How Readers Navigate Comic Book Pages: Evidence from Eye Movements

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Abstract

While a z-path is intrinsically part of how typically formatted text is read, it is less clear that this same approach is used when reading comics. Previous evidence for the z-path is limited to self-reported preferences from readers. The main aim of this paper was to objectively confirm that readers do use a z-path when navigating a comic book page by using eye-tracking technology. We examined the eye-movement behaviour of 90 participants when reading a textless page from the comic Watchmen. Participants were a mix of novice and expert comic book readers. Results indicated that the z-path was an accurate prototypical descriptor of how participants navigated the comic book pages, but that there was a great deal of variation from that prototype. In particular, it was shown that readers commonly demonstrated regressive saccades, where fixations moved back to the previous panel rather than to the next panel in the z-path order. These findings provide a strong first foundation for future work in this area that looks at reading behaviour in comic book pages.

Introduction

In recent years comic books and graphic novels have increasingly become part of mainstream popular culture and this has been accompanied by an increase in their academic study in a number of subject areas. However, before discussing some of this research, it is worth briefly examining what 'comics' are.

What do we mean by 'Comics'?

A commonly cited definition of comics is that they are "Juxtaposed pictorial and other images in deliberate sequence, intended to convey information and/or to produce an aesthetic response in the viewer" (McCloud, 1994). However, various authors have pointed out important nuances, exceptions, and cross-cultural differences that make it difficult to identify one universally-accepted definition (e.g., see Cohn, 2005; Earle, 2021; Aggleton, 2019). While a detailed exploration of the definition of comics is beyond the scope of this paper, it is worth briefly explaining how the term is used in the present study despite there being no accepted academic definition of the term.

This description is not intended as an alternative (or indeed a response) to the existing academic discussion on what constitutes 'comics' but given the complexity of the arguments made by various authors (for examples see above) this 'working definition' encompasses only those structural aspects that are directly relevant to the study in hand. Firstly, comics embody sequence, whereby one image follows another in order to display the passage of time. This definition excludes single panel cartoons that obviously do not involve sequence. We are also excluding comics that involve actual movement (via for example animation) and/or actual sound. Secondly, while comics typically involve images alongside text, there are numerous examples of comics that only include images. Thirdly, comics tend to involve abstraction in the images, most often as cartoons although more photo realistic comics, including those involving still photographs, are also in existence.

Finally, comics tend to involve a narrative or story-like element although, again, there are exceptions to this.

The Academic Study of Comics

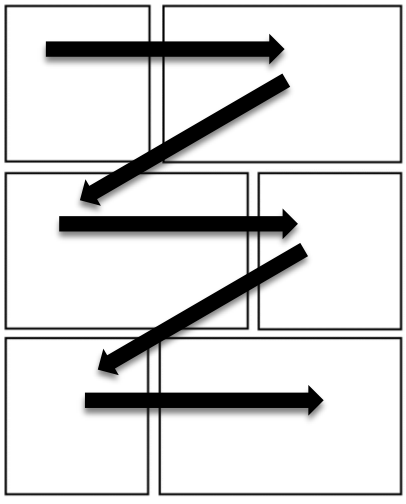
Comics research falls into two basic approaches. The first deals with applied research, particularly in relation to the potential benefits of comics for education or for communication with lay audiences (e.g., Aleixo & Norris, 2007; Syma & Weiner, 2013; Czerwiec *et al.*, 2015). The second deals with non-applied approaches that attempt to understand how comics are perceived and/or mentally processed by readers. This latter branch of research is crucial as it is not necessarily straightforward to read a comic and there are substantial differences from reading text alone. For example, the conjunction of both text and images that must be attended to and the potential inconsistency in layout relative to a fully textual medium pose challenges that readers must overcome (Coderre, 2019). In addition, there are stylistic conventions (e.g., thought and speech balloons) that may not be intuitive to novice readers (Golding & Verrier, 2021).

