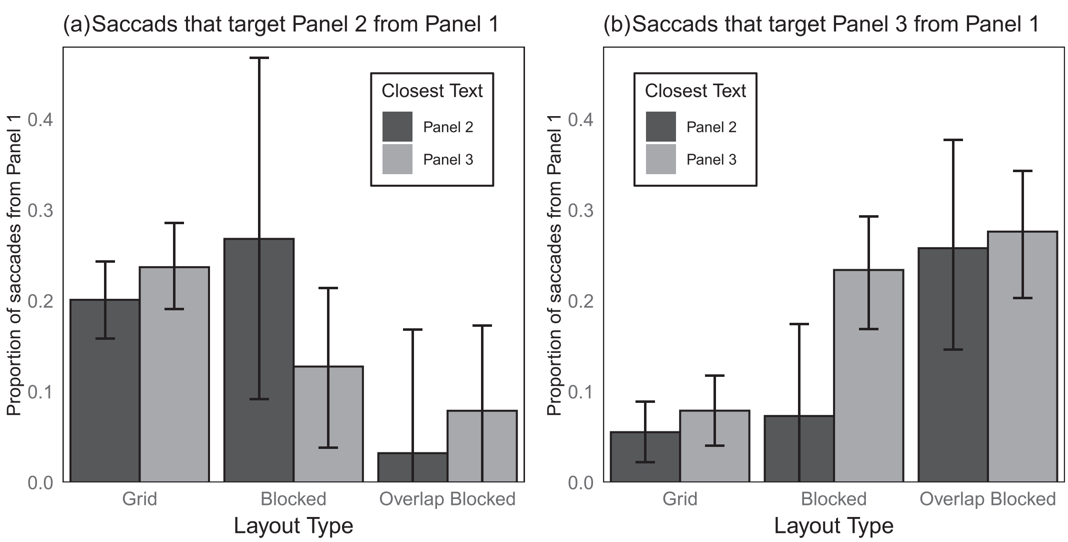


**FIGURE 4** The proportion of saccades from Panel 1, in Experiment 1, that (a) correctly target Panel 2, or (b) incorrectly target Panel 3 in the critical condition, each depending on whether the closest text to Panel 1 is in Panel 2 (dark gray bars) or Panel 3 (light gray bars). The error bars show LMEM-based 95% confidence intervals calculated using the LMEMinterval() function derived from Politzer-Ahles (2017). Like the Cousineau-Morey method (Cousineau, 2005; Morey, 2008), these intervals are adjusted to better represent the patterns of differences cross the experiment, however, unlike the Cousineau-Morey method, these LMEM-based intervals are suitable for crossed random effect designs.

between the panels were changed. The eye movement measures taken during reading indicated that readers had particular problems with correct reading order for the Blocked and Overlap Blocked layouts when compared to the standard Grid layout. For both versions of the Blocked layout, readers made more skips over the second panel in the narrative sequence, moving horizontally (and thus incorrectly) from the first panel to the third. They then often returned to the second panel from the third, suggesting they had realized their initial mistake, and were correcting it.

While readers showed similar behavior in terms of skips and regressions for Blocked and Overlap Blocked layouts, there were also differences between them. Readers were consistently correct in directing their saccades from Panel 1 to Panel 2 in the Grid layouts, while typically making incorrectly directed saccades (from Panel 1 to Panel 3) in the Overlap Blocked layout. However, for the Blocked layout, the position of text within the relevant panels also emerged as a potential factor. Readers' saccades out of Panel 1 in Blocked layouts were, therefore, influenced by the content of Panels 2 and 3, specifically the location of the text in these panels.

The influence of content is worth considering. The strongest effects were seen in viewing time on panels, where the amount of text increased viewing time. This is in line with previous work on comics (e.g., Laubrock et al., 2018; Kirtley et al., 2018) and other researchers looking at different types of mixed media (e.g., Rayner et al., 2001; Wang and Pomplun, 2011). Text is of high semantic importance when understanding a narrative, and so its presence in a panel means readers are more inclined to spend time on the region to take in the information.

In skipping measures, content also plays a (smaller) role, alongside the layout. The more words a panel contained, the less likely readers were to skip over it—although this was only seen when considering panels overall—at the level of the individual panel, the effect of words did not emerge. Thus, while layout had the stronger effect on navigation, the word content of the panels played a small but significant role in how readers selected the panels they moved to.

Expertise was not a strong influence on readers' tendency to skip panels. Previous work by Cohn (e.g., Cohn, 2014; Cohn and Campbell, 2015) has found that expertise and familiarity does play a role in comic navigation, with more expert readers better able to follow the Blocked layout versions, and so it might be expected that this would also be seen in skipping as a measure of navigation. In text reading, readers with higher spelling ability have been found to show greater skipping of words (Slattery and Yates, 2018) thus, it is possible that this behavior in comic reading has a similar, ability-linked reason behind it. However, unlike individual words, individual comic panels contain more information, from both the image and text, and thus skipping may not reflect quicker processing, but rather lead to poorer comprehension. Furthermore, the range of expertise scores within this sample is small, so further work with a greater range of scores is needed to explore this aspect more.

Overall, it appears that three aspects arise as influences on the navigation process, one very strong and two apparent modifiers of reading order in other areas. The strongest aspect is horizontal versus vertical progression of the narrative, while overlap between panels and the text location are the modifiers. These are discussed below, in relation to Cohn's (2013) findings.

### 2.3.1 | Horizontal versus vertical progression

Our participants showed a strong tendency to move through the panels horizontally, maintaining the Z-path. They did this even when the Z-path was incorrect for following the narrative, as in the Blocked and Overlap Blocked layouts. Cohn (2013) showed a similar tendency for participants to follow the Z-path, but that when confronted with a Blocked layout, his readers were more likely to deviate from the Z-path for this particular version. This difference appeared to be mediated by the readers' expertise and familiarity with comics, and this is likely to be the reason for the difference between our study and Cohn's. While Cohn's (2013) participants showed a range of scores on the VLFI, including those who were frequent comic readers, the participants in our study had an average score of 7.27 ($SD = 4.03$), indicating most readers had little or no familiarity with comics. The Blocked layout is one that is largely unique to comics, and so for this layout, they persisted in using the Z-path, despite the fact that this meant they often had to correct themselves.

