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# A Small Scale Study into the Effect that Text & Background Colour has on Processing and Self-Correction Rates for Childrens' On-Screen Reading

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*Abstract: Pedagogical practices in formal educational settings together with the nature of communication technologies in the media and elsewhere mean that children will encounter on-screen typography and screen-based learning opportunities in both formal school settings and during their daily recreational pursuits. Internationally, there is a lack of research informing what good reading practice might look like when teachers use reading material in a screen-based environment. More specifically, there is a lack of research around best practices for the design of this material for children. Greater understanding of how the colour of text and the colour of background influences the "readability" of these reading materials is required. This research sets out to determine the readability of text and background colours in on-screen books for young readers through discussion of the literature to date, as well as discussion of a small scale study which includes a rate-of-error experiment as well as qualitative feedback to provide greater knowledge of the most positive reading environments for children.*

Keywords: Children's Reading, On-Screen Books, Text and Background Differentiation, Self Correction, Rate of Error, Processing in Reading, Automaticity in Reading

## Background

**T**ODAY, CHILDREN ENCOUNTER screen-based learning opportunities in both formal education and daily recreational pursuits. Additionally, an increasing amount of their reading material is in a screen-based environment. It is, therefore, clear that the quality of material used in classrooms and available in schools for children's on-screen reading requires careful consideration to ensure that it is of a high standard and that it will facilitate children's learning. Greater understanding of how the colour of text and the colour of background influence the "readability" of these reading materials is a pre-requisite to achieving this goal.

Colours produce both emotional and physical responses in readers, and colour and contrast in print and on-screen, serve as motivational influences for both adults and children. Watts & Nisbet (1974) state that children and adults find colour "more attractive than black and white and consequently are more likely to choose a book printed in colour than one printed in black and white" (p. 70). Colour is also suggested by Watts & Nisbet, as serving as a learning aid for children. Colour and illustration are also said to make the material more meaningful and aid retention for young children.

Evidence from various studies indicates that children and adults reading rates (Evans & Joseph, 2002; Garcia & Caldera, 1996) and reading accuracy rates (Lin, 2003; Preston, Schwankl, & Tinker, 1932; Travis, Bowles, Seton, & Peppe, 1990) are affected by text and background colour combinations. Garcia and Caldera found that text and background colours that are not necessarily those that are frequently used can offer an alternative as long as the contrast is sufficient. In the research conducted by Lin it was found that the accuracy of reading was significantly affected by the contrast ratio of the text and background colours.

It has been argued by Vanderschantz (2008, 2009) that little research is available providing comprehensive design direction for the creation of well formed typography for children's on-screen reading material. Vanderschantz notes that much of the evidence upon which on-screen children's texts are created is based in research with adults and print based reading conditions. Dillon states "reading from screen is different from paper" (2004, p. 35). Dillon continues to reiterate his previous (1992) affirmations that the research in screen-based reading is still without rigour and much of the literature relevant to print is yet to be satisfactorily replicated for the screen. Use of colour in on-screen reading material for children is no more thoroughly investigated than for adults.

These researchers believe that a further reason for the investigation of on-screen reading conditions relating to colour is because colour on screen is different from colour in print. This is because on-screen colour is produced using an additive colour system, rather than the reflective colour system of visual colour mixing found in printed material created with ink or paint. It can also be argued that colour on screen is perceivably brighter than colour in print; thus, it would seem that contrast is an important factor in enabling the ease of discrimination of colours in an on-screen reading environment.

This research sets out to further the print-based research into childrens' reading and to ascertain whether colour considerations identified in print-based reading for adults correlate to considerations for childrens' on-screen reading. While this investigation does not seek to compare results for print and screen, it does present robust empirical results for reading from the screen using testing methodology detailed for print based research. While research on screen has primarily investigated two characteristics of text and background colour, that of polarity and that of colour combinations (Mills & Weldon, 1987), this paper does not attempt to address polarity directly, but instead looks at colour combinations with specific consideration of contrast as was found to be the key consideration by Mills and Weldon.