However, empirical studies that investigate the way readers process information from a sequential comic book are scarce. Theoretical ideas range from a comic book 'language' (e.g., Cohn, 2013a; Fischer, 1984; Oshiro, 1982) to ideas regarding the depiction of movement, passage of time, facial expressions, and symbolic images (e.g., McCloud, 1994) and most of this includes very little empirical support. It seems clear that there is a lack in the basic understanding of how comics are perceived and ‘read’, especially when compared to the substantial empirical and theoretical work that has been done in relation to reading text (e.g., see Snowling, Hulme & Nation, 2022). A more detailed exploration of these processes is crucial for fully understanding the potential advantages of comics in applied settings such as education.

Studies on Comic Page Navigation

One aspect of comic book reading that is important to understand is how readers follow the sequence of images in comics, as doing this effectively is necessary to make sense of the overall narrative. Cohn (2013b) and Cohn and Campbell (2015) investigated the way in which experienced comic readers navigate blank comic pages with differing panel arrangements. Both studies asked frequent comic book readers to number the order in which they would read each of the panels presented if they had been present in an actual comic book. They concluded that, for standard arrangements of panels, readers preferred a left to right 'z' shaped path, whereby top panel layers are read first followed by each subsequent layer on a page (see figure 1). Pages where there were 'unusual' arrangements of panels had less obvious reading paths, though some tentative suggestions were made for how readers make decisions about navigating through these.

Figure 1 – Example of 'z' shaped reading path proposed by Cohn (2013b) and Cohn and Campbell (2015).



Alt Text: Black and white diagram of six blank comic panels in three layers on one page. This shows two 'Z' shapes made up of five black arrows overlayed on the page displaying the route taken to read the page.

These studies, however, have at least two limitations. First, they contained blank pages, which removes any contextual information contained within panels that might provide information for panel reading sequence. This contextual information includes the placement of word balloons, which often inform readers which panel to read next (Chiarello & Klein, 2004; Starkings & Roshell, 2003), as well as the pictorial information within panels. Second, the responses were self-report rather than measures of actual eye movements across a page. Given that individuals' impressions of their eye movements whilst reading are far removed from the actual movements made by the eyes (Rayner *et al*., 2011) it seems likely that self-reported measures of intentions are of limited value in determining how page navigation actually takes place. Therefore, the measurement of eye movements could be very informative in understanding how comic book readers navigate pages. In addition, while Cohn (2013b) and Cohn and Campbell (2015) examined less straightforward panel arrangements in their studies, it is arguable that there is a greater need to understand basic panel arrangements (such as those shown in Figure 1) before trying to explain more complex page/panel organisation.

Eye-movement Studies

When individuals read or examine a scene, their eyes continually move in 'jumps' termed saccades. It is generally acknowledged that only limited information can be obtained from the environment during saccades and only in specific circumstances (e.g., Campbell & Wurst, 1979). In between saccades, the eyes stop moving during 'fixations'. It is during these fixations that new information is collected by the cognitive system (Rayner, 2009). Eye movements are necessary because the retina has most acuity at its centre (the fovea) so readers must keep their fovea over the part of the stimulus that they want to see clearly.

As such, eye movements are a way to measure overt attention during complex cognitive processing tasks, including reading a comic book page.

Eye movements during the viewing of pictorial scenes typically consist of longer fixations and larger saccades compared to those when viewing textual material for reading (Rayner *et al*., 2011). This may be because observers can take in much more information from an image at the periphery of the retina when compared with reading text (e.g. see Morgan & Meyer, 2005). While the range of fixation time for reading is between 225 and 250ms, it is between 260 and 330ms for viewing pictures, with more dense, detailed pictures requiring longer fixations (Rayner, 2009). Another difference is that people will spend more time fixated on areas that are particularly salient within pictures such as faces or, more generally, areas that stand out in some way (Parkhurst & Niebur, 2003). In contrast, there is a relative uniformity of salience of textual information. Therefore, while studies on eye movements when reading text can provide some information about the complex cognitive processing of comics, these are less applicable to the perception of pictorial information within comics.

