



RED-LETTER READING DAYS: AN EYE-TRACKING PERSPECTIVE ON DR SEUSS' GREEN EGGS AND HAM

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Abstract/Izveček

This article examines eye gaze while a multimodal text with vibrant and colourful images is read and furthermore specifically investigates the effect of the Stroop test on eye gaze. The Stroop colour-word test was designed to test the ability of a reader to suppress a habitual response. This particular variation of the test presented readers with words that refer to colour, but are presented in a different colour.

Results indicate images are used when unfamiliar objects are referred to and faces and characters attract attention. The use of incongruent colours definitely causes cognitive dissonance and negatively affect reading.

Keywords:

cognitive processing, eye-tracking experiment, eye gaze, Stroop colour-word test, multimodal text.

Ključne besede:

kognitivno procesiranje, poskus sledenja pogledu, pogled, Stroopov barvno-besedni test, večkodno besedilo.

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Članek preučuje premikanje pogleda pri branju večkodnega besedila z živahnimi in barvitimi slikami, poleg tega pa posebej raziskuje učinek Stroopovega testa pogleda. Stroopov barvno-besedni test je bil zasnovan za preverjanje zmožnosti bralca, da zatre običajen odziv. Ta posebna različica testa je bralcem predstavila besede, ki poimenujejo barvo, vendar so zapisane v drugi barvi. Rezultati kažejo, da bralci slike zaznavajo ob omembi neznanih predmetov, obrazi in liki pa pritegnejo pozornost. Uporaba neskladnih barv zagotovo povzroča kognitivno disonanco in negativno vpliva na branje.

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Introduction

Dr Seuss has left a rich legacy of children's books that have been popular among "children of all ages" over a number of decades (Moje & Shyu, 1992). His first book, *And to think that I saw it on Mulberry Street* was published in 1937 (Anderson 2001), merely two years after Stroop's (1935) Test. In this article, we link these concurrent historical events via an eye-tracking experiment. Our choice of the number-one selling Seuss book *Green Eggs and Ham* (Moje & Shyu, 1992) is consistent with our research on 'green' multimodality (e.g., Bergh & Beelders, 2014).

Problem statement, aim and objectives

Multimodality refers to the interaction of different semiotic modalities. In this study, the focus is the two profiled in Bergh and Beelders (2014); namely, colour and movement or action. The interactive modalities are designed to enhance reading experience or assist a reader in understanding what is read. However, it is unclear in what capacity and to what extent the different modalities are used. This study aims to investigate how the modalities complement one another and how readers use them during the reading experience. Hence, eye movements were captured via eye-tracking to determine what triggers the use of another modality and to what extent the other modality is viewed during the reading process.

The second objective of the study is to determine how the use of colour affects the reading process. The Stroop colour and word test is a well-known psychological test. However, thus far, very little literature on how the test affects eye movements and how readers assimilate words of different colours or how the colour assists or hinders the reading process has been found. The second objective of this study is therefore to track eye gaze while participants read a text that has colour references to determine how reading behaviour is affected.

Background

The Stroop test and congruent and incongruent colours

The Stroop colour-word test is a well-established psychological test that was designed in 1935 to test the ability of a reader to suppress a habitual response. This particular variation of the test presents readers with words that refer to colour, but which are presented in a different colour. For instance, the word "red" will be displayed but using a green font.

Depending on the task, the reader then either has to read the actual word (called reverse Stroop test) or name the font colour (Stroop test), thereby requiring the suppression of a habitual response. The time to perform the task is an indicator of cognitive flexibility and control (Uttl & Graf, 1997) and demonstrates the ability of the person to inhibit cognitive interference.

Previous studies have found that Stroop scores are significantly influenced by age, and that the executive function not only declines with age-but that the decline is more pronounced amongst those with a lower education level (Van der Elst et al., 2006). The latter study measured only the time for the task. In an enhanced study, participants were asked to point at the correct answer with the mouse when presented with a reverse Stroop colour-word test. This allowed more than just the time to be tested; rather providing more details on the facilitation and interference that could be occurring (Yamamoto et al., 2016). Results indicated that mouse trajectories were delayed for incongruent word colours (when the word and font colour do not match) but not for congruent presentations (when the word and font colour match).

One study (Vakil et al., 2016) on the Stroop effect analysed eye movements for adults with ADHD. This study found that adults with ADHD fixated longer and more times on the target than the distractor and that these adults made more transitions between the two than adults without ADHD. Interestingly, both interference and facilitation (Stroop effects) are reduced when the first fixation is controlled and the first fixation is located at the end of the word instead of the optimal viewing position (Perret & Ducrot, 2010).

Eye movements and eye tracking

There are two eye movements that researchers are interested in for reading analysis, namely fixations and saccades. Fixations are periods during which the eye is kept relatively still in order to see something - in the case of reading, the word being read (Rayner, 1998). Saccades are high velocity, ballistic movements used to reposition the eye over an object of interest (Rayner, 1998).

For reading analysis, these metrics can be indicative of cognitive processing and hence reading difficulty (Rayner, 1998). For instance, the length of the fixations will increase as the reader experiences more difficulty or concentrates more on the text being viewed.

During reading, there are three types of saccades, namely a line sweep - whereby the eye is moved from the end of one line to the start of the next line - a forward's saccade to progress the eye to the next word or viewing area within the same word and a backwards saccade to a previously read word. These backwards saccades are called regressions and are used to confirm something which has been previously read. An increase in saccades is also indicative of difficulties in comprehending the text being read (Rayner, 1998).

Colour coding has been used as a technique to promote effective learning. Eye movement analysis of texts that are colour coded shows that retention is better for colour coded texts than for conventional formats (Ozcelik, E. et al., 2009). With children, it was found that boys have shorter reading time with longer saccade durations and more saccades than girls when reading a text that has a coloured background (Jakovljević et al., 2021).

The eye-tracking experiment

Hardware

An eye-tracker is a piece of hardware that allows researchers to capture eye movements while a participant gazes at a stimulus that is presented on screen (Duchowski, 2007). For this study, data was collected on a Tobii Spectrum eye-tracker. Data was collected at a frequency of 1200Hz and fixations were identified using the Tobii velocity-based IVT-algorithm.

Stimuli

The stimuli presented to the participants were pages from a children's book: *Green Eggs and Ham* by Dr Seuss. Pages were scanned from the electronic version of the book to ensure that the images remained bright and vibrant as in the original. Pages were presented to the participants one page at a time.

As Hessels (et al., 2016:1694) explain, Areas of Interest (AOIs) are used as tools "to link eye-movement measures to part of the stimulus used (e.g. the time spent looking at a particular object in the stimulus)". In our study, Tobii software "calculates the desired metrics within the boundary" (Tobii Connect, 2022). "AOI statistics ... can make eye-movement data easier to interpret and are used in multiple fields of research such as user interaction, marketing research and psychology" (Hessels et al., 2016:1694).

Green Eggs and Ham by Dr Seuss was inspired by a bet between the author and a publisher who dared him that he would not be able to “write an articulate, entertaining book using only fifty words” (Tuesday Trivia, 2022). *Green Eggs and Ham* comprises “49 monosyllabic words and a fiftieth three-syllable word *anywhere*” (Tuesday Trivia, 2022). Participants read silently and at their own speed, pressing a key to turn the page. Each participant read the word passages as originally presented in the book; those using congruent colours for all references to colour, and those using incongruent colours. The order the passages were presented in was counter-balanced using a Latin Square design.