### 2.3.2 | Overlap

When panels overlap with one another, this can have an effect on the direction the reader chooses—although only in some situations. Cohn (2013) found that readers would use the overlap to guide their reading, although he noted that readers could be led into rejecting the Z-path if the overlap suggested moving horizontally. Our own readers preferred to follow the overlap only when it indicated the Z-path, as seen in the Overlap Block layout. However, vertical overlap, such as in the Overlap Staggered condition, appeared to have no such effect on readers' navigation decisions. This is perhaps another indication of the effect of our readers' low expertise, leading to their preference of a familiar path, whatever the context.

### 2.3.3 | Placement of text

The final influence appears to come from the content of the panels being read- specifically how the text was placed in key panels. Experiment 1 suggests that location was not a strong influence for all panel types, but is important in the Blocked layout, the most ambiguous type. In a version with no strong overlap cues, our less experienced readers seemed equally likely to follow the Z-path or not; however, when the presence and location of text is closer in one panel, it seems to increase the likelihood that they will choose that panel as their next step. While this is the first demonstration of panel content contributing to panel navigation (and in a specific layout), it is in agreement with previous work showing that readers often make their first fixations in a new panel on the regions containing text (Laubrock et al., 2018, Kirtley et al., 2018).

Taken together, these three factors appear to have a hierarchical effect. For low expertise readers such as those tested in Experiment 1, the tendency to follow the Z-path was the strongest, and the influence of overlapping panels is seen when the overlap direction agrees with this. Text location had the weakest effect, only showing a small influence when there was uncertainty about direction, and no other indicator in the form of overlap cues.

However, it is important to note that while Experiment 1 showed a likely pattern of this behavior, it was only marginally significant. This is likely due to the relatively small amount of data for these conditions. We therefore followed up this finding in a second study, which focused on Blocked layouts alone, as these are the most sensitive to the influence of panel content, in order to experimentally test the influence of text position within panels on reading order.

In Experiment 2, new layouts were created, all variations of the Blocked arrangement. Both the overlap of panels and text location were manipulated, allowing us to determine how much these aspects contributed to the navigation behavior. Panels could either have no overlap (the standard Blocked layout), an overlap between Panels 1 and 3 (the Overlap Block, emphasizing a horizontal path), or an overlap between Panels 1 and 2 (a new layout, emphasizing a vertical path). Text in Panels 2 and 3 was also manipulated, so that it was either clearly closer to or further from Panel 1 for each layout type, resulting in six new critical layouts.

Given the findings of Experiment 1 and previous work by Cohn and colleagues, we predicted different reading patterns for each of the layout variations. For layouts in which Panels 1 and 3 overlap horizontally, we expected to see readers continue to follow the Z-path, regardless of text location, as the overlap encourages the horizontal reading path, which seems to take precedence over text. For layouts in which Panels 1 and 2 overlapped vertically, we expected to find that readers would also continue to prefer the incorrect horizontal path: however, this may be affected by text location. When text in Panel 2 is closer to Panel 1, this may encourage readers to break out of the Z-path and follow the correct vertical route. Finally, for the Blocked layout, with no overlaps, we predict that the reading direction will be influenced by text location, affecting readers' tendency to follow the z-path, with readers moving from Panel 1 to the panel which contains the closest text. For all layouts, it is also possible that readers' expertise will mediate this behavior.

## 3 | EXPERIMENT 2

### 3.1 | Method

#### 3.1.1 | Participants

Thirty-three participants (11 males, $M_{\text{age}} = 25.58$, $SD = 9.89$) were recruited from the Psychology undergraduate and postgraduate population at the University of Aberdeen. Three participants were removed from the following analyses due to errors in recording. In return for their participation, they received either course credits, or £3 as reimbursement. All participants had normal or corrected-to-normal vision. The average VLFI score was found to be 10.67 ($SD = 6.62$), with the majority of participants being novice readers. The study was approved by the local ethics committee (reference PEC/3625/2017/4) and was in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki).

#### 3.1.2 | Stimuli and apparatus

*Stimulus comics*

The six comics used in Experiment 1 were again employed for Experiment 2. Six versions of each story were produced, based on three variations of the Blocked layout, each with two versions of text location in Panels 2 and 3. In half the versions, the text in Panels 2 and 3 was moved, so that the Panel 2 text was closer to Panel 1. For the other half, the Panel 3 text was closest to Panel 1. Figure 5 shows the six variations in layout type and text location. The three layout types were as follows:

*Blocked.* This was identical to the Blocked manipulation used in Experiment 1, apart from changes made to the position of text in Panels 2 and 3.

*Horizontal Overlap.* This layout was identical to the Overlap Blocked layout in Experiment 1. Thus, the overlap linked Panels 1 and 3, while Panel 2 remained unconnected.

*Vertical Overlap.* In this layout, the border of Panel 1 overlapped with the border of Panel 2 below it.

Stimulus presentation, response collection and eye-tracking were all identical to Experiment 1. The VLFI was again used to measure readers' familiarity with the medium.

#### 3.1.3 | Procedure

The study's procedure was identical to that of Experiment 1.

#### 3.1.4 | Analysis

Analyses methods for Experiment 2 were similar to those for Experiment 1. The same measures of eye-movement behavior (viewing time, first-pass skipping, regressions and progressions between panels) on the manipulated panels were used. The same variables (panel layout, panel content (text presence and position) and expertise) were used as factors in the models.

In Experiment 2, the predictor for layout type had three levels, and was coded using simple coding, with the Blocked type as the reference level. This was chosen as it was the simplest version of the Blocked type, having no overlap additions between panels. Full models for Experiment 2 can be viewed in Appendix C.[4]

## 3.2 | Results

### 3.2.1 | Viewing time

Using the measure of dwell time, we examined how long readers spent on each panel of the manipulated layout. As well as the layout type, features of the panel content, such as text presence and image focus were included as factors, alongside readers' expertise score (Model 5.1). Table 5 presents the mean total viewing time per panel for the three layout types.

The greatest influences on the time spent on a panel were those relating to panel content. Viewing time on panels increased as the number of words within a panel increased, $\beta = 0.017$, SE $= 0.001$, $t = 14.43$, $p < 0.001$. Readers' expertise score did not affect viewing time, $\beta = -0.0004$, SE $= 0.004$, $t < 1$.