Eye movement research on print advertising may be more relevant to comics, as adverts typically ask viewers to both read text and examine pictures. A review of research in this area by Higgins, Leinenger, & Rayner (2014) suggests that colourful adverts are fixated on more than black and white ones. They also found that larger *pictures* are more likely to be fixated on when there is competition between products, but that larger *text* is more important when products are presented alone. It is unclear from the review whether people tend to skip back and forth between text and image, or whether they have a preference to focus on first one, then the other. However, what *is* clear is that motivation for engaging with the material is important. For example, fixations are longer if reading an advert relevant to a possible future purchase. In this respect, we might expect eye-tracking behaviour when reading adverts to be different from when reading comics. Typically, one

is motivated by gaining information to inform possible future behaviour and the other is motivated by a desire to understand a narrative and the pleasure taken in reading.

Eye Tracking Studies of Comics

In terms of studies that have used eye tracking equipment to examine eye movements whilst reading comic pages, none appears to have focused specifically on the issue of panel navigation. For example, Foulshom, Wybrow and Cohn (2016) investigated the role of context in guiding eye movements whilst reading short wordless comic strips. They found that when comic strips were presented out of order (i.e., with reduced context) participants required a greater number of fixations and more regressions than when they were presented in the correct order. They concluded that context affects where people look, which suggests that a top-down process is occurring, whereby prior knowledge is used to guide eye movements. Notably, this study assumed that readers followed the default 'z-path' described by Cohn (2013b) but did not directly test this.

Eye-tracking equipment was used by Kirtley *et al*. (2018) to assess reading behaviour in relation to four typical comics that included both textual and visual information across panels. They found longer gaze duration (dwell time) for panels that contained text. The more text, and the more space taken up by text, the longer the dwell time. This makes sense, as panels that contain text will typically (though not always) be more informationally dense than panels without text. They also found that character images (i.e., people and faces) had longer dwell times than non-character images. This is in line with findings discussed above about the salience of visual information. Also in line with the findings discussed above, they found that saccades were longer when viewing pictorial information compared to textual elements, and that larger pictures led to longer saccades.

Kirtley et al. (2018) assumed that there was a particular order in which readers should progress from one panel to the next (presumably following a z-path, though this is not specified), and measured the factors that cause readers to "skip" panels in that order.

Certainly, there was strong evidence that the top left panel is a natural starting point (on average, only 1.9% of first fixations on a page occurred in other locations). Readers were less likely to skip panels that contained text or character images and were particularly likely to skip textless panels if the subsequent panel *did* contain text suggesting that it is the text which is driving the eye movements.

While previous work has assumed the presence of a normative z-path when reading comic book pages, the degree to which this actually occurs has not yet been specifically tested. The present study investigated Cohn (2013b) and Cohn and Campbell's (2015) hypothesis of the 'Z' path navigation in comic book pages using eye-tracking equipment to record the eye movements of participants whilst reading an extract from a comic book on a computer monitor. Previous studies have shown that differences in eye-tracking behaviour can be observed between experts and non-experts when viewing expertise-relevant material (e.g., Giovinco *et al*., 2015). Therefore, the present study also compared the eye movements of experienced (expert) and non-experienced (novice) comic book readers.

We were specifically interested in measuring page navigation in easy-to-read pages, so we used pages with a regular organisation of panels, unlike some of the more complex panel arrangements included in the above studies. We also wanted to use comic material that included contextual information to aid panel navigation and therefore chose to use an existing published work, which also increased the ecological validity of the material used. Furthermore, the comic book page used for analysis within this study did not include any textual information. This allowed the examination of eye movements across a comics page without the potentially 'distracting' effect of words.

Method

Participants

Ninety participants (48 women) aged between 18 and 58 years (*M*=31.24, *SD*=9.69) were recruited from attendees to one of the following public events: Sheffield Comicon, Leeds Thought Bubble Academic conference and Sheffield Micro-con. These were all comic book fan events in the Yorkshire region of the United Kingdom. In addition, some undergraduate psychology students also took part.

