Greater Understanding of Spacing Needs for Children's Eye Movements during On-Screen Reading is Required

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Abstract: This paper endeavors to consolidate current knowledge and empirical research concerning the use of typography for children's on-screen reading. This paper is not intended as a full literature review, but attempts to raise awareness of the areas required for future investigation. This evaluation indicates a significant gap in the literature of children's on-screen reading and proposes a need for further investigations in typographical spacing. These future studies need to objectively consider children's eye movements and the effect of screen based text presentation on children's comprehension.

Motivation

The nature of education and childhood today entails that children will encounter on-screen typography and screen based learning opportunities in both formal education and daily recreational pursuits. Children interact with on-screen text through reading in video & computer games, television, and the use of computer based multi-media, such as screen based books & the internet. It seems clear then that research which encourages best practices for the design of this children's reading material should be expedited.

Little empirical research is available for comprehensive design direction for the creation of well formed typography for children's on-screen reading material. Dyson (2004) states that there has been significant research into the legibility of print and the typographic considerations for effective eye movements for reading in print. Much of the work sited by Dyson discusses classical reading psychology research dating back to Tinker, Zachrisson, and Spencer in the 1960's and the more recent investigations for instructional text of Hartley in the 1990's. This work has shown only the results of adults' reading in print. The work of Watts & Nisbet (1974) is one of the most concise discussions of children's text legibility for print on record. These works, though important in empirically analyzing the legibility of typographic variables of print for adults' and children's reading, do little to shed light on the specific problem of children's reading from screen.

Readability and legibility of text is affected by many variables, each of which can not be investigated within a vacuum. When considering typography for the screen the researcher must understand the reciprocal results of adjusting one variable compared to another. Empirical research has investigated typeface style, size and line length in depth, however, some studies suffer from the investigation of single typographic variables without consideration of the effect of relational typographic treatment. While, typographical spacing, in the form of line spacing, word and letter spacing as well as margin and separation, has had relatively less investigation for either screen or print. Further, spacing is pursued by this writer as requiring investigation because it is believed that children's eye movements are less developed than adults and are more prone to reading errors and distractions caused by poorly spaced text.

Eye Movements in Reading

Much has been known about eye movements in reading of print since the early work of Huey (1908) and his contemporaries. Movements of the eye are affected by both contextual and typographic variables. These variables can increase *fixation* duration and shorten *saccade* length, whilst increasing saccadic regression frequency. Typographic variables including typeface, line length, and spacing all appear to influence eye movements (Rayner, 1998).

Saccade

Saccades are fast, frequent eye movements of varied lengths which continuously occur when a person reads, looks at a scene or searches for an object. The purpose of the saccade in reading is to move the eye along the line of text that is being read; therefore, bringing a new section of text into the fovea, the central two degrees of vision, to enable the text to be fixated and processed (Rayner, 1998).

Matin (1974), discusses *saccadic suppression* which is when visual input is reduced to a point where no information is processed during a saccade. According to Rayner (1998), Uttal & Smith in 1968, showed that saccadic suppression is caused by the eyes moving too quickly across the printed information, causing this information to become blurred.

Fixation

Fixations are the periods between saccades where the eyes are virtually motionless. It is during this time, that textual information is processed. Fixations occur 5-7 letter spaces into a word and do not tend to happen in the blank spaces between words or sentences. Adults make approximately four fixations per second in most reading conditions, with fixations lasting about 200-250ms. Not all words are fixated (Pelli, Burns, Farell, & Moore-Page, 2006) .

During a fixation, the *fovea* is the central two degrees of vision, the *parafovea* the five degrees either side of the fovea, and the *peripheral* is the further extension from the parafovea. The majority of visual information is processed and fixated in the foveal region. Whilst fixated, the eye can also take in a small amount of information in the parafoveal region, such as small function words. Very little is able to be processed in the peripheral (Rayner, 1998).