While failing to reach significance marginal effects of layout were found: readers spent marginally less time on panels of the Vertical Overlap condition, $\beta = -0.053$, SE $= 0.028$, $t = -1.94$, $p = 0.052$, and marginally less time on panels within the Horizontal Overlap condition than the Blocked condition, $\beta = -0.048$, SE $= 0.028$, $t = -1.74$, $p = 0.083$.[5]

### 3.2.2 | Skips and regressions within a layout

*First pass skipping*

Experiment 1 showed that the majority of skips and regressions occurred around the second panel of the Blocked and Overlap Blocked layouts: therefore, for Experiment 2, we focused on this panel to determine what pattern readers were following. We also included the new factor of text location in the analysis, as the presence of nearby text might attract the reader's attention to an incorrect panel. Table 6 presents the average proportion of first pass skips for panels in the three layouts.

The average proportion of first pass skips in all critical layouts was 0.198, (SD $= 0.40$) skips occurring across all three panels. For Panel 2 (Model 6.1), the average proportion of first pass skips was higher, at 0.48 (SD $= 0.50$). Again, this was uniformly high for all three layout types, and did not differ significantly between these three layout types (see Table 6).

The Vertical Overlap layout was found to show significantly fewer skips over Panel 2 compared to the Blocked layout, $\beta = -1.83$, SE $= 0.7731$, $t = -2.36$, $p = 0.018$. Text location was also a significant influence, with increased skipping over Panel 2 when the closer text was in Panel 3, $\beta = 1.77$, SE $= 0.406$, $t = 4.36$, $p < 0.001$. The

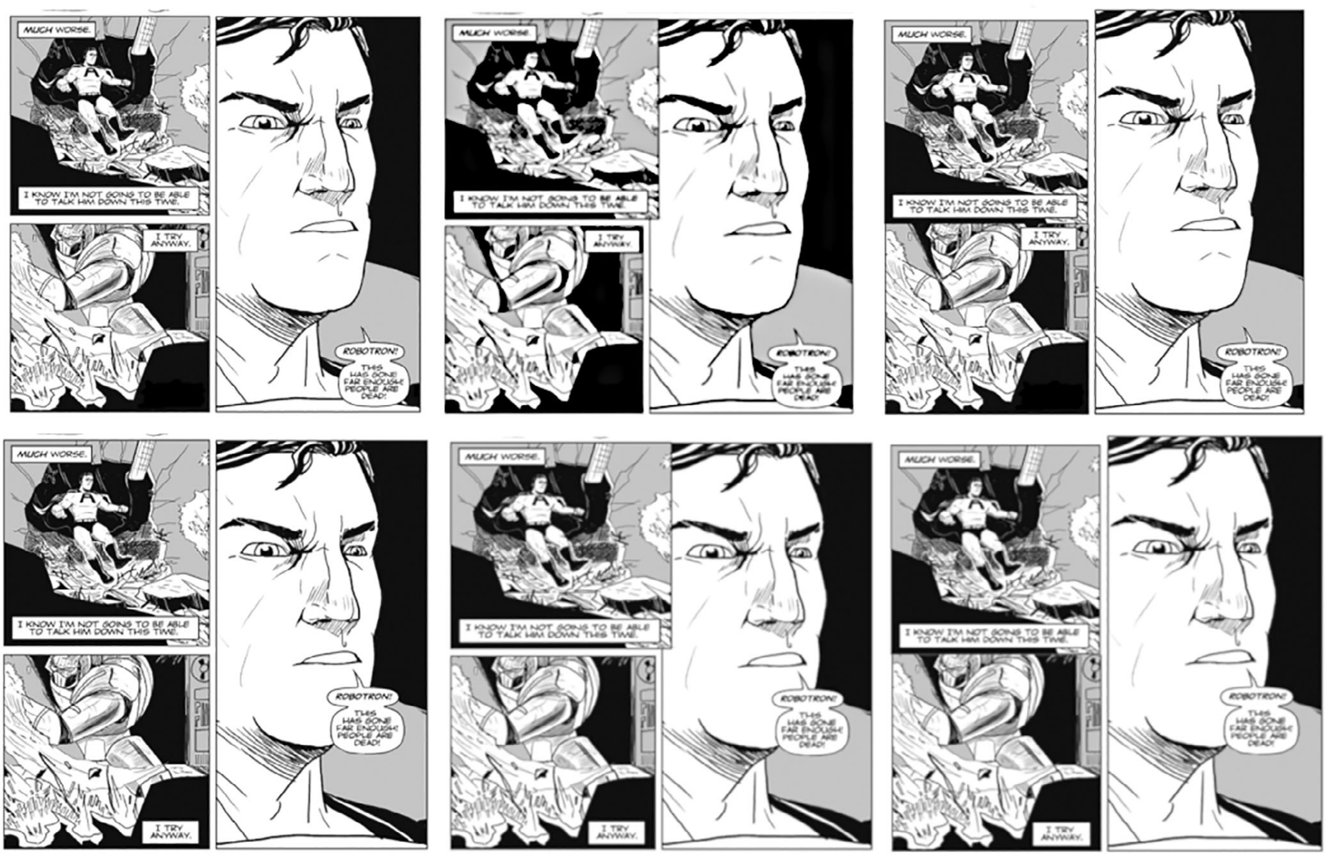


**FIGURE 5** Examples of the six layout styles used in Experiment 2; (L-R): Blocked, Horizontal Overlap, Vertical Overlap. Stimuli on the upper line show closest text in Panel 2, stimuli on lower line show closest text in Panel 3.

readers expertise score also influenced this reading behavior, such that readers who scored higher on the VLFI were less likely to skip this panel, $\beta = -0.076$, SE = 0.035, $t = -2.15$, $p < 0.032$. Interactions between text location and layout were examined, showing a marginal effect only for the Vertical Overlap layout, likely due to the lower level of Panel 2 skips when the closest text was in Panel 2.

*Regressions to earlier panels*

Examining the proportion of regressions in Experiment 2 found that 39.9% of saccades between panels were those returning to earlier locations within the critical panel group. Again, we focused on regressions into Panel 2, the panel most likely to have previously been skipped (Model 7.1). Of the regressions made within the critical panels, we found no influence of expertise on this behavior. However, participants were significantly less likely to make regressions from Panel 3 to Panel 2 when reading the Vertical Overlap layout, $\beta = -0.827$, SE = 0.307, $t = -2.70$, $p = 0.007$.