Most participants received an incentive in the form of a gift voucher for taking part (most received £5 although some received £10 in order to increase the sample size of those considered 'high' in comic book reading expertise). The student sample received course credits for participating. Using the Visual Language Fluency Index (VLFI; Cohn, 2014) which measures experience with comics (including reading), it was determined that 35 participants would be considered low in comics experience, 32 medium experience and 23 high in comics experience.

No participants were included where they indicated the use of varifocal spectacles (given that the use of these can affect the results of the eye tracking equipment) whilst reading or if they reported being diagnosed with a learning difficulty or developmental impairment. A basic comprehension check was also made to ensure that participants were attending to the content of the story. Any participants that therefore could not recall the basic premise were also not included.

Ethical Approval

The project was approved by Sheffield Hallam University ethics board and given approval number 357-ALE.

Materials

Visual Language Fluency index (VLFI, Cohn, 2014)

This scale measures what Cohn describes as 'visual language fluency' and captures the degree to which people are familiar with comics. Participants rate the frequency with which they read a variety of popular media on a scale of 1-7, including different types of comics (e.g., manga, comic strips, and comic books). In addition, participants also rate their experience and expertise in both reading and drawing comics. These ratings are made for both the present day and during childhood. Scores range from 1 to 52.5 with higher numbers representing greater experience with comics. In the current study, participants were categorised as having 'high' (score > 19), medium' (8 < score < 19), or 'low' (score < 8) expertise.

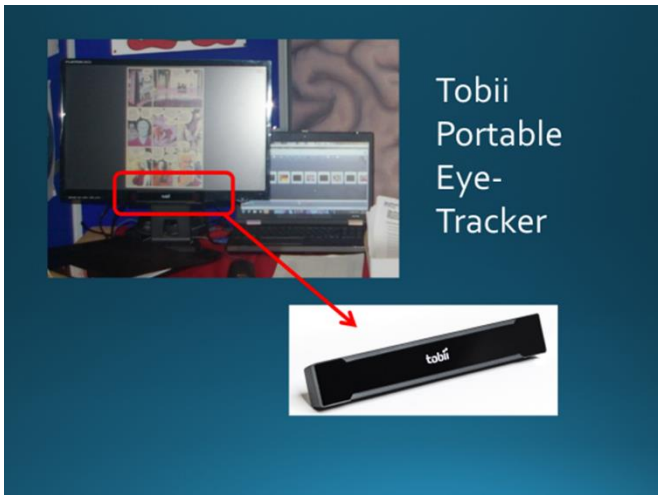
Comic Book Stimuli

The comic pages used in this study consisted of digital versions of the cover and the first eight pages of 'Watchmen' (Moore, Gibbons & Higgins, 1987). These were presented in the intended sequence and were displayed as large as the screen allowed in portrait orientation. Pages were presented on a 30cm x 48cm (diagonal 55cm) flat-screen monitor. These pages were chosen because firstly, they are ecologically valid given that they are part of a commercially available (and indeed best-selling) graphic novel/comic. Second, they are mostly based on a standard nine panel grid system to allow straightforward testing of the z-path hypothesis. Third, the selection includes both pages that contain text (pages 1 to 4) and pages that contain no (or minimal) text (pages 5 to 8), potentially allowing for later assessment of the effect of text on eye-movement across matched stimuli.

Procedure

Once agreement to participate was obtained using a written information sheet and a signed consent form, participants sat in front of the monitor to which was attached a portable Tobii X2-60 eye tracker (see fig. 2).

Figure 2 – Tobii Portable Eye tracker



Alt Text: Photograph of a computer monitor with highlighted and magnified oblong eye tracking camera at its lower edge.

After a short explanation of the eye tracking system and eye-tracking calibration, participants were informed to 'follow the instructions on screen'. These instructions explained that participants should read the materials at their own pace and press the space bar when they were ready for the next page. Once the spacebar was pressed, each page was followed by a black screen of 400 milliseconds duration in order to reset the reading position of the next page. This black screen was mostly imperceptible to participants yet allowed a perceived smoother transition between pages.