Participants

In total, 23 participants participated in the study and read all the presented stimuli. All participants had normal or corrected-to-normal vision and were either students or staff of the university where the data was collected. A breakdown of participant demographics is shown below:

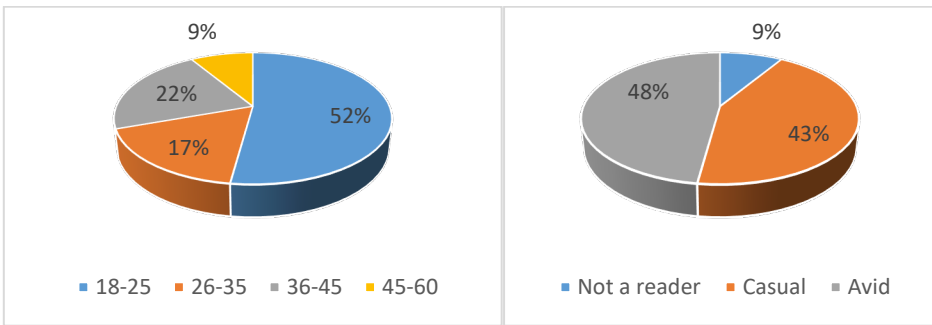


Figure 1: Charts showing age range (left) and type of reader the participant considers themselves (right)

Twenty participants indicated that their predominant reading language was English. One participant indicated that Afrikaans was the predominant reading language and the remaining two did not consider themselves habitual readers. Nevertheless, all participants were fluent in English, the language the passages were presented in. The reading habits of participants who considered themselves casual or avid readers are shown below:

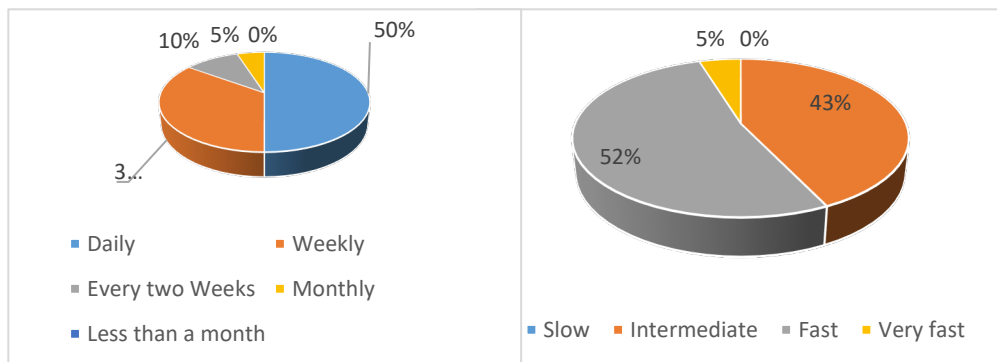


Figure 2: Charts showing reading frequency (left) and participant's self-assessed perceived reading speed (right)

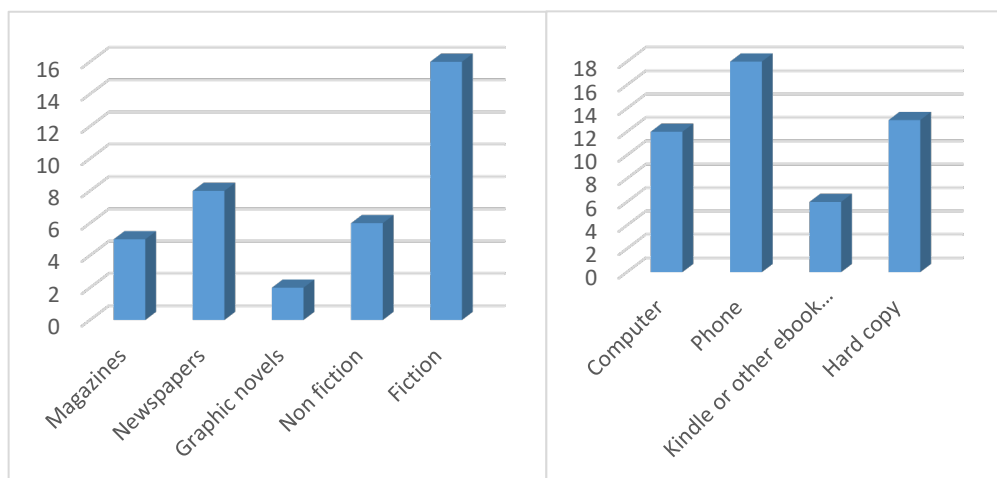


Figure 3: Charts showing reading material (left) and reading medium favoured by the participants (right)

Results

Visualisations of the use of images while reading word text

Dr Seuss relies heavily on images, making either implicit or explicit references to the images that accompany the word text.

The images used are also very colourful and vibrant and characters have unusual features or depictions, making them possibly even more attractive to readers.

A heatmap is a colour overlay that is scaled according to the length and number of fixations. The warmer the colour, the longer the participants looked at that area and the cooler the colour, the less they looked at that area. Heatmaps aggregate the gaze data for all participants into a single visualisation.

A gaze plot shows individual fixations for each participant as coloured circles. The larger the circle, the longer the fixation was. The gaze plot provides more information by also including direction of saccades and the index of the fixation in the sequence of fixations over the stimulus. Gaze plots can include all participants, with each participant having a different colour for their fixations, but participants can also be selected in order to have a cleaner visualisation that is representative of the larger group. Selected gaze plots of individuals will be included in this section.

Below is a heatmap of the first page in *Green Eggs and Ham*.

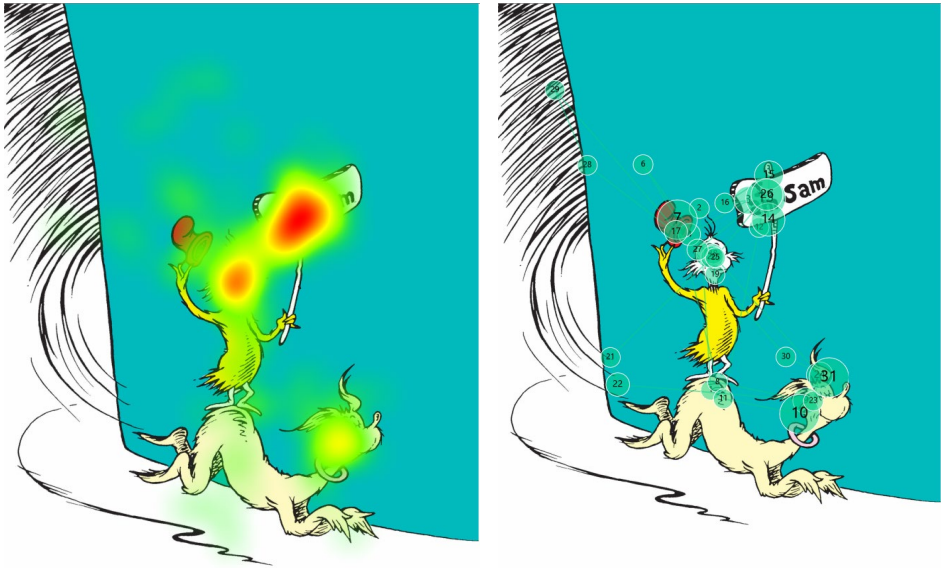


Figure 4: Heatmap for all participants (left) and gaze plot for single participant (right) of first page in *Green Eggs and Ham*

As would be expected for a reading task, the text has a high concentration of fixations (Figure 4) since the text requires more time to read and participants have to glance at all, or most, of the words in order to read.

Viewing of images is, in general, much quicker as it is not always necessary to look at the whole image in order to assimilate it.

What is noticeable is that, similar to most other types of texts, the faces of the characters attract a lot of attention while the remainder of the body and the rest of the image attracts less attention.

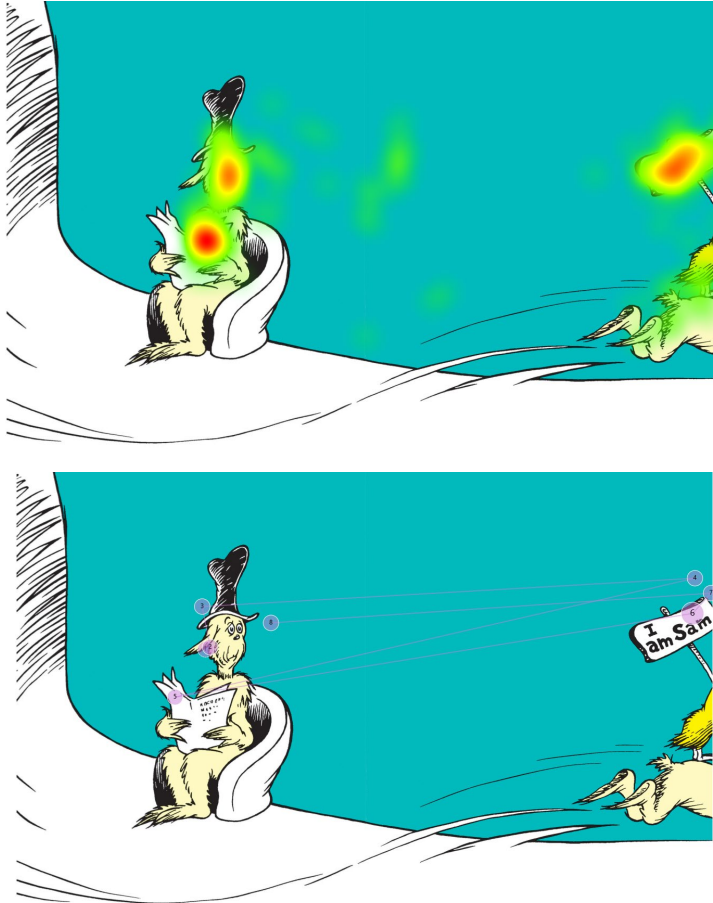


Figure 5: Heatmap (top) and gaze plot of an individual participant (bottom) of second page in *Green Eggs and Ham*

In the image above (Figure 5), it can once again be seen that the faces attract attention, as does the object, in this case a newspaper, the character is holding in his hand.