These findings indicate that, similar to Experiment 1, there are high incidences of skipping the second panel and returning to it from the third panel. However, regression behavior is affected by the comic layout, with less regressions made when the overlap indicated the correct reading direction.

*Proportion of progressive saccades*

As for Experiment 1, we examined the proportion of saccades launched from Panel 1 that ended in Panel 2 (the correct panel in the narrative sequence) and Panel 3 (the incorrect panel to fixate next; Model 8.1). The position of the text in Panels 2 and 3 was introduced as a factor. Here, the text position had been purposefully manipulated to ensure that the text of either Panel 2 or Panel 3 was closer to Panel 1.

Examining the proportion of correct saccades (Model 8.1; Figure 6a) showed that readers were affected by the placement of text across all three layout types, $\beta = 0.291$, SE = 0.106, $t = 2.74$, $p = 0.006$, with a higher proportion of saccades from Panel 1 to Panel 2 when the nearest text was in Panel 2 ($M = 0.36$, SD = 0.48), than when the nearest text was in Panel 2 ($M = 0.24$, SD = 0.43). There was a marginal effect of layout, with marginally more saccades from Panel 1 to Panel 2 in the Vertical Overlap layout than in the Blocked layout, $\beta = 0.496$, SE = 0.261, $t = 1.90$, $p = 0.058$. No interactions between layout type and text location were found to be significant. A significant effect of expertise was found, showing that readers with more experience in reading comics were more likely to make the saccades to panels in the correct/intended order than those with lower expertise scores, $\beta = 0.035$, SE = 0.016, $t = 2.15$, $p = 0.032$.

The proportion of saccades made to the incorrect panel in the narrative sequence within critical panel groups (i.e., transitions from Panel 1 to Panel 3; Model 8.2; Figure 6b) was similarly significantly influenced by several factors. Readers were more likely to (incorrectly) saccade from Panel 1 to Panel 3 when the nearest text was in Panel 3 ($M = 0.36$, SD = 0.48) than when the nearest text was in Panel 2 ($M = 0.21$, SD = 0.41), $\beta = -0.444$, SE = 0.115, $t = -3.87$, $p < 0.001$. Readers made more such saccades when navigating the Horizontal Overlap ($M = 0.36$, SD = 0.48) compared to the Blocked (M = 0.25, SD = 0.44) layout, $\beta = 0.578$, SE = 0.260, $t = 2.22$, $p = 0.026$.

Expertise was also a significant predictor of this behavior, with less expert readers making more incorrect progressions from Panel 1 to Panel 3, $\beta = -0.037$, SE = 0.018, $t = -2.08$, $p = 0.038$. No significant interactions between layout and text location were found.

## 3.3 | Discussion

Experiment 2 examined how readers navigated a specific subset of panel layouts: the Blocked variations. Of particular interest in this

**TABLE 5** Mean viewing time per panel for the three panel layouts in Experiment 2

| Panel | Layout type: Blocked M (SD) | Horizontal Overlap M (SD) | Vertical Overlap M (SD) |
|---|---|---|---|
| 1 | 2999.93 (2327.53) | 3106.75 (2543.40) | 2868.40 (2485.14) |
| 2 | 2327.05 (1322.43) | 2169.07 (1470.30) | 2139.33 (1649.85) |
| 3 | 5125.58 (4920.31) | 4963.38 (4727.84) | 5330.72 (5155.04) |

**TABLE 6** Average skip proportions per individual panel across the three layout types and two text locations in Experiment 2

| Panel number | | | | | | |
|---|---|---|---|---|---|---|
| Panel no. | 1 | | 2 | | 3 | |
| Closest text | P2 | P3 | P2 | P3 | P2 | P3 |
| Blocked | 0.033 | 0.067 | 0.367 | 0.633 | 0.0 | 0.0 |
| Horizontal overlap | 0.103 | 0.034 | 0.500 | 0.667 | 0.103 | 0.034 |
| Vertical overlap | 0.133 | 0.067 | 0.100 | 0.600 | 0.033 | 0.067 |

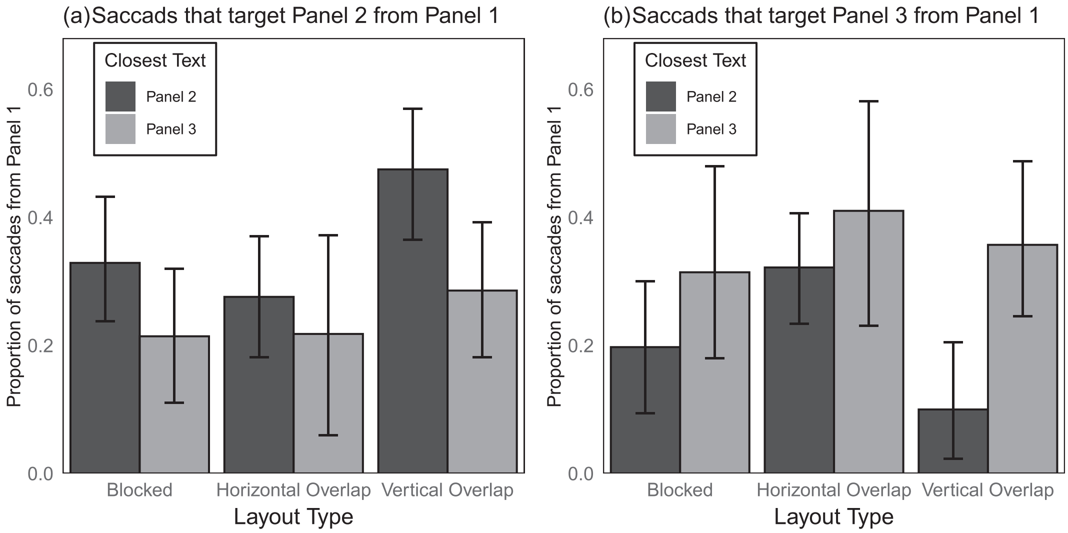


**FIGURE 6** The proportion of saccades from Panel 1, in Experiment 2, that (a) correctly target Panel 2, or (b) incorrectly target Panel 3 in the critical condition, each depending on whether the closest text to Panel 1 is in Panel 2 (dark gray bars) or Panel 3 (light gray bars). The error bars show LMEM-based 95% confidence intervals calculated using the LMEMinterval() function derived from Politzer-Ahles (2017). Like the Cousineau-Morey method (Cousineau, 2005; Morey, 2008), these intervals are adjusted to better represent the patterns of differences cross the experiment, however, unlike the Cousineau-Morey method, these LMEM-based intervals are suitable for crossed random effect designs.

study was the idea suggested in Experiment 1 that text location could be used to indicate the correct narrative sequence in ambiguous layouts, where stronger external cues from the panel outlines were absent.