## **Typography & Colour**

As indicated by Timpany (2009), typography and colour, and how each of these can have an affect on both the legibility and the readability of text, have been explored widely. Reading and typographic research has been conducted with reference to typeface choice, typeface style and there has been some investigation into text and background colour (Bix, 2002; Fukuzumi, Yamazaki, Kamijo, & Hayashi, 1998; Hill & Scharff, 1997). It is however apparent that much of this research with both text and colour is focussed on print, and that the majority of the research used adult subjects rather than children.

There is extensive debate in the literature around issues of legibility and readability. Legible type is said to be that which is large enough and clear enough to be read and comprehend. These conditions for legibility are where letterforms and groups of letterforms are able to be easily discriminated, decoded and processed. Perhaps most clearly, these are de-

scribed as “the visual properties of a character or symbol[s] that determine the ease with which it is read” (Fukuzumi et al., 1998, p. 90). Optimal legibility is achieved when all typeface characteristics, and other factors such as type size, line width and leading, are set in such a way as to produce text which can be easily understood, and read without complication or error.

Readability from this perspective refers to a reader’s ability to read a text with ease and without fatigue or the disinterest of the reader. White (2004) describes readability as “the quality of reading, determined by letterspacing, linespacing, paper-and-ink contrast, among other factors” (p. 205). Legibility is therefore determined by the typeface designer, and readability by the typographer. Often there is very little agreement as to what these type characteristics specifically need to be, but one thing is almost unanimous, there needs to be high contrast between the text and its background colour.

The relationship between colour and typography has been studied by researchers in many different fields. Miles A. Tinker conducted much research in this field that was widely published from the late 1920s and it is still relevant today. Text and background colour combinations have been found to enhance readers understanding, and equally other text and background colour combinations have been shown to make reading material more difficult to interpret. However, there is a paucity of research that considers the effects of text and background colour on screen as contrasted by printed text, and this is the focus of the present research.

In his book, *Bases for effective reading*, Tinker (1966) summarises the early research relating to the reading of black print on varied coloured backgrounds. Various testing procedure were used during these studies including eye movement studies, perceptibility studies and speed of reading studies. Tinker continues to discuss research with varied coloured text on varied coloured backgrounds. This research found evidence of legibility and speed of reading differences for various combinations.

Tinker (1966) notes that his own studies, and those that he summarises, suggest that combinations of text and background with the greatest brightness contrast showed the best legibility and speed of reading results. Tinker also discusses the research that suggests reading conditions which do not exceed 100 footcandles of illumination and avoiding reading in direct sunlight. Due to the reflective nature of paper and the illuminative nature of the screen this single fact suggests that reading from the screen will require different colour considerations.

Legge et al. (1990) suggest that it is important for ease of reading that the colour-contrast or the luminance-contrast between the text and background colour needs to be significant. It does not provide any greater benefit to the reader to create texts with significant contrasts in both colour and luminance of text and background.

## **Reading Research Methodologies**

In the investigation of colour and contrast issues related to reading, a range of different methodologies have been employed including rate of reading (Evans & Joseph, 2002; Garcia & Caldera, 1996), single letter-, letter combination- and word-decoding studies (Lin, 2003; Preston et al., 1932; Travis et al., 1990) as well as visual search (Ling & van Schaik, 2002) and subjective preference (Fukuzumi et al., 1998). The wide gamut of methodologies used for assessing readability of text and background colours means that direct comparison of

results from the research is problematic because of different confounding factors being measured and effecting results. These studies, however, have helped to shape the methodology used in this investigation.

A consideration of automaticity, the ability to conduct activities with minimal conscious effort and attention (LaBerge & Samuels, 1974; Logan, 1997) was important to the present experiment. Automaticity is noted to be present in a range of daily activities for adults and children, but is an important part of reading due to the dual-task requirement of advanced reading – the ability to decode and to comprehend simultaneously (Samuels & Flor, 1997). The reading research literature seems to concentrate primarily on reading conducted automatically by the subjects. Processing considerations and its correlation to automaticity have not played influential roles in the research. This investigation involved measuring the degree of automaticity and the processing exhibited by the subject in a rate of error test. Consideration of processing errors and the ability to self correct will be addressed by this research.