Participants were then asked to complete a questionnaire consisting of the VLFI, demographic information, and some questions that checked basic understanding of the material they had just viewed and whether they had read Watchmen (or seen the movie

version) previously (40% reported having read Watchmen beforehand and 60% reported having seen the film). Following this, all participants were given the opportunity to view the recording of their own reading of the materials accompanied by a brief explanation of the process as a debrief.

Approach to Analysis

Participants' eye movements whilst reading the stimulus material were recorded using Tobii studio version 3.4.8 software. As this study was particularly focused on how readers navigate comics pages that use a straightforward layout of panels and that do not include text, only the eye movements of participants on page 5 which contains no text were analysed (see fig. 3). In nine identically sized panels, this page depicts a shadowy figure dressed in a trilby hat and trench coat approaching a building, investigating an object on the floor and climbing up the building by means of a grappling hook fired from a hand-held device.

Figure 3. Page 5 of Watchmen

This page was chosen as it is the first page in the sequence that does not contain any text and, like most pages in this comic, is built around a standard 9 panel grid. The absence of text was important given that previous eye-movement studies have shown that text is prioritised whilst looking at media that have both text and image components (e.g., newspaper articles and recipes; Leckner, 2012; Wang, Tsai, & Tsai, 2016). By using a wordless page, the most straightforward aspect of comic page navigation could be examined by looking at images in a deliberate sequential context. However, as participants also read the previous four pages, it allowed for examination of eye movements whilst readers were engaged with the narrative of the material.

For this page, we specified each panel as a Region of Interest (ROI) such that any fixations were recorded as being linked to each panel (labelled 1 to 9 from top left to bottom right). We then examined the sequence/order in which panels were looked at (scan paths) by measuring the first fixations in each panel of the target page. We concentrated on fixations as these are the phenomena where readers will be processing information into their cognitive system to make sense of the narrative.

Results

Comic Book Expertise

Table 1 shows means and standard deviations for Number of Fixations and Fixation Time shown by comic book expertise (based on scores obtained on the Visual Language Fluence Index measure – VLFI). A one-way Analysis of Variance was calculated to examine the differences between the means for each level of comic book experience. All mean differences were found to be non-significant [Number of fixations: $F(2, 50.9)=0.272$; $p>0.05$; Mean fixation Time: $F(2, 56.6)=2.497$, $p>0.05$)].

Table 1 – Watchmen Page 5 Means and standard deviations for Number of Fixations and Fixation time for each panel categorised by Comic Book Experience.

	Comic book Experience	N	Mean	Standard Deviation	Minimum	Maximum
Number of Fixations	Low	35	37.6	19.4	2.00	96.0
	Medium	32	36.1	16.3	4.00	75.0
	High	23	40.2	22.9	17.00	124.0
Mean Fixation Time (milliseconds)	Low	35	292.3	75.4	30.40	500.0
	Medium	32	330.3	63.3	234.71	469.3
	High	23	316.3	54.0	215.95	427.7

Z-Path Analysis

Data Adjustment

As participants were allowed to read at their own pace and given that eye fixation will naturally vary from person to person, there was found to be a large range in the number of fixations made by the participants. These ranged from 2 to 124 fixations (mean= 37.62, SD=19.11). To ease statistical analysis, two adjustments to the data were carried out:

Adjustment 1: Any sequential repeat fixations in the same panel were removed. This was justified as we were just interested in the overall area the eyes fixated upon (i.e., a panel) rather than fixations within a panel.

Adjustment 2: By far the most frequent first panel to be fixated upon was panel 5, which is the panel at the centre of the page. About 36% of first fixations were on panel 5, compared to 21% on panel 1 (the next most frequent). Given that this is likely to be an artefact due to the eyes being in the centre of the screen when the next page appeared it was felt justified

to remove all those instances when participants' first fixation was panel 5 and use their second fixation as their first intended fixation.

Panel Fixation Order

Table 2 shows the frequency and associated chi-squared values of participants' order of fixations for each panel that followed the z-path route. Only significantly greater number of participants than expected frequencies are shown. Here, "expected frequency" refers to a model where people are equally likely to fixate on any of the nine panels.