We predicted that readers, particularly those of low expertise, would continue to follow the incorrect, but more familiar horizontal path when Panels 1 and 3 overlapped with each other. When the overlap indicated the correct but unfamiliar path of 1 to 2, readers would be more likely to take this route. For the plain Blocked layout with no overlaps, readers would be directed by text location, choosing the panel, which had the closest text. However, while it was found that text location did have an influence on navigation, this effect did not interact strongly with the layout type.

It is worth noting first that our findings regarding behavior such as regressions and skipping in all versions indicate that, whatever the other aspects, this layout is a difficult one for participants. In every version, readers frequently made the mistake of skipping panel two and having to return from the third panel at the same high incidence level, which is comparable with those seen in Experiment 1. This is in line with work by Abel and Madden (2008), as well as the general anecdotal accounts of many comic creators. For inexperienced readers, like our participants (VLFI $M = 10.67$, $SD = 6.62$), it seems the novel nature of this layout is one that cannot be overcome easily without repeated exposure. Indeed, there is a strong similarity between the values of skips and regressions around Panel 2 for the layouts used in this study, and in Experiment 1, indicating consistency between how participants responded within the two studies. There is also a similar influence of content in this second study—again, the panel content exerts the strongest effect on viewing time, and also influences skipping behavior. The effect of the more specific content manipulation, changing text location, is considered in the following section.

### 3.3.1 | Influence of text location

According to the External Compositional Structure (ECS; Cohn, 2013), when presented with a Blocked layout, experts should use the inner borders to move from 1 to 2; while non-experts will ignore the borders to some extent, and move from 1 to 3, at least initially (Cohn, 2013). The overlap between 1 and 2 in the Vertical Overlap condition should encourage the correct path to be followed—Cohn and Campbell (2015), looking at vertical overlaps in Grid layouts, found that overlaps on the left hand side of a layout led to the most deviation from the Z-path, due to the strengthened continuation of the inner borders. Similarly, in the Horizontal Overlap, 1 to 3 should be preferred, due again to the continuous borders, and the grouping indicated by the panel closeness (Cohn, 2013). We support these predictions (readers made more correct saccades and fewer Panel 2 skips in the Vertical Overlap, and more incorrect saccades in the Horizontal), and further add an influence of text location that is independent of the underlying panel layout (participants tended to go to the panel with more accessible text from Panel 1, regardless of whether and how the panels overlapped). This was particularly clear for saccades that were correctly directed to the second panel in the narrative sequence: indeed, text location had a strongly significant influence on this behavior, alongside an effect of expertise which further confirms that navigating these layouts is largely a matter of experience (in line with Cohn, 2013). A similar pattern emerges for skipping behavior—closer text in Panel 3 increases the likelihood of the reader skipping Panel 2 and going to Panel 3 first—and while a marginal interaction with layout shows that the Vertical Blocked version can reduce skipping when Panel 2 has the closest text region, it appears for our readers, the continuous border between panels 1 and 2 did not help when the Panel 3 text was closer to when they were viewing Panel 1.

For saccades that incorrectly targeted Panel 3 instead of Panel 2, there was also influences from the external panel structure: in the horizontally overlapping layout, where everything indicates the more familiar but incorrect path, there were more mistakes overall. This was also independent of the text placement, where again participants were more likely to be drawn to the closest text region across all layouts. Overall, it appears that the panel content, specifically the presence and location of text, was a stronger factor in guiding reading than the findings of Experiment 1 would indicate.

The finding that the Blocked layout in particular is not significantly affected by text location is perhaps unexpected: this is the layout that has no other hints at the correct direction from the panel borders, so it might be expected that text would have the strongest effect here. It is possible that this may also be a finding which would be mediated by expertise (low expertise readers, as in this study, use text for all layouts, higher expertise readers use a combination of text and border information as cues.)

The importance of text is something, which has been noted in earlier studies of comics and word-image combinations in general. Rayner et al. (2001), looking at how readers viewed multimedia magazine adverts, noted that the first goal seemed to be to get to the text first, before attending to the image for a longer period. This is further seen in Caroll et al.'s (1992) study of single panel cartoons, and the earlier work on comic reading by Kirtley et al. (2018) and Ishii et al. (2004). In the present study, 41% of first fixations into a panel were to text regions, despite the fact text occupies a smaller area of a panel than the image (on average text occupied just 14% of the comic page). Indeed, even in real-world scenes, gaze is strongly drawn to regions of text (Wang and Pomplun, 2012). Text is highly informative, and, as Rayner et al. (2001) note, prioritizing this information may be the result of much exposure to multimedia stimuli over the years. This suggestion raises further questions with regard to expertise, however: while text is typically more informative, it is not always the case in comics (see McCloud's (1993, 2006) seven word-image combinations, where text can play a much reduced role in providing information compared to image). Less expert readers who have not had this experience may be more swayed by text location than experts, who are guided by the External Compositional Structure alone. This would be in line with Cohn's previous findings (Cohn, 2013; Cohn and Campbell, 2015), but the current study cannot provide stronger evidence for this proposal. Further work which compared high and low expertise readers is required to determine if the two groups perceive text in the context of comics differently as a guide for navigation through the panels.

The pattern we predicted for Experiment 2 based on the findings in Experiment 1 were not borne out—but the suggestion from Experiment 1 was based on only a small subset of the data, in which there were naturally occurring variations in text placement within the panel. Experiment 2 shows more clearly that, for variations of the Blocked panel layout, internal panel content is as strong a guide as the external panel structure.