It is believed that as word length increases, the probability of fixating on such a word, increases. Rayner further discusses the work of Rayner & McConkie, (1976), who showed that 2-3 letter words are fixated approximately 25% of the time, compared to longer words of 8 letters and more, which are always fixated and at times more than once. Fixations often do not fall at the very beginning or end of a word. Abrams & Zuber, according to Rayner (1998), have shown that readers do not fixate in the blank spaces between words and sentences.

Developmental Changes

It is well established, that there are trends in developmental changes in eye movements during reading. Buswell (1992), according to Rayner (1998), discussed how increases in reading skill resulted in decreases of fixation duration, saccade length increases and decreases to the number of fixations, all occurring while frequency of regressions decrease. Children usually use more frequent and smaller saccades, and suffer from drifts during fixation more predominantly than adults. Saccade latency and accuracy is said to be less precise for preschool children. Rayner further discusses McConkie et al.'s 1991 conclusions that the primary differences between adults and children when reading, is the frequency of refixations that a child makes. Adults were shown to refixate 5 letter words 15% of the time, while a first grade child was shown to refixate 5 letter words 57% of the time. (Rayner, 1998)

Rayner (1998), further discusses the 1991 research of McConkie et al, who examined children's eye movement behaviour and found that compared to adults, the children had more variability in their eye movement patterns.

Interestingly, McConkie's research also showed that children, in their first year of reading, did show the same landing position patterns as adults who commonly saccade to fixations in the middle of a word.

Pelli et al. report the findings of Gibson, Gibson, Pick, and Osser (1962), who found "dramatic improvement in children between the ages of 4 and 8, in the ability to match letter-like shapes." (Pelli et al., 2006) This appears to indicate the rate at which children develop processing and reading skills and shows that not only are there clear differences between children of different ages, but also, clear differences between children and adults.

Typographic Spacing Considerations

Stanley Morison writes in the introduction of A Psychological Study of Typography, "Spacing, in fact, is more important than choice of size or design of type." (Burt, 1959) Spacing affects the ability for the eye to traverse successive lines of type with ease. The space between individual letters affects the ease with which letters can be identified and in turn, the ease of recognition of words. The space between words, affects successful transition from fixation to fixation, while, the space between lines, affects the ability of the eye to navigate correctly from the end of one line to the beginning of a new line. For these reasons, we must carefully assess our spacing decisions when approaching a typographic layout, particularly that for children.

Linda Reynolds & Sue Walker (2004), state that word and letter spacing has had very little investigation in the research of children's reading. They describe type size, line spacing and line length, as having been examined as important factors, in the design of books for children. This, Reynolds & Walker claim is evident in the research of Huey (1908), Tinker (1965) and Watts & Nisbet (1974), who make no reference to investigation regarding either letter spacing or word spacing. In later studies of reading print, Walker (2005), states that children in these studies, discussed tight letter, word and line spacing as being seemingly more difficult or confusing to read. This was often due to the children perceiving the size of the type to be smaller and harder to comprehend. From a motivational point of view, taking care not to set type overly tight, may therefore, assist with children's reading and comprehension.

Letter Spacing (Tracking & Kerning)

Spiekermann & Ginger (2003), discuss the complexity of the letter shapes as requiring care when being set in order to "respect" the space between each letter. Letters require enough space either side to ensure clarity and, as type becomes smaller, yet more space is needed either side of a letter. Crowding is the phenomenon of letters being tracked too closely. This results in meaning being difficult to ascertain from the letter combination. This may result in a slowing of the reading rates for experienced readers. A letter surrounded by other letters, when seen in the periphery or para-fovea, is much harder to identify than a single letter. (Hess, Dakin, & Kapoor, 2000) It is thought that "crowding may determine the visual span and thus reading rate." (Pelli et al., 2006)

A survey of horizontal space in contemporary reading schemes, undertaken by Cooper-Tomkins in 1994, is reviewed by Reynolds & Walker. This survey revealed that many contemporary children's books suffered from very tight letter and word spacing. Reynolds & Walker describe this as being contradictory to the findings of Yule (1988), and Sassoon (1993); while other materials surveyed, were so widely spaced, that children would have difficulty perceiving lines of text. Reynolds & Walker, in their research, conclude that normal and wide letter spacing might prove better for young children's reading material, than tight and very wide letter spacing.