The gaze plot shows how the gaze of the participant alternates between the left and right figures a few times. The movement, as implied by the lines, can serve to lead the eye to alternate between the two characters.

Especially the images in Figures 5 and 6 reveal the value of combining multimodality and eye-tracking perspectives in our study. One multimodal principle of composition discussed by Kress and Van Leeuwen (2001; 2006) is known as *framing* – which refers to the way in which elements “may be disconnected, marked off from each other, for instance by framelines, pictorial framing devices (boundaries formed by the edge of a building, a tree, etc.), empty spaces between elements, discontinuities of colour, and so on. ... elements of a composition may [also] be connected to each other, through the absence of disconnection devices, through vectors and through continuities and similarities of colour, visual shape and so on” (Kress and Van Leeuwen 2001:2-3).

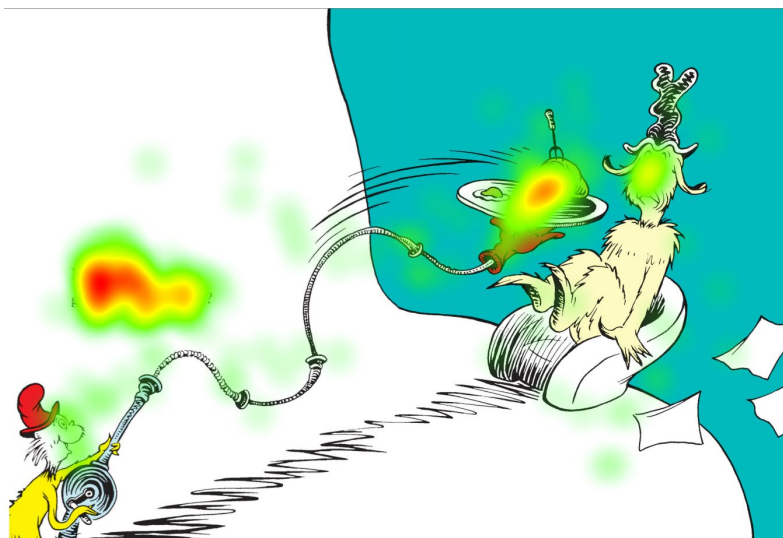


Figure 6: Heatmap of page in *Green Eggs and Ham* with first reference to the succulent dish

Figure 6 is the first reference to *Green Eggs and Ham* and is accompanied by the character Sam-I-Am extending a dish of green eggs and ham to the other character. The dish attracts attention, as – among other possible reasons – this is the first time that readers have encountered it, and the text refers to it explicitly in this case.

The implied movement of the extension should assist readers in locating the dish successfully and it can in fact be seen that there is minimal eye movement along the extension as the eye is guided towards the plate of green eggs and ham.

Kress and Van Leeuwen (2006:59) explain that when “participants are connected by a vector, they are represented as *doing* something to or for each other”. Such vectorial patterns are *narrative*; “narrative patterns serve to present unfolding actions and events, processes of change, transitional spatial arrangements” (Kress and Van Leeuwen, 2006:59). A narrative visual is thus characterised by movement directionality captured by a vector, which can be manifested by “depicted elements that form an oblique line, often quite a strong, diagonal line ... by bodies or limbs or tools ‘in action’” (Kress and Van Leeuwen, 2006:59). Figure 6 furthermore illustrates a transactional reaction (Kress and Van Leeuwen, 2006:574) in that an eyeline vector (the extension line) connects two participants.

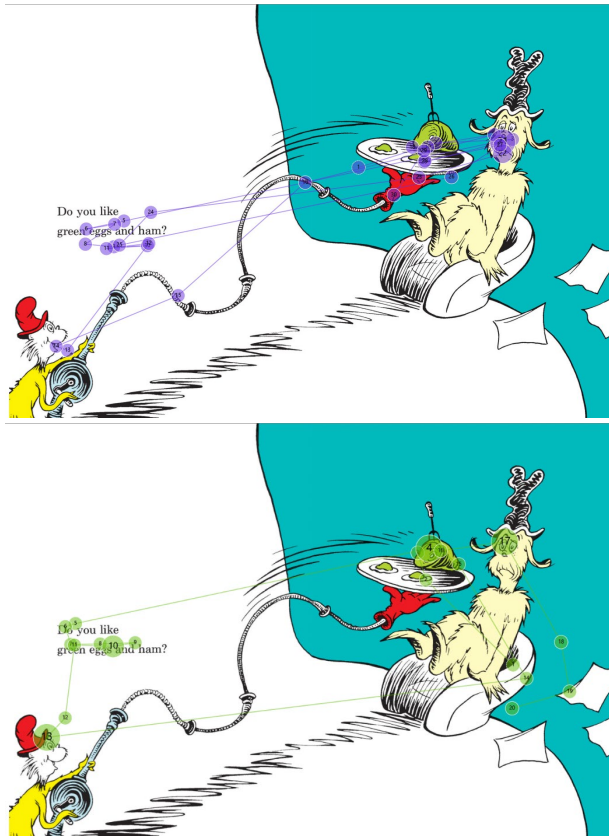


Figure 7: Gaze plots of page in *Green Eggs and Ham* with first reference to the succulent dish

Figure 7 (top) shows the gaze of a single participant who had definite fixations on the extension to guide the eye, while Figure 7 (bottom) is indicative of a participant who still followed the intended line but without making explicit fixations on the extension. In instances such as these the peripheral vision of the participant may allow them to assimilate enough movement to make a well-executed saccade in the direction of the extension without explicitly fixating on it.



Figure 8: Heatmap of page in *Green Eggs and Ham* with implicit references

The text in Figure 8 asks “would you like them here or there?”; the position is implicitly referred to as the place the enlarged hands are pointing to. In this case, the heatmap affirms that participants looked at the pointing fingers to integrate the deictic meaning of the words they have read. Furthermore, even though the characters are now well known, they still glance at the faces of each of the characters. Figure 9 shows gaze plots for two participants who fixated on both the “here” and “there” positions as indicated by the pointing figures. These gaze plots are representative of the majority of the participants, most of whom looked at the pointing fingers. Interestingly, very few did so when reading the implicit reference, instead first finishing reading the passage and then looking at the picture. Hence, it is entirely possible that the gaze falling on the pointing fingers is guided more by the picture itself, the arms acting as guides for the gaze, than the text.

This use of guiding elements, in this case then arm that extends and ends with a pointing finger, is similar to the previous image with the extension leading the eye to the plate of eggs and ham.