## 3.4 | General discussion

Two experiments were conducted to examine the influence of panel content and layout on readers' navigation decisions. Experiment 1 showed that the external structure of the panels was a major factor in participants' decisions of how to move between panels, although a small role of panel content, specifically text location, was seen in certain more ambiguous layouts. Experiment 2 focused on these ambiguous Blocked layouts and text location, and found text location had an influence regardless of the layout variations for that type.

Our findings are largely in agreement with Cohn's proposals about the role of the external structures of a panel (Cohn, 2013; Cohn and Campbell, 2015). The key aspect of Cohn's theory is that, while the content of a panel is important for comprehending the narrative, reading order is not. As stated in Cohn and Campbell (2015), 'A single four-panel comic strip might be arranged horizontally, vertically or in a 2 × 2 grid, so long as the panels are still read in the same successive order, the meaning of the sequence should not change' (p.194). However, our inclusion of content and the findings regarding the text indicates that additions should be made to the process.

Both studies show that content has its strongest effect on the viewing time, with high-interest images (characters) and text increasing the time a reader spends on the location. However, while less prominent, content also affects how readers move through the panels. Content, particularly that which may be informative to the readers' understanding of the story, is therefore playing a role in how readers select panels. From Experiment 2, it seems that we can go further, and identify that text location in particular is affecting the initial navigation of the layout.

Cohn's (2013) iteration of the ECS suggests two first steps when readers are deciding how to progress from the first panel of a layout-checking the inner and outer borders to determine whether one or both are contiguous (see Figure 2). This influences the decision to move right, or down. We suggest that another aspect should be added here, specifically for ambiguous layouts, such as variations on the Blocked item. This addition would state that readers should search for the closest text source in the upcoming panels, and go to this panel if uncertain regarding the next step. From Experiment 2, it seems this ambiguity is not just related to lack of features such as overlap between panels, but any situation where there is a vertical blockage of the inner borders. It is possible that this may only be a factor for low-expertise readers, and raises questions about how affected high expertise readers are likely to be by this: for example, will they ignore text location entirely, and rely solely on the ECS, or will there be situations when text is enough to draw them in? These questions are something that should be addressed in future work.

Overall, the two experiments reported here add more detail to the current literature on comic navigation, by both confirming earlier findings, and showing a role for content. Furthermore, these findings contribute to the growing body of evidence that supports the view that comic navigation is not a random or disorganized process but a strategic one. Reading comics, just as reading text, is about using the information from the material, and the readers' own experience in order to properly navigate the narrative.


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## CONFLICT OF INTEREST

The authors confirm they have no conflicts of interest to declare

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.


## ORCID

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## ENDNOTES

[1] It should be noted that Panel 3 in the Blocked layout was larger than Panel 3 (or any other panels) in any of the other layouts. This alone may be why participants spent longer viewing each panel in the blocked layout than in the grid layouts. To test this, we ran an additional analysis that considered summed viewing time across all panels in the critical group. This removed the effect of having an increased viewing time on panels in the blocked layout, meaning that we cannot be sure whether the increased viewing time per panel in blocked layouts arises because of some difficulty in processing the narrative flow of the story or merely from the larger panel. However, this is not the focus of our interpretation and does not undermine the effect of the amount of text that is found in this analysis.

[2] We carried out the same analyses including both look-aheads and longer digressions and found a similar pattern of increased skipping in the Blocked layout overall, and for Panel 2 in both the Blocked and Overlap Blocked layouts, indicating that the layout type is a factor in both of these behaviors.

[3] Note that for blocked layouts (blocked and overlap blocked) the critical panel group comprised only three panels and so the analysis of Panel 4 skipping did not include these two types of layout.

[4] Note that the model did not converge with the inclusion of word number, so it was removed from the final model

[5] All of these marginal effects of layout disappeared when the total viewing time summed across all panels of the critical panel group was used modeled rather than the time per panel. This means that as in Experiment 1, effects of layout on panel viewing times may be because of differences in sizes of panels between layouts.

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## APPENDIX A: MODEL STRUCTURE

Model 1.1/5.1: Average viewing time (log corrected) per critical panels.

$$\log 10\text{Viewing Time} \sim \text{Layout Type} + \text{Word Number} + \text{Expertise} + (1\,|\,\text{Subject}) + (1\,|\text{Comic}).$$

Models 2.1–2.5: Proportion of first pass skips of comic panels.

$$\text{First Pass Skip} \sim \text{Layout Type} + \text{Word Number} + \text{Expertise} + (1\,|\,\text{Subject}) + (1\,|\,\text{Comic}).$$

Model 3.1/7.1: Proportion of regressions launched from Panel 3 and landing in Panel 2.

$$\text{Proportion of Regressions from P3 To P2} \sim \text{Layout Type} + \text{Expertise} + \text{Word Number} + (1\,|\,\text{Subject}) + (1\,|\,\text{Comic}).$$

Model 4.1/8.1: Proportion of saccades launched from Panel 1 and landing in Panel 2.

$$\text{Saccade}: \text{P1 to P2} \sim \text{Text Location}^{*}\ \text{Layout Type} + \text{Expertise} + (1\,|\,\text{Subject}) + (1\,|\text{Comic}).$$

Model 4.2/8.2: Proportion of saccades launched from Panel 1 and landing in Panel 3.

$$\text{Saccade}: \text{P1 to P3} \sim \text{Text Location}^{*}\ \text{Layout Type} + \text{Expertise} + (1\,|\,\text{Subject}) + (1\,|\text{Comic}).$$

Models 6.1: Proportion of first pass skips of comic panels.

$$\text{First Pass Skip} \sim \text{Layout Type}^{*}\ \text{Text Location} + \text{Expertise} + (1\,|\,\text{Subject}) + (1\,|\,\text{Comic}).$$

## APPENDIX B: EXPERIMENT 1 MODEL SUMMARIES

Model 1.1: Model to predict viewing time per critical panels in the layouts.