## **Experiment Design**

The experiment consisted of a rate-of-error test conducted using a random word list in four different text and background colours, followed by a four question survey. The whole procedure took approximately 20 minutes for the average reader and slightly longer for the younger and slower readers. This time included a short break to account for reading fatigue.

This experiment employed a stratified random sample methodology to investigate the effects of typography and screen colour of the reading ability of 61 participants from two different schools and three different primary year levels. Ten male and ten female participants were sampled at years three, five and seven of the New Zealand education system. Instead of ten male students, eleven male students were sampled at Year 3, this anomaly occurred because of the colour blindness screening mechanism. Students were selected by the deputy principal at each school as representative of the reading age which matched their year level and age. Students at Year 3 were 7-8 years old reading at an 8-8.5 year old reading age, students at Year 5 were 8-9 years old reading at a 9-9.5 year old reading age and students at Year 7 were 11 years old reading at an 11 year old reading age.

The Year 7 students attended a decile 9 middle school while the year 3 and 5 students attended a decile 10 primary school. The New Zealand decile rating (Ministry of Education, n.d.) indicates the range of students from low-socio-economic communities. A decile 1 rating indicates a high proportion of students from low-socio-economic communities while a rating of 10 indicates a low proportion of students from low-socio-economic communities.

Only students with no colour blindness deficits and with no known vision issues were tested. Students with corrected vision were still considered for this experiment. To ensure that no student with a colour blindness deficit was sampled, students at Year 7 who had no colour blindness were selected, having been tested by the school health system. Colour blindness testing in New Zealand schools only occurs as of Year 7, for this reason, students at Years 3 and 5 were colour blindness tested by the researchers before the experiment began using plates 1, 2, 7 and 10 of the Ishihara Colour Vision test, which is used within the New Zealand education system.

Two researchers administered the tests with individual students in separate offices located at each school. The rooms were illuminated with natural light and supplemented with electrical light bulbs or fluorescent tubes. No visible reflections fell on the screens.

Testing was conducted on Apple iMac 20” Widescreen Intel Core Duo computers running Mac OS X 10.5.8 with a screen resolution of 1280 x 800 pixels. These systems have a monitor depth of millions of colours and support up to 1680 x 1050 pixels with a viewable area of 20”.

Tests were conducted in a reading-aloud reading situation with the results both recorded by the researcher in person and via audio recording for later confirmation. Reading aloud with an observer is a common practice for children in a New Zealand primary school environment and thus should have no effect on the results of this experiment.

Students sat approximately 50cm away from the screen, directly in front of the screen with only a keyboard in front of them. Students were asked to position the chair and sit in such a manner that they were comfortable for reading. The students’ position was checked by the researcher to ensure the student was approximately centred in relation to the screen. The researcher was positioned at a desk to the side of the student able to observe the students movements during reading as well as the material being read.

## **Testing Material**

The words chosen for this research were chosen from four stories at each reading level that had been selected for a related study from recent *New Zealand School Journals*, published by Learning Media. The *New Zealand School Journal* is published at graded levels intended as appropriate to the interests and experiences of readers in each reading level (Learning Media, n.d.). From these stories word lists of 60 words at each reading age were created. Only words of no less than five letters per word were selected for inclusion in these lists. The lists were randomised for each colour combination tested to avoid factors of learning. The reading lists were set in 4 columns of 15 words each.

## **Text Presentation**

Text was formatted with consideration to create highly legible and readable texts for children’s on-screen reading. This was done in an attempt to ensure that the factor influencing children’s reading was the colour and not the text presentation. The typeface used for all testing materials was *Trebuchet MS*. Originally designed as a screen-based typeface *Trebuchet MS* and its Macintosh equivalent *Trebuchet* are freely available on both Windows and Macintosh based operating system platforms. Characteristics of a typeface suitable for children’s reading are discussed in depth by Burt (1959), Watts & Nisbet (1974) and Walker & Reynolds (2000). According to Vanderschantz (2008) characteristics of *Trebuchet* such as its long ascenders, generous x-height, generous bowls and counters, and the relative width of the typeface and its soft, rounded, friendly and engaging nature creates a typeface suitable for children’s on-screen reading.