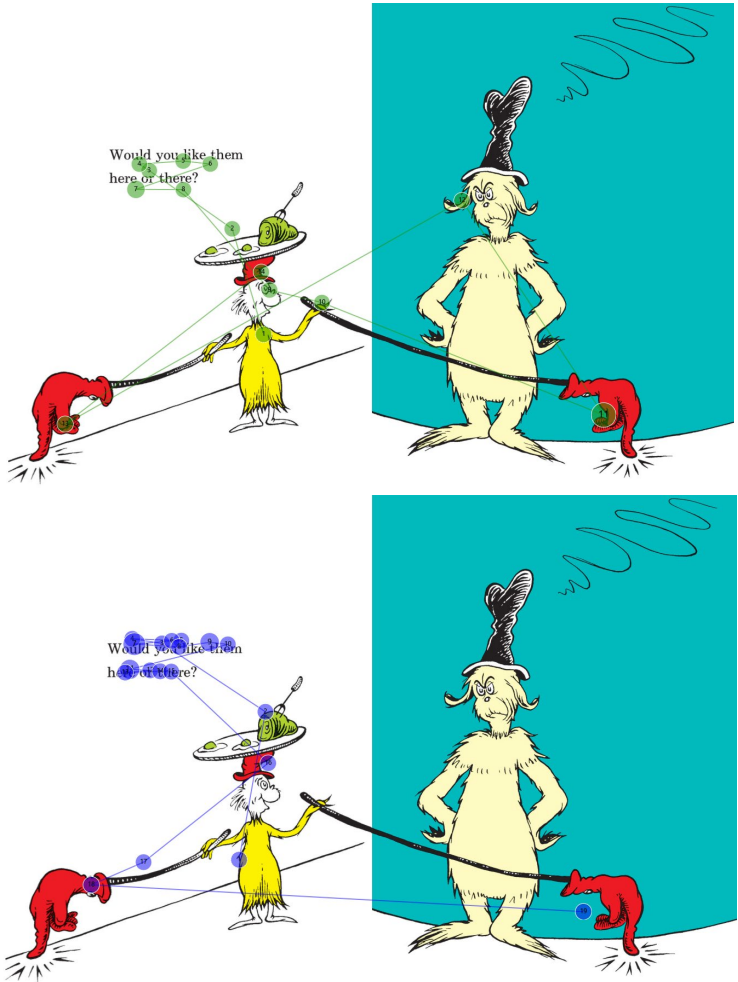


Figure 9: Gaze plots of page in *Green Eggs and Ham* with implicit references

Figure 10 shows one of the characters appearing to talk and gesture with his hand. There is however minimal attention on the character and the attention that is there is mainly focused on his face, as with the previous images. The right hand that is extended downwards gets more attention than the gesturing left hand. This asymmetrical attentiveness is discussed in more detail in Bergh and Beelders (forthcoming)

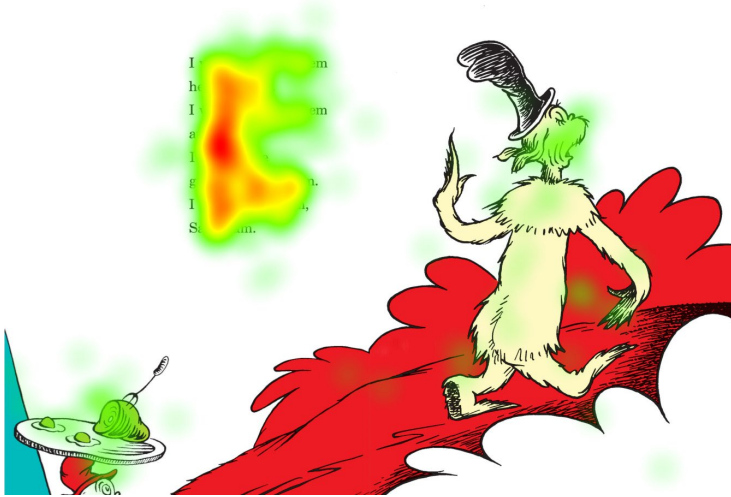


Figure 10: Heatmap of page in *Green Eggs and Ham* with talking character (and gesture)

Figure 11 explicitly refers to a box and a fox, both of which are shown in the image to the right, together with the green eggs and ham. With the explicit reference, the first made to fox and then box, many participants did look at both these objects as well as the plate of eggs and ham. They also looked at the characters' faces again.

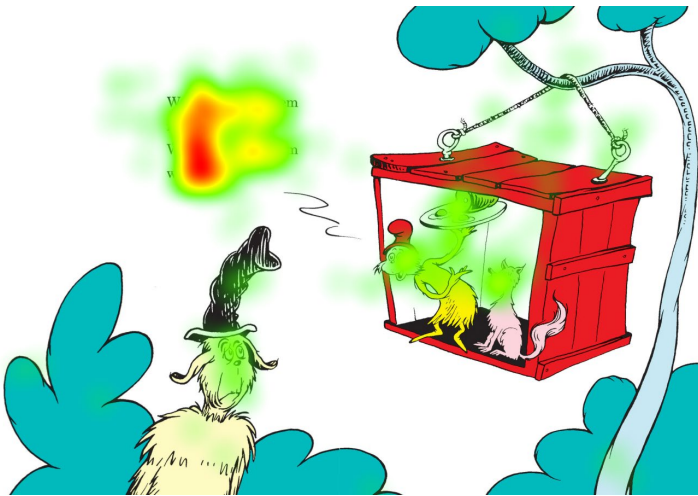


Figure 11: Heatmap of page in *Green Eggs and Ham* with explicit reference to image

Figure 12 shows three gaze plots, each with only a single participant's gaze to avoid clutter and keep the image clear. The three gaze plots show the different behaviours on this page, with some participants looking at many details in the image, others with limited fixations on the image and some with no fixations on the image. The varying degrees of interest in the image illustrate that reliance on the image differs according to the reading participant, personal preferences and individual cognitive styles in relation to attention and perception. Additionally, the passages are easily understandable for an adult reader, hence it is possible that references to common objects such as “fox” and “box” do not need the image to assist integration and understanding but a reference to something unusual like “green eggs and ham” needs some visual cue to assist integration. So too with the implicit references to positions “here” and “there”. As Figure 12 shows, these usual and unusual elements are combined via multimodal framing in a box for novel integration.

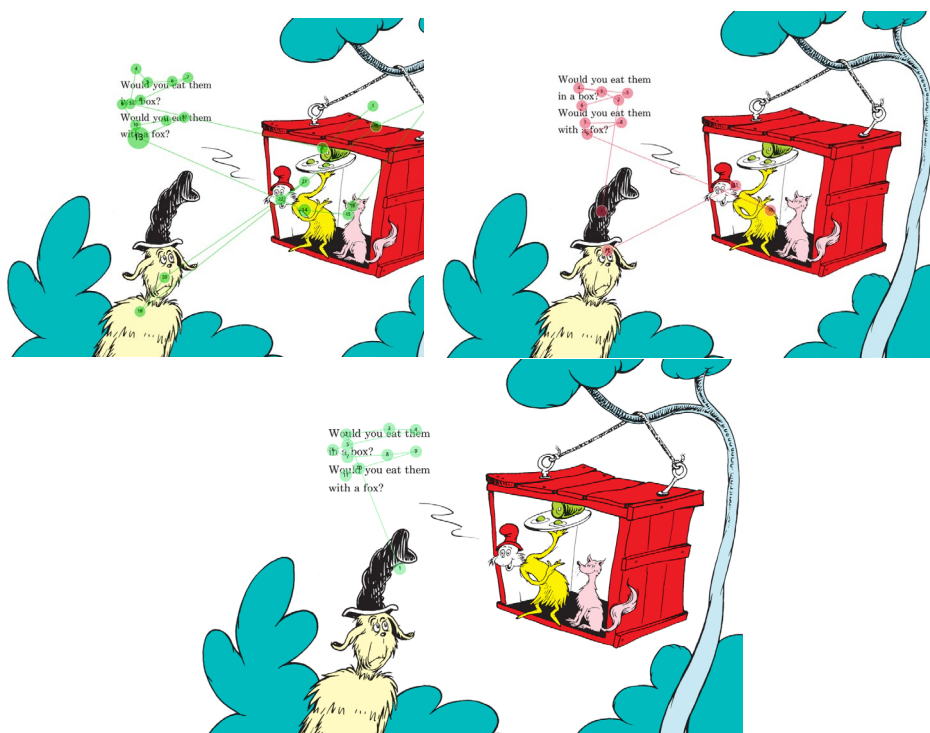


Figure 12: Gaze plot of page in *Green Eggs and Ham* with explicit reference to images showing varying degrees of interest in the image

Figure 13 has some explicit references to objects, some of which are depicted (box) and some are not (fox). Very little attention was spent on the image in this instance, perhaps as it has been referred to numerous times at this stage in the book or the fact that is very small and tucked away in the corner of the page makes it unimportant to the participant. The implied movement of the character down the hill does garner attention and does well to draw the gaze to the character once again.