| Fixed effects | Estimate | SE | *t* | |
|---|---|---|---|---|
| (Intercept) | 3.20 | 0.068 | 46.69 | <0.001 |
| Layout Type: Overlap Grid | 0.008 | 0.032 | 0.26 | 0.800 |
| Layout Type: Staggered | 0.006 | 0.030 | 0.21 | 0.834 |
| Layout Type: Overlap Staggered | −0.004 | 0.003 | −0.01 | 0.989 |
| Layout Type: Blocked | 0.073 | 0.033 | 2.21 | 0.028 |
| Layout Type: Overlap Blocked | −0.014 | 0.033 | −0.42 | 0.674 |
| Word Number | 0.018 | 0.001 | 18.83 | <0.001 |
| Expertise | −0.004 | 0.005 | −0.82 | 0.421 |
| Random effects Variance | | | | |
| Subjects | 0.009 | | | |
| Items | 0.017 | | | |

Model 2.1: Model to predict proportion of overall first pass skips in critical layouts.

| Fixed effects | Estimate | SE | *z* | |
|---|---|---|---|---|
| (Intercept) | −2.320 | 0.304 | −7.64 | <0.001 |
| Layout Type: Overlap Grid | −0.486 | 0.497 | −0.98 | 0.328 |
| Layout Type: Staggered | −0.737 | 0.519 | −1.42 | 0.156 |
| Layout Type: Overlap Staggered | 0.103 | 0.425 | 0.24 | 0.808 |
| Layout Type: Blocked | 1.214 | 0.390 | 3.11 | 0.002 |
| Layout Type: Overlap Blocked | 0.956 | 0.399 | 2.37 | 0.017 |
| Word Number | −0.005 | 0.011 | −0.44 | 0.659 |
| Expertise | 0.049 | 0.030 | 1.60 | 0.109 |
| Random effects Variance | | | | |
| Subjects | 0.0 | | | |
| Items | 0.052 | | | |

Model 2.2: Model to predict proportion of first pass skips over Panel 1 in critical layouts.

| Fixed effects | Estimate | SE | *z* | |
|---|---|---|---|---|
| (Intercept) | −7.799 | 0.171 | −0.09 | 0.931 |
| Layout Type: Overlap Grid | 0.141 | 1.563 | 0.09 | 0.928 |
| Layout Type: Staggered | −23.46 | 40.95 | −0.04 | 0.965 |
| Layout Type: Overlap Staggered | −0.029 | 1.567 | −0.02 | 0.985 |
| Layout Type: Blocked | 1.352 | 1.377 | 0.98 | 0.326 |
| Layout Type: Overlap Blocked | 1.176 | 1.406 | 0.84 | 0.403 |
| Word Number | −0.256 | 0.136 | −1.87 | 0.061 |
| Expertise | 0.210 | 0.111 | 1.89 | 0.058 |
| Random effects Variance | | | | |
| Subjects | 0.147 | | | |
| Items | 0.0 | | | |

Model 2.3: Model to predict proportion of first pass skips over Panel 2 in critical layouts.

| Fixed effects | Estimate | SE | *t* | |
|---|---|---|---|---|
| (Intercept) | −1.753 | 0.525 | −3.34 | <0.001 |
| Layout Type: Overlap Grid | −0.190 | 0.819 | −0.23 | 0.816 |
| Layout Type: Staggered | −1.481 | 1.154 | −1.28 | 0.199 |
| Layout Type: Overlap Staggered | 0.277 | 0.732 | 0.38 | 0.705 |
| Layout Type: Blocked | 2.36 | 0.664 | 3.55 | <0.001 |
| Layout Type: Overlap Blocked | 2.20 | 0.661 | 3.34 | <0.001 |
| Word Number | 0.030 | 0.038 | 0.91 | 0.364 |
| Expertise | 0.030 | 0.051 | 0.591 | 0.555 |
| Random effects Variance | | | | |
| Subjects | 0 | | | |
| Items | 0 | | | |

Model 2.4: Model to predict proportion of first pass skips over Panel 3 in critical layouts.

| Fixed effects | Estimate | SE | *t* | |
|---|---|---|---|---|
| (Intercept) | 6.12 | 141.33 | −0.04 | 0.965 |
| Layout Type: Overlap Grid | −18.01 | 847.96 | −0.021 | 0.983 |
| Layout Type: Staggered | −0.452 | 0.966 | −0.468 | 0.640 |
| Layout Type: Overlap Staggered | 0.017 | 0.877 | 0.019 | 0.985 |
| Layout Type: Blocked | 0.010 | 0.877 | 0.011 | 0.991 |
| Layout Type: Overlap Blocked | −1.20 | 1.20 | −0.996 | 0.319 |
| Word Number | 0.01 | 0.015 | 0.84 | 0.400 |
| Expertise | 0.047 | 0.078 | 0.61 | 0.544 |
| Random effects Variance | | | | |
| Subjects | 0.188 | | | |
| Items | 0.048 | | | |

Model 2.5: Model to predict proportion of first pass skips over Panel 4 in critical layouts.

| Fixed effects | Estimate | SE | *t* | |
|---|---|---|---|---|
| (Intercept) | −2.38 | 0.816 | −2.92 | 0.003 |
| Layout Type: Overlap Grid | −0.218 | 0.829 | −0.26 | 0.917 |
| Layout Type: Staggered | −0.307 | 0.828 | −0.37 | 0.710 |
| Layout Type: Overlap Staggered | 0.081 | 0.777 | 0.12 | 0.917 |
| Word Number | 0.025 | 0.014 | 1.78 | 0.076 |
| Expertise | 0.028 | 0.074 | 0.38 | 0.703 |
| Random effects Variance | | | | |
| Subjects | 0 | | | |
| Items | 0 | | | |

Model 3.1: Model to predict proportion of regressions launched from Panel 3 and ending in Panel 2.

| Fixed effects | Estimate | SE | *z* | |
|---|---|---|---|---|
| (Intercept) | −1.98 | 0.468 | −4.23 | <0.001 |
| Layout Type: Overlap Grid | −0.308 | 0.666 | −0.46 | 0.647 |
| Layout Type: Staggered | 0.261 | 0.566 | 0.46 | 0.629 |
| Layout Type: Overlap Staggered | 0.033 | 0.542 | 0.06 | 0.952 |
| Layout Type: Blocked | 1.87 | 0.485 | 3.85 | <0.001 |
| Layout Type: Overlap Blocked | 2.24 | 0.504 | 4.45 | <0.001 |
| Expertise | 0.009 | 0.028 | 0.33 | 0.608 |
| Random effects Variance | | | | |
| Subjects | 0 | | | |
| Items | 0 | | | |