These results suggest that for most participants the order of fixations followed the panel number, such that fixation 1 was made by most participants in panel one, fixation 2 in panel 2 and so on. However, there were also frequent deviations from this standard pattern. For example, while panel 3 was the third panel fixated on for 41% of participants, panel *4* was the third panel fixated on for 31%. Similarly, while 42% of people fixated on panel 7 seventh, 22% of participants fixated on panel *8* seventh.

Table 2 – Frequencies and Chi-Square values for number of participants whose fixations were linked to panel numbers.

Panel number and Fixation order number	**Observed Frequency (number of participants)**	**Expected Frequency (Chance)**	**Chi-Square (X^2) Value**	**% Frequency**
Fixation 1 - Panel 1	43	17.4	37.66 ***	49
Fixation 2 - Panel 2	31	14.83	17.63 **	35
Fixation 3 - Panel 3	33	11.43	40.70 ***	41

Fixation 3 - Panel 4	25	11.43	16.11 **	31
Fixation 4 - Panel 4	29	12.14	23.42 ***	34
Fixation 5 - Panel 5	39	9.89	85.68***	44
Fixation 6 - Panel 6	39	12.43	56.79 ***	45
Fixation 7 - Panel 7	37	12.29	49.68 ***	43
Fixation 8 - Panel 7	22	9.56	16.18 *	26
Fixation 8 - Panel 8	36	9.56	73.12 ***	42
Fixation 9 - Panel 9	54	11.13	165.12 ***	61

* Sig at p<0.05, **sig at p<0.01, *** sig at p<0.001

Fixation Progressions

Table 3 shows the frequency and associated chi-squared values for pairs of fixations from one panel to another that were significantly higher than expected frequencies. So, for example, 'Panel 1-2' in the column labelled 'Sequence' shows the number of participants whose fixations went from the first to the second panel.

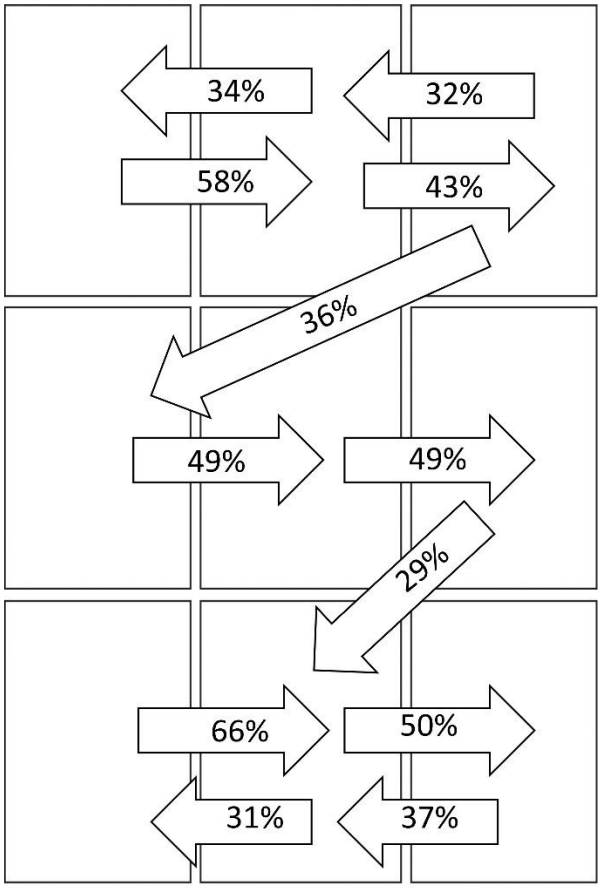
Table 3 – Frequency and Chi-Squared Values for Panel Pairs of subsequent fixations that were significantly higher than expected frequencies (only significant findings shown, all other pairs were non-significant).