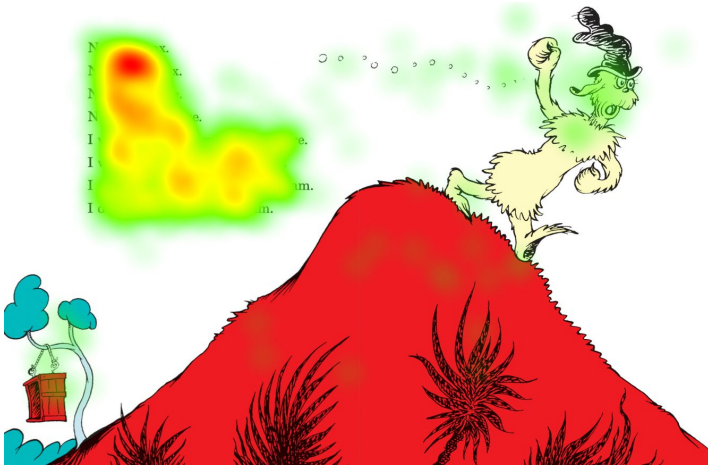


Figure 13: Heatmap of page in *Green Eggs and Ham* with movement

As with the previous page depicting movement, some participants (Figure 14 top) had explicit fixations on the movement depicted in the image and some did not (Figure 14 bottom), instead relying on peripheral vision to execute a saccade straight to the end of the movement path.

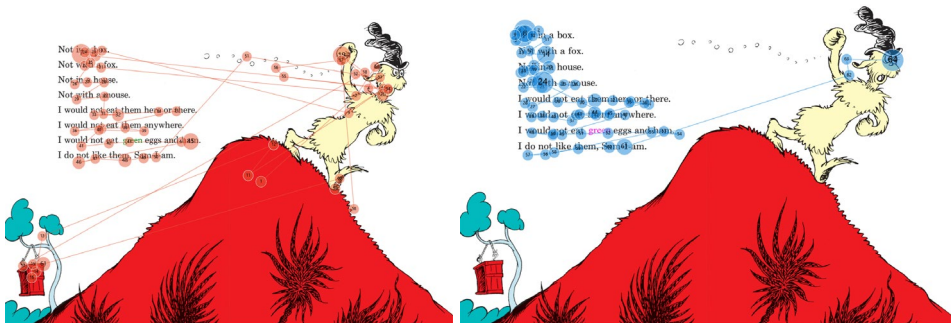


Figure 14: Gaze plots of page in *Green Eggs and Ham* with movement

Comparison of the use of images while reading word text

The average fixation duration when reading English is between 225ms and 250ms (Rayner, 1998). The following chart shows the mean fixation durations for each page, broken down into fixations on text, green eggs and ham dish and any other image. The grey horizontal band is the range for typical fixation duration while reading English.

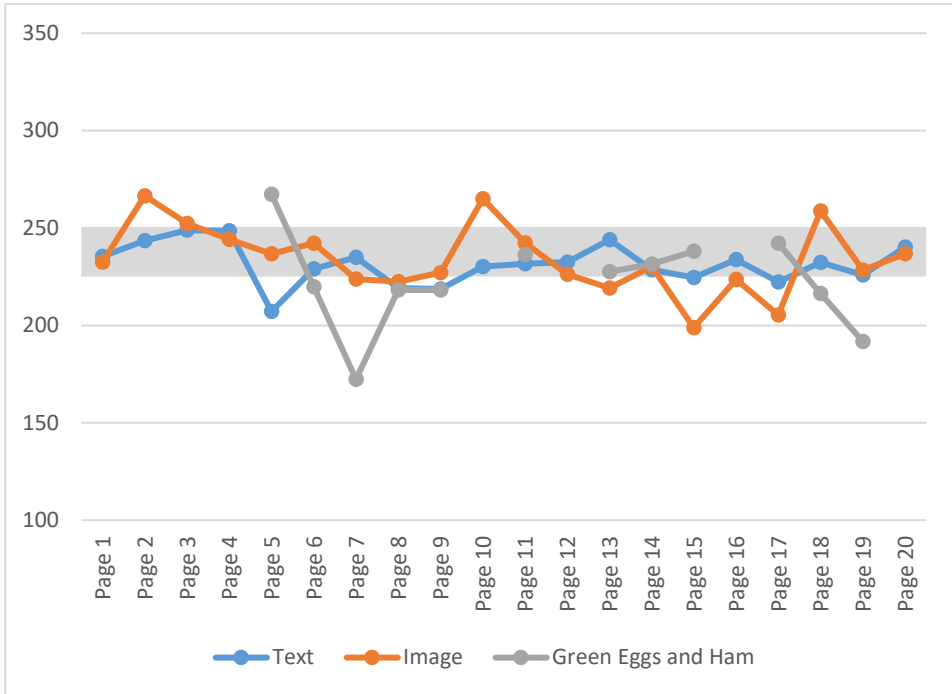


Figure 15: Mean fixation durations while reading *Green Eggs and Ham* in original format

Mean fixation durations for the original book (Figure 15), where all the words are in black font, was nicely in the typical reading range (as illustrated by the grey horizontal band) for all pages. Fixations on the images, which includes all images except the dish of green eggs and ham, fluctuated between 198ms and 265ms. The length is most likely affected by the complexity of the image and how much information the image contains.

The first viewing of the green eggs and ham dish (on page 5) had a very high mean fixation duration of 267ms, whereafter it dropped significantly.

Interestingly, pages 17-19 show the same trend where the image garnered a long fixation on page 17, after which it tapers. Note that the image of the green eggs and ham does appear on page 16 but is small and contained within a much larger image, hence a separate Area of Interest (AOI) was not made on page 16. Also, from a multimodality perspective and specifically framing, the small image of the green eggs and ham are clearly indicated as belonging to, being part of the particular, much larger image.

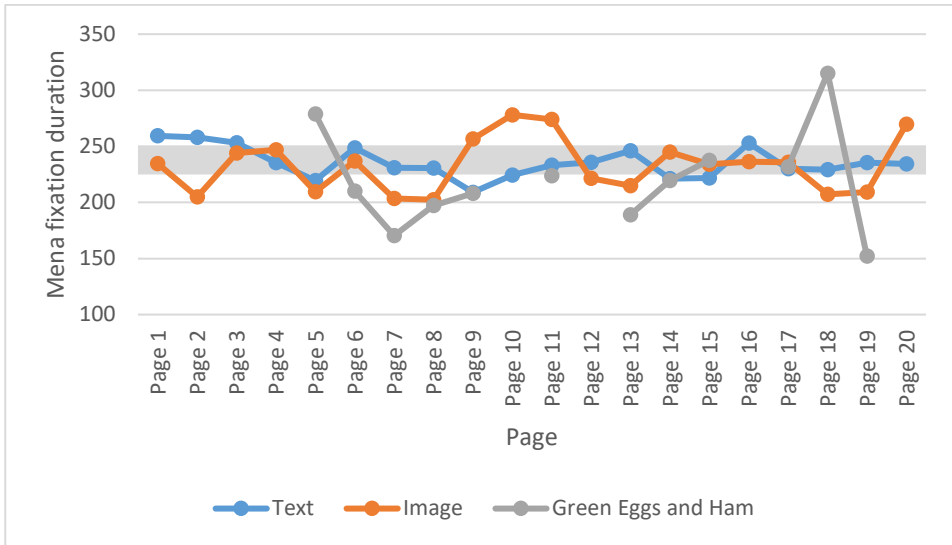


Figure 16: Mean fixation durations while reading *Green Eggs and Ham* in congruent format

For the congruent text (Figure 16), where “colour” words used the font colour of the word – in other words the word green would be in green font colour – fixation durations vary substantially more than for the original word text. Oddly, the first few pages, which have no reference to colour, have a higher than typical fixation duration but, thereafter, the fixations largely stay within the typical range. Perhaps the change in colour on the cover page influenced the behaviour on the first few pages. The mean fixation durations do appear to vary more than with the original word text. The same sharp decline in fixation duration for the green eggs and ham dish is seen here, with a long initial fixation for the first viewing, followed by much shorter fixations. Fixation durations on images fluctuate significantly as well.