Text was set with a size of 17 pixels and a line spacing of 34 pixels. The columns were horizontally spaced with gutters of 100 pixels. The text fell within an 800 by 600 pixel portion of the viewable area centred horizontally and vertically within the screen.

### **Testing Software Presentation**

The viewable area had a pixel size of 1280 x 800 pixels with no menu or interface details visible on the screen.

The material consisted of 4 colour tests with a pre-test for which data was not collected. The colour combinations tested were black text on white, yellow text on black, black text on yellow and blue text on white. The pre-test was white text on black. A mask was used between each test consisting of a white “+” symbol on black.

### **Colours Tested**

The colours chosen for the experiment took into consideration previous research and recommendations on text and background colours for effective reading. The widely referenced research by Tinker (1963) found that the colour combinations of blue and white and black on yellow to be the combinations with greatest legibility in print. Tinker’s ranking places black on white as the fourth most readable colour combination in print. Specifically in on-screen research the investigations into children’s colour combination preferences and best-practices are minimal, because of this, information to inform the choice of colours in the design of the experiment was drawn from research with older participants.

There are conflicting findings regarding the research into colour combinations which provide greatest readability, recent research by Humar et al. (2008) in their paper titled *The impact of color combinations on the legibility of a Web page text presented on CRT displays*, attempts to identify the most readable colour combination on screen showing a strong correlation between readability and luminance contrast as well as colour contrast

Several factors were considered when choosing the test colours. These considerations included colour combinations that had been found to provide high readability in either print or screen based environments, colour combinations that supported findings regarding the need for high colour difference and colour contrast for readable text, and the consideration of what children may be likely to encounter in their screen based reading environments. (Luminance contrast was also a consideration but this was not able to be measured.) This is supported by Ling & van Schaik (2002) who state that contrast (rather than hue) may have the greatest effect on the clarity of text when displayed on screen. The importance of contrast in readability is discussed by Hall & Hanna (2004) who determine the colour brightness contrast and colour difference of the colour for their experiment using two algorithms published by the World Wide Web consortium (w3c) in the working draft of their document ‘*Techniques for Accessibility Evaluation and Repair Tools*’ (World Wide Web Consortium, 2000).

In this document w3c provide two algorithms to be used as a guide for calculating colour brightness contrast and colour difference between text and background combinations based on the RGB values of each colour. Colour difference is calculated using the algorithms: (maximum (Red value 1, Red value 2) - minimum (Red value 1, Red value 2)) + (maximum (Green value 1, Green value 2) - minimum (Green value 1, Green value 2)) + (maximum (Blue value 1, Blue value 2) - minimum (Blue value 1, Blue value 2)).

The algorithms for the calculation of colour brightness difference is given as:  
$$((\text{Red value} \times 299) + (\text{Green value} \times 587) + (\text{Blue value} \times 114)) / 1000$$

It is recommended by w3c that the colour difference should be greater than 500 and the colour brightness contrast should be greater than 125.

Previous related research informed the choice of the four to be used, and from these the four text and background colour combinations to be used for this study. These colour combinations were; black on white, black on yellow, yellow on black and blue on white.

**Table 1: Colour Values Tested**

	HEX	RGB
<b>Black</b>	000000	0,0,0
<b>White</b>	FFFFFF	255,255,255
<b>Yellow</b>	FFFF00	255,255,0
<b>Blue</b>	0000FF	0,0,255

From previous related research four colour combinations were chosen for this experiment. Black on white was chosen for several reasons, it is convention, both in print and screen based media as well as having the greatest colour difference and colour contrast, Humar et al. (2008) also rank it as having the greatest luminance contrast. The combination of black on yellow was selected as it has been ranked in other research as being highly legible both in print and on screen (Ling & van Schaik, 2002; Preston et al., 1932). Yellow on black has a negative polarity, which is one of the reasons for selecting this combination for inclusion in the experiment; it also has the same high colour brightness contrast and colour difference as black on yellow. The final combination chosen for the experiment was blue on white, this colour combination has colour brightness contrast and colour difference that are equally high as the black/yellow combinations of text and background colour.