Word Spacing

Word spaces appear to be important for reading English, as they make it clear to the reader where a given word begins and ends. (Rayner, Fischer, & Pollatsek, 1998) It is believed by some theorists, that eye movements and saccade programming, are aided and determined, by the length of upcoming words. It is believed that, low-level visual processes, in the parafovea and peripheral, first, analyze the text ahead of the currently fixated word, thus, detecting the length of words ahead by the spaces that segregate these. Secondly, this information is then used to guide the eye to its next Optimal Viewing Position (Rayner et al., 1998).

Research by Epelboim et al (1997) and Rayner et al (1998), suggest that spaces in text also allow for increased ease of reading compared to text with no spaces. Both conclude that this was not due to word length detection alone; but also due to word recognition being made difficult by other words and letters obscuring the shape of the letters and words they now fall next to.

Reynolds & Walker (2004), have shown that until recently, a large amount of the material for children was set fully justified, resulting in extreme variables of word and letter spacing. Research discussed by Reynolds & Walker, suggests that researchers who have investigated word spacing for children's reading, have encouraged "wider than normal word spacing". (p. 89) According to Reynolds and Walker, Dowding suggested in 1954, that wide word spacing and ample leading was "desirable" for children's books. Burt is also stated as having written in 1960, of "thick space" as a minimum, rather than a maximum for children's material. However, it is stated by Reynolds & Walker that these views are not based on research evidence and that there is little experimental research into horizontal spacing for children learning to read. These suggestions, like those for letter spacing, are based on insight, rather than empirical testing.

Line Spacing (Leading)

Continuous set lines of type must be set in such a way, that the type on the line below, is far enough away from the line being read, in order not to distract the eye from its current reading path. In so doing, the next line must be so close that the eye is able to find this line with ease on its return path, after completion of the line above. Should spacing be too wide, the reader becomes aware of both the lines and the space between the lines.

Pages set with little or no space between lines, can make correct line selection on a return sweep difficult and the reader may skip lines. Correct line selection can also be difficult when lines of type are set too loose. Both Burt (1959) and Spiekermann & Ginger (2003), suggest that line spacing should be considered carefully for children's reading material because children "are particularly prone to doubling and skipping" lines. (Burt, 1959) Burt also suggests that lines set solid, are not only difficult to read, but would "repel all but the hardened scholar" (p. 14).

Margin

Margins are particularly useful in reading consecutive text, as these allow for guiding the eye, while giving visual barriers to the information space and the surrounding information. Margins are important when text abuts illustrations or the edges of books or monitors. Burt (1959) suggests that narrow margins produce visual fatigue. He continues, stating that when type is set too close to the edge of a printed page, a young reader will often follow the type right off the page. However, he concludes that for adult readers, large margins prove mostly aesthetic in value.

Burt (1959) suggests the two side margins should occupy approximately 1/3 of the page width. This size should then be increased as leading is increased. He continues, for children, margins should be wider still. For the very young child, Burt suggests, lines end with the end of a phrase or sentence, thus leaving ragged margins on the right.

Margin and visual separation between areas of text to be read and image or interface area seem obvious to assist with reduction in distraction to a young on-screen reader. This area of investigation relating to separation of interface from content is specific to on screen reading and would greatly benefit future investigation.

Screen-specific Considerations

While certain principles of design and typography, developed over many centuries of visual communication, are quite clearly transferable from print to screen, many new principles and investigations must be undertaken to understand fully the nature of visual communication in this screen-based medium. Designers, typographers and researchers must acknowledge that issues surrounding readability and legibility currently require further investigation. Dillon continues to discuss the work of Creed et al (1987) as indicating that when reading from screen compared to print, even when all variables are replicated, reading differences in each media can be found. The rapid development in technology and the large disparity in testing methods has rendered much of this research

questionable and uncertain. It is however important for this knowledge to be discussed and future studies to be directed by these.