Figure 17: Mean fixation durations while reading *Green Eggs and Ham* in incongruent format

The incongruent word text uses a font colour different to the word, causing a mismatch between what colour is read and what colour is seen. Here it can be seen (Figure 17), that in many more instances the mean fixation duration on the text is longer than the typical reading fixation. The first few pages have increased fixation durations as do later pages, a phenomenon not seen in the original or congruent texts. Closer examination of gaze behaviour in a later section, focusing on the use of the congruent and incongruent colours, might shed some more light on this.

Transition diagrams

Transition diagrams illustrate how many transitions are made and between which AOIs the transitions are made. Of particular interest here are the transitions between the word text and the images as a sign of the use of images required to integrate the word text being read.

The number of transitions to the image for each of the different word texts are shown in Figure18.

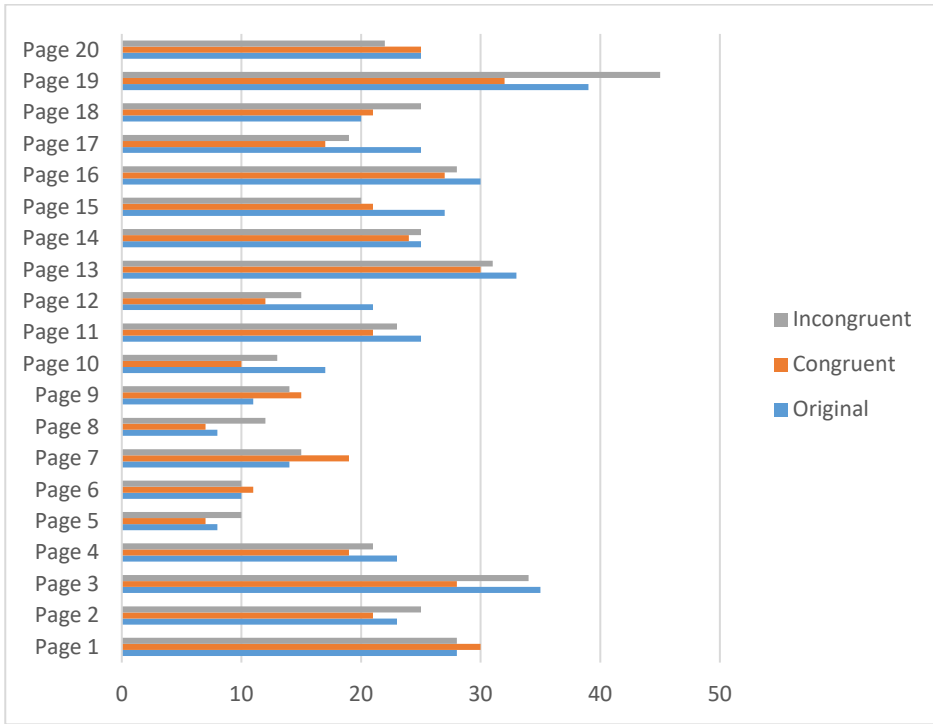


Figure 18: Number of transitions per page and per text

From the chart it appears as though the use of the original, congruent or incongruent word text does not affect the number of transitions to the image. Throughout the story, the participants referred to the images while reading the wording, a trend that continued to the last page.

Since the story focused on green eggs and ham, transition diagrams (Figure 19) are provided for all transitions made to the image of the green eggs and ham. The transitions from wording only are shown and the word that triggered the transition is shown on the diagrams below. The keyword “other” in the graphs is a grouping of all text that does not explicitly refer to something contained in the image. All other keywords are explicit references to an object found in the image.

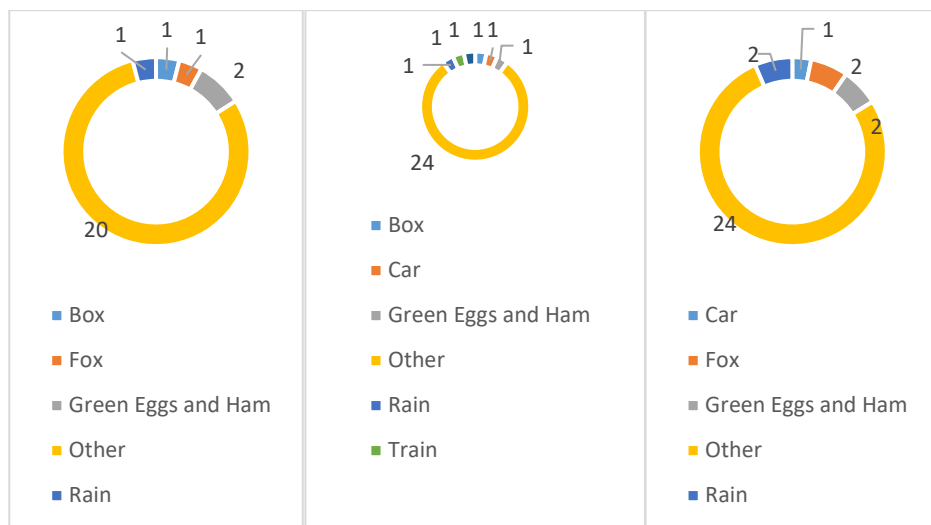


Figure 19: Transitions to green eggs and ham for (a) original (b) congruent and (c) incongruent

As can be seen from the graphs, it is rarely the explicit reference to “green eggs and ham” that causes the participant to look at the image, instead they transition from many other places in the text.

In terms of how many explicit references (Figure 20) that caused a transition to the referenced object in the accompanying image, very few explicit transitions were made regardless of the type of word text.

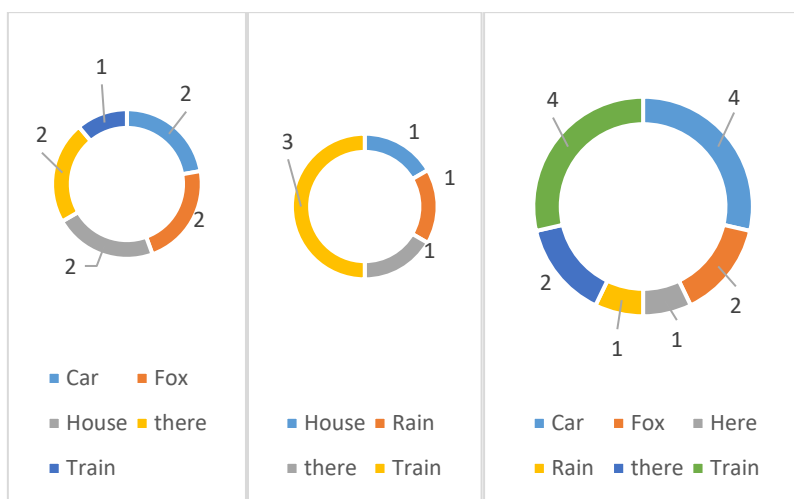


Figure 20: Explicit references and transitions for (a) original (b) congruent and (c) incongruent

Changes in the font colour of words

Figure 21 shows fixation durations for all pages that referred explicitly to “green eggs and ham” in the word text. The bars labelled “text” show the mean fixation duration for all word text on the page, other than the words “green eggs and ham”. The bars labelled “green word” show the mean fixation duration for the words “green eggs and ham” on that particular page.

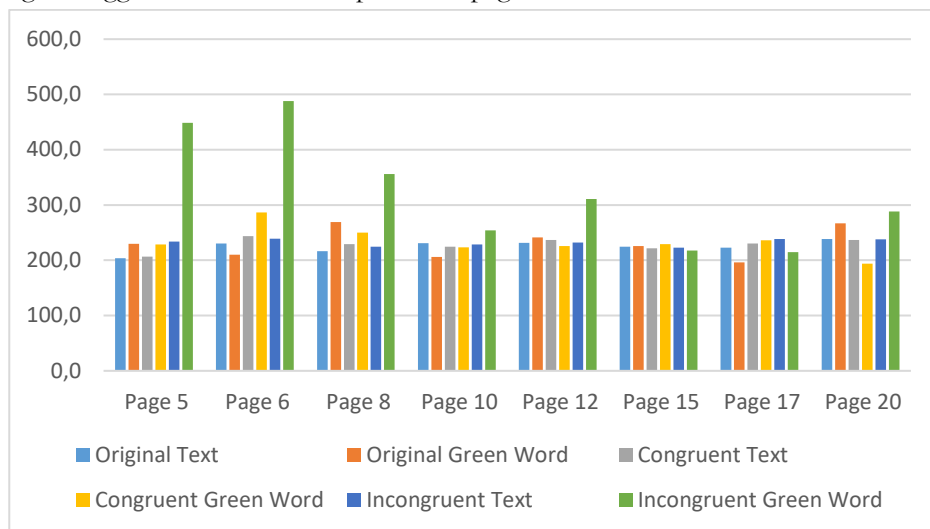


Figure 21: Fixation durations for text versus “green” word for original, congruent and incongruent passages

Noticeably, the mean fixation duration on the incongruent “green” is longer than the fixations on any other word for the first few pages. This normalises after about the fifth (page 12) occurrence of the word and remains in the same range as the other word text after that. The congruent and original word text are on the same level throughout. The original word text could be considered incongruent as it appears in black; however, since stories generally appear in black text this is considered normal for most people and did not cause any hesitation. The obvious use of the incongruent colour, however, does appear to affect fixations.