Sequence	Observed Frequency	Expected Frequency (Chance)	Chi-Square Value	% Frequency
Significant Panel Progressions				
Panel 1-2	108.00	23.25	308.93 ***	58%
Panel 2-3	91.00	20.74	238.09 ***	43%
Panel 3-4	50.00	17.38	61.22 ***	36%
Panel 4-5	95.00	24.25	206.41 ***	49%
Panel 5-6	96.00	24.25	212.29 ***	49%
Panel 6-8	44.00	19.00	32.89 ***	29%
Panel 7-8	83.00	15.75	287.15 ***	66%
Panel 8-9	96.00	23.88	217.81 ***	50%
Significant Panel Regressions				
Panel 2-1	72.00	26.38	78.90 ***	34%
Panel 3-2	44.00	17.38	40.77 ***	32%
Panel 8-7	60.00	23.88	54.63 ***	31%
Panel 9-8	37.00	12.50	48.02**	37%

* Sig at p<0.05, **sig at p<0.01, *** sig at p<0.001

Figure 4 is graphical representation of Table 3. From these, it is clear that the most common route is for readers to follow the z-path, moving from one panel to the next in order (e.g., panel 1 to panel 2). The one exception to this is the transition from panel 6 to panel 7, where most participants instead fixated on panel 8 after panel 6. In addition, there are frequent regressions (e.g., panel 2 to panel 1) where readers return to the panel they have just read. Also of note is that these significant percentage numbers range from 29% to 66%, meaning there is a large number of participants whose fixations do not follow the pattern described.

Figure 4 – Graphical Representations of Table 3 significantly higher than expected frequencies of subsequent fixations with percentages of fixations noted.



Alt Text: Black and white diagram of a comic page made up of nine identical panels. Each panel has an arrow pointing to another panel with the percentage of fixations noted within them.

Table 4 shows the frequency of panel-to-panel progressions that were significantly *lower* than expected. In other words, it was very rare for participants to jump from one of these panels to the other. In general, the least common progressions were from the top of the page to the bottom (e.g., panel 1 to panel 9), or from the bottom of the page to the top (e.g., panel 8 to panel 1). In combination, Tables 3 and 4 show that there was a typical sequence of fixations that follow the expected z-path and that participants were not randomly fixating around the page.

Table 4 – Frequency and Chi-Squared Values for Panel Pairs of subsequent fixations that were significantly lower than expected frequencies (only significant findings shown, all other pairs were non-significant).

Sequence	Observed Frequency	Expected Frequency (Chance)	Chi-Square (X^2) Value	% Frequency
Panel 1-7	1.00	23.25	21.29*	0.005%
Panel 1-9	1.00	23.25	21.29*	0.005%
Panel 2-6	4.00	26.38	18.99 **	0.02%
Panel 2-7	1.00	26.38	24.42 ***	0.005%
Panel 2-8	3.00	26.38	20.72 **	0.014%
Panel 2-9	1.00	26.38	24.42 ***	0.005%

Panel 3-8	.00	17.38	17.38 *	0%
Panel 3-9	1.00	17.38	15.44 *	0.007%
Panel 5-3	5.00	24.25	15.28 *	0.025%
Panel 5-7	5.00	24.25	15.28 *	0.025%
Panel 6-1	1.00	19.00	17.05 *	0.006%
Panel 7-2	1.00	15.75	13.81 *	0.008%
Panel 7-3	.00	15.75	15.75 *	0%
Panel 8-1	3.00	23.88	18.26 **	0.016%
Panel 8-2	2.00	23.88	20.05 **	0.01%
Panel 8-3	1.00	23.88	21.92 **	0.008%
Panel 8-4	3.00	23.88	18.26 **	0.016%
Panel 8-6	5.00	23.88	14.93 *	0.026%

* Sig at $p<0.05$, **sig at $p<0.01$, *** sig at $p<0.001$

Discussion

While a z-path is intrinsically part of how typically formatted text is read, it is less clear that this same approach is used when reading comics. While papers looking at comics reading behaviour have assumed the existence of a z-path (e.g., Foulshom, Wybrow and Cohn, 2016), and readers have reported following a z-path when reading comics (Cohn, 2013b; Cohn & Campbell, 2015), there has not yet been a study that has objectively demonstrated that this is the route that readers follow. This paper mainly set out to confirm that readers do use a z-path when navigating a comic book page by using eye-tracking technology.