Type on screen is presented via rectangular pixels; thus, size and shape of typefaces chosen, are of consideration. A typeface and its letterforms must be robust, clear and recognizable, with considered use of letter spacing in order to be readable and legible in this less than satisfactory text presentation medium.

Reynolds & Walker (2004) have shown that complexity on screen has a negative effect on children's preferences and can scare children away from the material. Teachers in their study discuss the less effective screen based search techniques of children and the need for clear presentation of text and effective visual cues for reading. For this reason, careful consideration of layout, navigation and division of text and image will benefit young users. Line length and margin is an aesthetic consideration on screen that will aid in avoiding visual complexity. Children's preferences seem to lean toward a somewhat shorter line length with generous use of margins and text block padding.

Dyson & Kipping (1998) discuss findings that different line lengths also have "small, but significant, differences in reading rate" (p. 9) in on-screen reading experiments. The findings of Dyson & Kipping suggest, that lines of 100 characters per line (the longest line length in their experiments) were read the fastest, while comprehension remained constant. It is mentioned, that subjects did refer to the 100 CPL lines as "rather daunting". (p. 10) Dyson & Kipping tested screen reading speeds of lines set at 25, 40, 55, 70, 85, and 100 characters per line. They found that reading comprehension was consistent across all. Dyson & Kipping posit that longer lines being read faster, may be due to reductions in time required in scrolling documents. However, there is also evidence from paged documents that longer lines in such environments, also result in faster reading rates.

Bernard et al (Bernard, Fernandez, & Hull, 2002) found no significant differences in reading rate or efficiency of three different screen-based line length tests. These tests were performed by 20 adults between 19 & 61 years, and 20 children between 9 & 12 years. Bernard et al suggest that the results of these tests and the post test surveys, support findings that shorter line lengths are preferred by readers. Adults tended to prefer the medium line length of approximately 76 CPL, while children chose the short line length of approximately 45 CPL, when questioned.

Conclusion

It seems clear from the literature, reading relies on effective use of typographic spacing to facilitate effective eye movements. The eye movements required for effective on screen reading for children differ from those required by adults. Dillon (1992) and Dyson & Kipping (1998) point out that the empirical investigations of typographical issues related to reading in print remain unduplicated for the screen, while other studies replicate rather than extend the results. As is supported by Dyson (2004), this writer would argue that after 30 years of empirical research for screen based reading, the body of knowledge is still without rigor. Much of this research has been experimentation conducted only with adults. Therefore, it is clear that specific knowledge of children's screen based reading needs are not currently understood. While research has begun more recently into the effects of typography for children's reading in print (Reynolds & Walker, 2004; Walker, 2005) and on screen (Vanderschantz, 2007, 2008), more research into the effects of typographical space on eye movements during children's on-screen reading is required.

The role of saccades and fixations in reading should dictate the development of future research of children's on screen reading. Children and adults have different eye movement patterns – this suggests that reading is different for the two and thus specific eye movement and reading research must be undertaken in this area. Investigation which expands what is currently known about adults reading for screen and print and how this *differs* for children is required. Further research which specifically targets children's particular reading and eye movement needs in print and for the screen should form a high priority in the research in this area.

It also seems reasonable that researchers with diverse areas of disciplinary expertise align in their investigations of typographic legibility. Collaborative investigation from the fields of graphic design, typography, education, psychology and HCI will result in testing methods and results with greater validity and rigor than has been seen to date. As is suggested by Dyson (2004) and Burt (1959) the aligning of experts with a scientific knowledge of the testing procedures and eye movements with the practical knowledge of experts with typographic presentation

knowledge will enhance testing in the future. This writer calls for the inclusion of experts within the fields of education to offer practical reading and usage insights, while, experts within the filed of human computer interaction may reliably be expected to bring forward a view to effective interaction and specific screen based reading considerations. This combined with the knowledge of the printing and typographic industries built up over centuries of practice will deliver the much needed research which is lacking in this area.

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