In order to provide more perspective, the charts in Figure 22, separated between original, congruent and incongruent, show the mean minimum and maximum durations of a fixation on the word “green”. For all three, the solid grey bar is the range of a typical fixation during English reading.

From these graphs, it can clearly be seen that typically the original and congruent use of font colour have minimum fixation durations below or within the typical band and very rarely are the maximum fixation durations outside the typical reading range. However, when using incongruent colours, the fixations are well beyond the typical fixation length when reading – in particular the first few occurrences of the word.

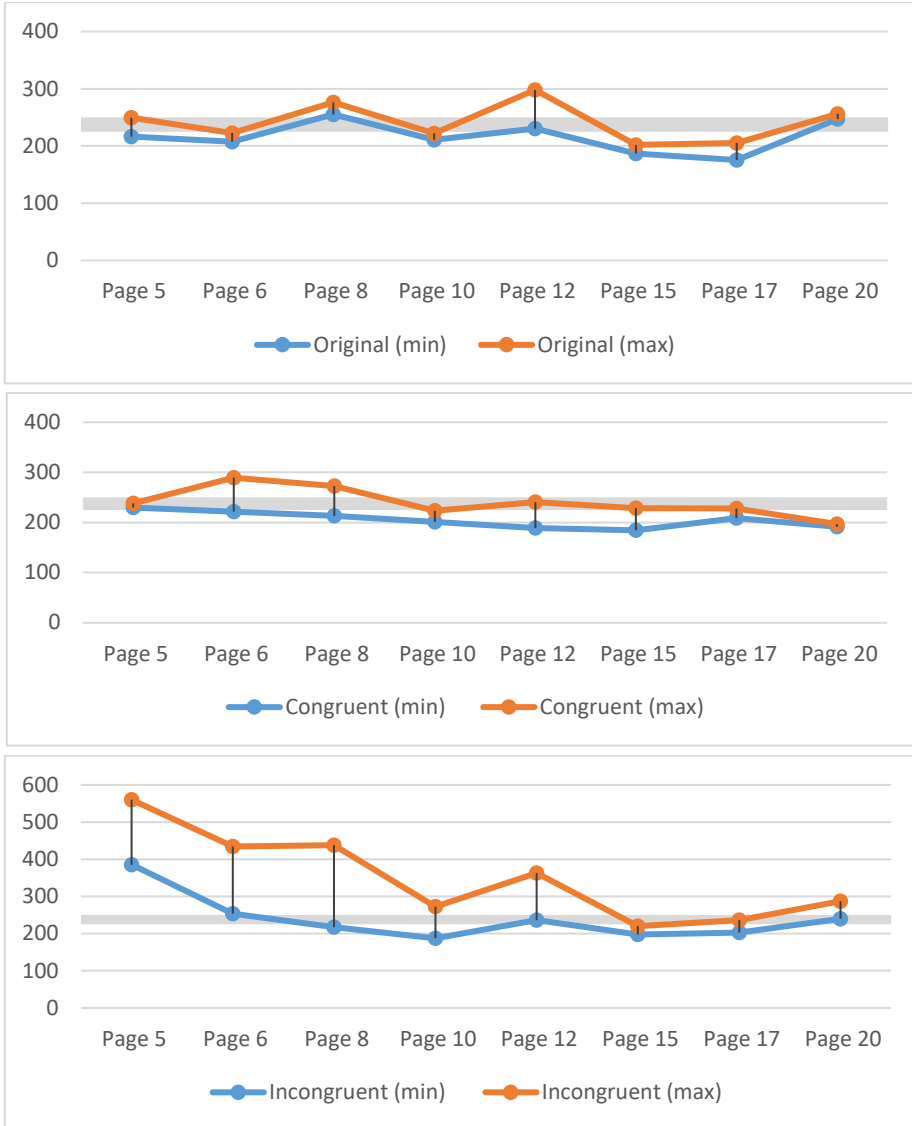


Figure 22: Minimum and maximum fixations durations (a) original, (b) congruent and (c) incongruent passages

Figure 23 indicates the number of fixations on original, congruent and incongruent instances of the word “green”. In nearly all instances, the use of an incongruent colour results in more fixations on the word than the original black word text or the use of a congruent colour. Therefore, not only are the fixation durations longer, but there are also more fixations on the word when using an incongruent colour.

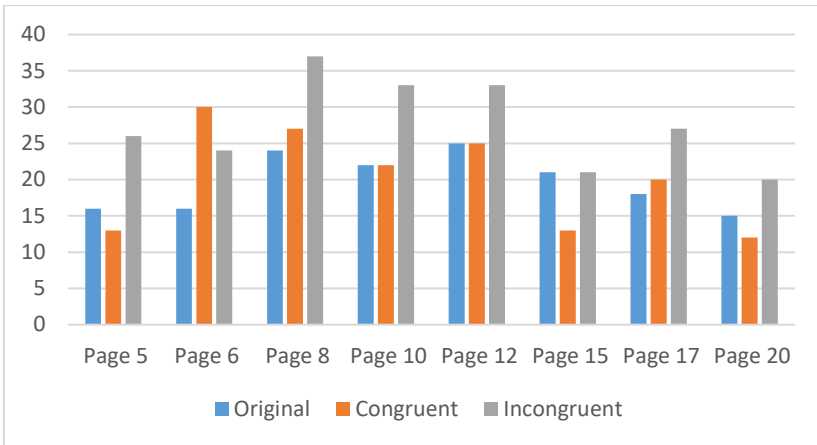


Figure 23: Number of fixations on “green” words

The number of visits is a rudimentary measurement of regressions, showing how many times the reader returned to the word. Figure 24 shows the number of visits made to the word “green” for the original, congruent and incongruent texts.



Figure 24: Number of visits to “green” words

For all pages, apart from Page 6, there are more visits to the incongruent word than the original and the congruent. This gives an indication that the use of the incongruent colour caused readers to regress more than with the original and congruent colour.

Discussion

In *Green Eggs and Ham*, by using merely 50 words, Sam-I-am succeeds in convincing an unnamed and reluctant character to eat green eggs and ham (Moore, Moore & Moore, 2022). Images are often used when reading to assist the integration and understanding process. In this instance, references to common everyday objects such as “fox” and box” do not require much assistance to understand and not all participants looked at these objects when they were referred to. However, in the images, movement, action, faces and also hands received much gaze attention, in accordance with findings in Bergh and Beelders (2014). The way in which facial attention differs among age groups is emphasised in Hanulíková (2021), particularly also in relation to expected emotion expressed. The relatively simply drawn faces in the studied text represent positive cognitive affordances (Bergh & Beelders, 2014) with much openness and imaginative potential. In our view, combined, these observations tie to a theme in the first Seuss book, *And to think that I saw it on Mulberry Street* – that although all age groups focus on faces and movement, children simply see, notice and imagine different agents and objects (Anderson, 2001). Raymo (1992) links these qualities in Seuss’ books to the value of learning about science through mystery, fantasy and imagination: “There is no better time to acquire scientific habits of mind and no better instigator than quality children’s books In children’s books we are at the roots of science – pure, childlike curiosity, eyes open with wonder to the fresh and new, and powers of invention still unfettered by convention and expectation”.

The findings regarding the use of images when reading indicate that simple word texts, even when accompanied by colourful and vibrant images, rarely require additional use of the images in order to understand. This could be different for a younger demographic, in particular early readers who are the actual intended audience of the book. However, the innate compulsion of humans to look at figures, in particular faces, is still relevant even in a simple child’s book.