**Table 2: Colour Difference and Brightness Contrast for Combinations Tested**

	Colour Difference	Colour Brightness Contrast
<b>Black on White</b>	765	255
<b>Black on Yellow</b>	510	225.93
<b>Yellow on Black</b>	510	225.93
<b>Blue on White</b>	510	225.93

The colour combinations chosen for this experiment are also featured in the research conducted by Humar et al (2008) whose findings ranked black/white, blue/white, yellow/black and black/yellow in their top ten most readable colour combinations. Their measure was concerned with the effect that luminance contrast has on readability rather than using the colour brightness contrast and colour difference provided by w3c. It should be noted that there are several definitions of luminance contrast and colour difference.

## Results

### Error Tests

An initial analysis of the data indicated no interaction between the four presentation conditions and words recognised automatically, irrespective of gender, age or reading age when rate-of-reading was considered. However, an initial analysis of self corrections in the four presentation conditions indicated that students self-corrected words more frequently in the black on white condition and least frequently in the blue-white condition (see Table 1). Self-corrected words include those words attempted twice or more before accurate word recognition occurred. Attempts took the form of segmentation for compound words, syllabification and phonological deconstruction.

**Table 3: Frequency and mean Scores of Self-correction in Four Presentation Conditions**

Presentation Condition	Total Number of Self-corrections	Mean Number of Self-corrections	SD
<b>Black-white</b>	146	2.40	2.28
<b>Black-yellow</b>	134	2.21	2.17
<b>Yellow-black</b>	114	1.87	2.06
<b>Blue-white</b>	107	1.75	1.84

This result seemed worthy of further investigation, so a series of paired t-tests were performed to establish whether these differences were significant. Significant differences in self correction rates were seen in two conditions:

1. Black on white and yellow on black
2. Black on white and blue on white

A paired sample test was conducted to calculate any differences in the impact of the black on white and yellow on black presentation condition on students’ oral reading self correction rates. There was a statistically significant interaction between the number of self corrections in the black on white presentation condition (M=2.40, SD=2.28) and the yellow on black presentation condition (M=1.87, SD=2.06),  $t(60) = 2.17, p=0.03$ . The eta squared statistic (.07) indicated a moderate effect size (Cohen, 1998). This difference was also significant ( $p<0.05$ ) for male subjects.

A second paired sample test was conducted to calculate any differences in the impact of the black on white and blue on white presentation condition on students oral reading self correction rates. There was a statistically significant interaction between the number of self correction in the black on white presentation condition (M=2.40, SD=2.28) and the blue on white presentation condition (M=1.75, SD=1.84),  $t(60) = 2.43, p=0.02$ . The eta squared statistic (.09) indicated a moderate effect size (Cohen, 1998). This difference was also significant ( $p<0.05$ ) for male subjects and for subjects with 9 year reading ages.

## Survey

After the completion of the reading exercises all subjects were asked four short questions to gauge their reading preferences and perceptions during this test. The students were asked to consider the colour combinations that they had read during this exercise and to detail which they preferred, found easiest and found hardest to read. They were also asked which colour combination they most often read during their everyday reading activities.

**Table 4: Frequency of Responses to Survey Questions**

	Black-White	Blue-White	Yellow-Black	Black-Yellow	White-Black	None	Unsure
<b>Preference</b>	13	10	7	9	2	17	3
<b>Easiest</b>	13	11	8	12	2	13	2
<b>Hardest</b>	4	6	21	10	0	18	2
<b>Most read</b>	58	1	1	0	0	0	1

Of the 61 students sampled in this experiment test there was no clear preference for a particular colour combination. The majority of students (17) did not show a preference while the next largest group felt black on white was their most preferred colour combination. For this first question of preference and for the question of which was easiest two students did indicate that the pre-test colours of white on black were preferred. Students were able to articulate the reason for their preference for these colours often stating “it was easiest” or “it was easiest to see”. An interesting observation as to why the black on white preference may have been dominant was made by one of the students themselves, stating because we “always read black on white”.