A key finding was that the z-path does provide an excellent model for how readers navigate a comic book page. The most typical order in which panels were fixated upon matches the order of panels in the z-path – the first panel was most frequently the first panel to be fixated on, the second panel was most frequently the second panel to be fixated on, and so on. However, there was also a lot of variation from this prototypical pattern. For example, 49% of people made their first fixation on panel 1, which means that 51% of people had their first fixation on some other panel (2-9) or outside the page.

We also looked at specific panel progressions, as the z-path model assumes that people will move from one panel to the next in order (i.e., 1 to 2, 2 to 3, etc.). Compared to a model where readers were equally likely to go to any other panel after reading a particular panel, the z-path progression was much more likely. For example, 58% of the time, readers moved from panel 1 to panel 2 (and 42% of the time they moved to some other panel). Simultaneously, fixation progressions that markedly contravened the z-path, such as jumping from the top of the page to the bottom, or vice versa, were far less likely to occur.

Within the z-path progression, however, we also observed many regressive saccades where readers returned to the panel that they had just read. For example, after fixating on panel 2, 43% of subsequent fixations were on panel 3, moving forward with the narrative. However, 34% of subsequent fixations were on panel 1. It might be suggested that returning to the last read panel indicates a process of context checking, where ambiguity in a panel needs to be resolved through

reference to prior information. While we observed multiple regressions from a panel to the previous one (at a significantly greater than chance level), no regressions of two or more panels were found to occur at a greater than chance level. This same pattern, where regressive saccades are more likely to be "local", was also observed by Kirtley et al. (2018).

Another important finding was that there were no significant differences in either the mean number of fixations or the mean fixation time across the three levels of comic book experience, suggesting that eye movements do not change as individuals gain experience of reading comics.

Previous work has shown that the presence of text has a major impact on where readers fixate (Kirtley *et al*., 2018). As such, we chose to analyse movements when reading a textless page, which is a decision that other comics researchers have also made (e.g., Foulsham, Wybrow and Cohn, 2016). However, while this allowed a clearer and more controlled view of eye movement behaviour when reading comic books, it does limit the applicability of the findings to textless/wordless pages in comics which appear to be less frequent in, at least Anglo-European, comics which typically contain juxtaposed images *and* text. In other respects, however, the stimuli can be considered to have excellent ecological validity given that they were taken from *Watchmen*, which is widely regarded as one of the great works of comics literature (see for example Aleixo & Norris, 2013).

Having established that the z-path is a relatively accurate model for how readers navigate a textless, tightly structured (3x3 panel grid) comic book page, future research needs to build on this work to evaluate eye-movement preferences in more complex pages. This includes pages that contain both images and text. In relation to text, factors that might determine attention could include the salience of the text (e.g., larger or more colourful lettering), the volume of space taken up by the text, or the density of the textual information within a space. Comic book reading expertise should also be considered in relation to this. While this study did not observe any differences in eye-movement behaviour based on whether readers were expert or not, it is conceivable that novice readers might prioritise text over images (as they are more used to retrieving meaning from textual information alone) than experienced readers.

This paper provides the first evidence that the z-path is an accurate prototypical descriptor of how people navigate comic book pages. It also makes it clear that the z-path is just a model, and that, in the real world, there is a lot of variation in the order in which panels are read. Readers may not start on the first panel, though it is most likely, and after completing a panel readers could go on to any other panel. Again, though, it is most likely that they will go on to the next panel in the z-path order and highly *unlikely* that they will jump to a panel that is far away. In particular, we demonstrated that readers commonly demonstrated regressive saccades, where fixations moved back to the previous panel rather than to the next panel in the z-path order. These findings are intended to provide a robust foundation for future work in this area that looks at reading behaviour in more complex comic book pages.

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