Furthermore, as expected, a reference to a new or unfamiliar concept, in this case green eggs and ham, does require the participant to look at the dish in order to make sense of what has been read, as the word text is outside the normal frame of reference and needs assistance in order to facilitate integration. The use of the images rarely comes precisely when the image is referred to; instead, the majority of the participants finished reading the word passage and only then did they look at the images – indicating a late integration of the concepts covered in the word passage. Again, this is something that might differ for younger or beginner readers, who might not have the ability to integrate the entire passage at its conclusion.

Overall, it is clear that the use of the incongruent font colour impacted the reading experience by causing more and longer fixations, with mean minimum and maximum fixation durations for initial occurrences of the incongruent colour being significantly longer than a typical reading fixation length. Participants also returned to the incongruent word more times than to the original and incongruent word text. This clearly shows that the use of an incongruent colour causes cognitive dissonance by introducing an inconsistency in what the participant is reading and what they are seeing, thus impacting reading. While this finding is well known in standard Stroop tests showing only single words, as far as could be ascertained, this is the first study to confirm it by inserting the Stroop test into a reading task.

Eye-tracking takes the cognitive load off participants in that they do not need to describe how they read a multimodal text (Matheson & MacCormack, 2021). We requested our participants to complete a supplementary questionnaire on reading habits and general demographic information. In future studies, age-varied participants might be asked to capture freely and spontaneously ‘who and what they saw’ when gazing into the faces of the characters of an illustrated book.

Conclusion

Dr. Seuss’ wife is cited to have explained that he “doesn’t sit down and write for children. He writes to amuse himself. Luckily, what amuses him also amuses them” (Moje & Shyu, 1992).

Moje and Shyu (1992) point out that regardless of meanings that critics have ascribed to Seuss books, “his personal reason for writing was clear: Seuss wanted to write so children could have fun reading. ‘I’m trying to capture an audience. Most every child learning to read has problems, and I’m just saying to them that reading is fun.’”

These words answer to Kuruyer et al. (2017, p.810), who argue that acquisition of reading skills actually starts when the baby is born. Experiences, and prior knowledge brought by students to the basic education process partially determine what kind of readers they will be. Some of the most influential elements of this process are the attitudes and behaviors developed by students toward reading skills, how their reading-related cognitive development is supported, what kinds of opportunities are provided for them and what kind of guidance they are offered. In short, what is important is to establish an enriching learning environment suitable for the language acquisition and cognitive development of the child. Our study reveals how this is done multimodally via colour and movement, as the image assists in integration and understanding of the word text for unfamiliar or new concepts – these concepts will of course differ according to age and skill of the reader. The heavy reliance of Dr Seuss on colour is an excellent examination of the Stroop colour test when it is embedded in a reading passage. The clear cognitive dissonance caused by the use of an incongruent colour leads one to argue that beginner readers will be better served by the use of congruent (and not black) text to increase understanding. A similar experiment using another Dr Seuss text that is accompanied by images in the referred colour will be used to investigate this. Heatmaps and gaze plot confirm the salience of faces and action, as in prior studies.

References

- Anderson, H. (2001). Sense and nonsense in the wisdom of Dr. Seuss. *New Theology Review*, August 2001, 37–50.
- Bergh, L. & Beelders, T. (2014). An eye-tracking report on reference points, cognitive affordance and multimodal metaphors. In A. Maiorani & C. Christie (Eds.) *Multimodal epistemologies: Towards an integrated framework* (p.13–27). London: Routledge.
- Bergh, L. & Beelders, T. (forthcoming). Dr Seuss and red and green choices: An eye-tracking perspective.
- Dr. Seuss. (1960). *Green Eggs and Ham*. New York: Publisher Beginner Books.
- Duchowski, A. (2007). *Eye Tracking Methodology: Theory and Practice* (2nd ed.). London: Springer.
- Hanulíková, A. (2021). Do faces speak volumes? Social expectations in speech comprehension and evaluation across three age groups. *PLoS ONE* 16(10): e0259230. <https://doi.org/10.1371/journal.pone.0259230>
- Hessels, R.S., Kemner, C., van den Boomen, C., Hooge I.T. (2016). The area-of-interest problem in eyetracking research: A noise-robust solution for face and sparse stimuli. *Behav Res Methods*. Dec2016, 48(4):1694–1712. doi: 10.3758/s13428-015-0676-y.
- Jakovljević T., Janković M.M., Savić A.M., Soldatović I., Mačuz'ić I., Jakulin T.J., Papa, G. & Ković, V. (2021). The effect of colour on reading performance in children, measured by a sensor hub: From the perspective of gender. *PLoS ONE*, 16(6): e0252622. Available at <https://doi.org/10.1371/journal.pone.0252622>

- Kress, G. & Van Leeuwen, T. (2001). *Multimodal Discourse. The modes and media of contemporary communication*. London: Hodder Arnold.
- Kress, G. & Van Leeuwen, T. (2006). *Reading Images. The grammar of visual design*. (2nd edition). London: Routledge.
- Kuruyer, H.G., Akyol, H., Karli Oğuz, K. & Has, A.C. (2017). The effect of an enrichment reading program on the cognitive processes and neural structures of children having reading difficulties. *International Electronic Journal of Elementary Education*, 9(4), 809–828.
- Matheson, I.A. & MacCormack, J. (2021). Avoiding left-right, top-to-bottom: An examination of high-school students' executive functioning skills and strategies for reading non-linear graphic text. *Reading Psychology*, 42(1), 1–21.
- Miller-Naudé, C., Beelders, T., Naudé, J.A. & Bergh, L. (2017). Visual Grammar: An eye-tracking perspective on cognitive complexity in Biblical Hebrew pronunciation. In F.E. Greenspahn & G. A. Rendsburg (Eds.) *Le-ma 'an Ziony. Essays in honor of Ziony Zevit* (pp. 316–344). Eugene, Oregon: Cascade Books.
- Moje, E. & Shyu, W-R. (1992). The places you've taken us, Dr. Seuss! *Education Digest*, 0013127X. Dec92, 58(4). Available at <https://eds-p-ebSCOhost-com.ufs>
- Moore, J., Moore, P.J.A. & Moore, B.C. 2022. Green eggs and ham by Dr Seuss: employing digital tools to improve readability of patient-facing materials. *Ulster Med J*, 91(1), 50.
- Ozcelik, E., Karakus, T., Kursun, E. & Cagiltay, K. (2009). An eye-tracking study of how color coding affects multimedia learning. *Computers & Education*, 445–453.
- Perret, P. & Ducrot, S. (2010). Viewing-position effects in the Stroop task: Initial fixation position modulates Stroop effects in fully colored words. *Psychonomic Bulletin & Review*, 17(4), 550–555.
- Raymo, C. (1992). Dr. Seuss and Dr. Einstein. Children's books and scientific imagination. *Horn Book Magazine*, 00185078, Sep., 68(5). Available at <https://eds-p-ebSCOhost-com.ufs>
- Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin*, 124(3), 372.
- Stroop, J. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, 18, 643–662.
- Tobii Connect (2022). Digging into Areas of Interest (AOIs). Available at connect.tobii.com/s/article/digging-into-areas-of-interest-aois?language=e_US#:~:text=Areas%20of%20Interest%20are,over%20the%20time%20of%20interest
- Tuesday Trivia. (2022). The inspiration for Dr. Seuss' Green Eggs and Ham. *Plan Sponsor News*, Mar2022. Available at <https://eds-p-ebSCOhost-com.ufs>
- Uttl, B., & Graf, P. (1997). Color-Word Stroop test performance across the adult life span. *Journal of Clinical and Experimental Neuropsychology*, 19, 405–420.
- Vakil, E., Mass, M. & Schiff, R. (2016). Eye movement performance on the Stroop test in adults with ADHD. *Journal of Attention Disorders*, 23(10), 1160–1169. Van der Elst, W., Van Boxtel, M., Van Breukelen, G. & Jolles, J. (2006). Influence of age, sex and educations; and normative data for a large sample across the adult age range. *Assessment*, 13(1), 62–79.
- Yamamoto, N., Incera, S. & McLennan, C.T. (2016). A reverse Stroop task with mouse tracking. *Frontiers in Psychology*, 7, 670. doi: 10.3389/fpsyg.2016.00670.

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