When asked to discuss the colour they found easiest to read there was again an even distribution of students across each of the colour combinations sampled as well as those with no preference. Students stated a range of reasons for why they felt a colour combination was easiest to read, for example “[Black on white] used to reading black on white in reading books” and “[Blue on white] blue is bright and I can see it properly.”

Perhaps most interesting was the high proportion of subjects who found yellow on black to be the hardest to read. Students indicated that this was hardest to read because “it was too bright to read” or “because the yellow is dark and the background is darker.” Again, it was also interesting that almost as many students found that none of the colours were perceived as being the hardest to read.

Not surprisingly the majority of the students were able to categorically indicate that black text on a white background was the most common colour combination that they read. This in itself may indicate the preference towards this colour combination for many readers.

## Discussion

It would appear that presentation condition does not impact on students’ ability to read words that they can recognise automatically (automaticity). This may be because any confounding effects on word recognition processes that might stem from presentation condition are ac-

commodated by a word recognition system that has an excess of processing capacity. Thus any effect of presentation condition on word recognition may not appear until processing capacity is compromised. In the present research, this compromise was apparent when subjects self-corrected. The extra effort made to recognise an initially unknown word seemed to be differentially compromised by the various presentation conditions, and as the results indicate, especially in the yellow on black and in the blue on white presentation conditions.

While there were not significant preferences and perceptions of ease in the qualitative feedback there may be a tendency towards a preference for black on white which correlates to self-correction rates appearing to be higher in this reading instance. This perceived preference is also likely to be due to the agreement among the clear majority of subjects stating that black on white was the most common reading combination that they come across. It was also interesting to discover the perceived difficulty with yellow on black is replicated in the lower total number of self corrections present on this colour combination.

## Conclusions

This research was designed to determine the need for further research in this area, and to test the rigor of the experimental methodology. The results gathered from this small scale study have given us a clear understanding of the direction that the research needs to develop. This study has indicated that there is evidence that colour combinations in childrens' on-screen reading material can affect their ability to comprehend text. These results have also lead the researchers to the conclusion that there is a need to progress to a large scale sample, with a wider range of ages and a greater demographic.

Context is an important aspect of comprehension processing, which this and many similar studies to date have not considered. A further study influenced by the results of this study will investigate the effect of text and background colour when words are presented within sentences and paragraphs. This related study will assist with indicating how context effects processing with consideration for automaticity and self corrections when children read different text and background colours on screen.

The results from this small scale study also indicate that there is a need to further investigate the effect of different colour conditions on young readers' comprehension, thus allowing the researchers to compare the results from this study, which dealt with processing ability of individual words, and a corresponding small scale study which investigates context-based processing ability in sentence and paragraph.

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### *Nicholas Vanderschantz*

Nicholas' area of research focus has been in childrens' on-screen reading. These investigations have specifically looked into how typographic spacing could best affect childrens' eye movements during reading. This area of exploration saw him graduate with a Masters in Computer Graphic Design from Whanganui School of Design, New Zealand in 2007. Nicholas is a lecturer in Computer Graphic design at the University of Waikato in New Zealand. As a central part of his teaching and research at the University of Waikato Nicholas pursues his interests in typography for children as well as socially responsible graphic design and graphic design education.

### *Claire Timpany*

Claire completed her Masters in Computer Graphic Design at Wanganui School of Design, New Zealand. She is currently a lecturer in Computer Graphic Design at the University of Waikato, New Zealand, teaching both print and screen based papers. Claire's main areas of interest and research are typography, print design and physical interaction design. Because of her love for both printed books and interactivity this is where her research interests lie. Her research is currently focussed on the way in which people interact with printed material and how the benefits of electronic media can be applied to traditional media, such as print, to aid it in developing and become more beneficial and keeping up with the digital age.

### *David Whitehead*

Dr. David Whitehead is senior lecturer in the Arts and Language Education Department of the School of Education at the University of Waikato. He teaches post-graduate classes in language, cognition and neuro-linguistics, literacy and thinking and language and cognition in life.

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