Model 4.1: Model to predict proportion of saccades launched from Panel 1 and landing in Panel 2, incorporating text location.

| Fixed effects | Estimate | SE | *z* | |
|---|---|---|---|---|
| (Intercept) | −1.79 | 0.261 | −6.84 | <0.001 |
| Layout Type: Block | −0.182 | 0.255 | −0.71 | 0.475 |
| Layout Type: Overlap Block | −1.66 | 0.56 | −2.97 | 0.003 |
| Text Location | −0.037 | 0.202 | −0.18 | 0.857 |
| Expertise | −0.015 | 0.024 | −0.62 | 0.537 |
| Layout Type: Block* Text Location | 0.564 | 0.254 | 2.21 | 0.027 |
| Layout Type: Overlap* Text Location | −0.368 | 0.560 | −0.66 | 0.511 |
| Random effects Variance | | | | |
| Subjects | 0.0 | | | |
| Items | 0.0 | | | |

Model 4.2: Model to predict proportion of saccades launched from Panel 1 and landing in Panel 3, incorporating text location.

| Fixed effects | Estimate | SE | *z* | |
|---|---|---|---|---|
| (Intercept) | −2.02 | 0.260 | −7.77 | <0.001 |
| Layout Type: Block | 0.773 | 0.364 | 2.12 | 0.034 |
| Layout Type: Overlap Block | 1.65 | 0.294 | 5.17 | <0.001 |
| Text Location | −0.310 | 0.146 | −2.13 | 0.034 |
| Expertise | 0.025 | 0.029 | 0.84 | 0.403 |
| Layout Type: Block* Text Location | −0.485 | 0.363 | −1.33 | 0.182 |
| Layout Type: Overlap* Text Location | 0.145 | 0.294 | 0.50 | 0.621 |
| Random effects Variance | | | | |
| Subjects | 0.0 | | | |
| Items | 0.0 | | | |

## APPENDIX C: EXPERIMENT 2 MODEL SUMMARIES

Model 5.1: Model to predict viewing time per critical panels in the layouts.

| Fixed effects | Estimate | SE | *t* | |
|---|---|---|---|---|
| (Intercept) | 3.18 | 0.084 | 38.02 | <0.001 |
| Layout Type: Horizontal Overlap | −0.048 | 0.028 | −1.74 | 0.083 |
| Layout Type: Vertical Overlap | −0.053 | 0.028 | −1.94 | 0.052 |
| Word Number | 0.017 | 0.001 | 14.43 | <0.001 |
| Expertise | −0.0004 | 0.004 | −0.10 | 0.923 |
| Random effects Variance | | | | |
| Subjects | 0.013 | | | |
| Items | 0.028 | | | |

Model 6.1: Model to predict proportion of first pass skips over Panel 2 in critical layouts.

| Fixed effects | Estimate | SE | *z* | |
|---|---|---|---|---|
| (Intercept) | −0.247 | 0.562 | −0.44 | 0.664 |
| Layout Type: Horizontal Overlap | 0.639 | 0.773 | 1.07 | 0.284 |
| Layout Type: Vertical Overlap | −1.826 | 0.773 | −2.36 | 0.018 |
| Text location | 1.770 | 0.406 | 4.36 | <.0001 |
| Expertise | −0.076 | 0.035 | −2.15 | 0.032 |
| Layout Type: Horizontal Overlap* Text Location | −0.507 | 0.850 | −0.60 | 0.551 |
| Layout Type: Vertical Overlap* Text Location | 1.608 | 0.972 | 1.65 | 0.098 |
| Random effects Variance | | | | |
| Subjects | 0.439 | | | |
| Items | 0.525 | | | |

Model 7.1: Model to predict average number of regressions launched into Panel 2 in critical layout.

| Fixed effects | Estimate | SE | *z* | |
|---|---|---|---|---|
| (Intercept) | 0.135 | 0.328 | 0.41 | 0.681 |
| Layout Type: Horizontal Overlap | −0.292 | 0.299 | −0.98 | 0.329 |
| Layout Type: Vertical Overlap | −0.827 | 0.307 | −2.70 | 0.007 |
| Expertise | −0.023 | 0.021 | −1.14 | 0.256 |
| Random effects Variance | | | | |
| Subjects | 3.181 e−10 | | | |
| Items | 0.264 | | | |

Model 8.1: Model to predict proportion of saccades launched from Panel 1 and landing in Panel 2, incorporating text location.

| Fixed effects | Estimate | SE | *z* | |
|---|---|---|---|---|
| (Intercept) | −1.289 | 0.240 | −5.38 | <0.001 |
| Layout Type: Horizontal Overlap | −0.118 | 0.267 | −0.44 | 0.660 |
| Layout Type: Vertical Overlap | 0.496 | 0.261 | 1.90 | 0.058 |
| Text Location | 0.291 | 0.106 | 2.74 | 0.006 |
| Expertise | 0.035 | 0.016 | 2.15 | 0.032 |
| Layout Type: Horizontal Overlap* Text Location | −0.163 | 0.267 | −0.61 | 0.540 |
| Layout Type: Vertical Overlap* Text Location | 0.088 | 0.261 | 0.34 | 0.737 |
| Random effects Variance | | | | |
| Subjects | <0.001 | | | |
| Items | 0.057 | | | |

Model 8.2: Model to predict proportion of saccades launched from Panel 1 and landing in Panel 3, incorporating text location.

| Fixed effects | Estimate | SE | *z* | |
|---|---|---|---|---|
| (Intercept) | −0.641 | 0.279 | −2.30 | 0.022 |
| Layout Type: Horizontal Overlap | 0.578 | 0.260 | 2.22 | 0.026 |
| Layout Type: Vertical Overlap | −0.255 | 0.302 | −0.85 | 0.398 |
| Text Location | −0.444 | 0.115 | −3.87 | <0.001 |
| Expertise | −0.037 | 0.018 | −2.08 | 0.038 |
| Layout Type: Horizontal Overlap *Text Location | 0.159 | 0.259 | 0.62 | 0.538 |
| Layout Type: Vertical Overlap* Text Location | −0.471 | 0.301 | −1.57 | 0.117 |
| Random effects Variance | | | | |
| Subjects | 2.565 e−09 | | | |
| Items | 0.174 | | | |