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Exploring the Role of Colour in Sustaining Preschool Children's Attention: An Eye-Tracking Study

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ABSTRACT

Sustaining visual attention in early childhood is essential for cognitive development and literacy acquisition. This study examines the effectiveness of complementary colour contrast, based on Johannes Itten's (1973) colour theory, in enhancing Total Fixation Duration (TFD) among preschool children viewing picturebook illustrations. A quasi-experimental quantitative approach involved 54 children (N = 54; mean age 5 years 8 months) enrolled in KEMAS preschools in Banting, Selangor, divided evenly into a baseline group (n = 27) and an experimental group (n = 27). The experimental group viewed illustrations digitally manipulated with complementary colour pairs (e.g., red-green, blue-orange), while the baseline group viewed the original picturebook. The Tobii T120 eye-tracking system tested the effectiveness of measuring attention span through TFD in young children. It successfully captured visual behaviour, revealing a statistically significant increase in TFD for the experimental group, indicating deeper and more sustained visual attention ($t(26) = 12.32$, $p<.0001$; Cohen's $d = 2.46$). This study hypothesised that specific colour manipulation using complementary contrasts would increase the mean duration of participants' attention span. The results supported this hypothesis and rejected the null hypothesis. Prolonging attention span improves visual engagement and may also encourage greater interest in picturebooks, indirectly supporting early reading motivation. These findings suggest that complementary colour contrast is a low-cost, evidence-based strategy for improving early learning, particularly in resource-constrained settings. Aligned with sustainable learning goals, this approach supports the creation of inclusive and effective visual materials.

1. Introduction

Sustaining attention in early childhood is foundational for effective learning and long-term cognitive development [1]. Picturebooks, widely used in preschool education, rely on visual design to engage learners, especially those in the pre-literate stage. Among visual elements, colour plays a critical role in attracting and maintaining a child's gaze [2][3]. This study investigates how complementary colour contrast, based on Johannes Itten's [4] colour theory, can enhance Total Fixation Duration (TFD). In this study, TFD means the total time (in milliseconds) that a child's eyes

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stay focused on a certain part of a picturebook image. It shows how long the child pays attention to that part, helping to measure how well the image holds their attention. This TFD was measured using the Tobii T120 eye-tracking device. The research was conducted in KEMAS preschools across a suburban area in Banting, Selangor, involving children aged 4 to 6 years from socioeconomically disadvantaged backgrounds, a group often requiring additional support in developing early literacy and attentional skills [5][6].

Complementary colour contrast by Itten was specifically chosen because it generates maximum visual tension and harmony by pairing hues from opposite sides of the colour wheel, such as red and green or blue and orange. These combinations stimulate the visual cortex and are more likely to draw and hold visual attention than less contrasting pairs [4][7]. Prior studies have shown that high-saturation, high-contrast colour combinations increase perceptual salience and may lead to longer visual fixations [8] [9]. By applying this design strategy to the most visually engaged areas of the picturebook, this study aims to determine whether complementary colour contrast can sustain attention more effectively than the original, unmanipulated images. Prolonging the attention span not only enhances visual engagement but may also foster greater interest in the picturebook itself, thereby indirectly encouraging children to develop a broader interest in reading picturebooks in general. In line with the principles of Education for Sustainable Development Goals [10]this research supports the creation of visually strategic and inclusive learning materials that foster deep, sustained engagement, especially in resource-constrained preschool settings. Enhancing attention through intentional design offers a low-cost, scalable intervention that can help close early learning gaps and promote equitable access to quality education.

This study hypothesised that the specific manipulation of colours on the picturebook, using colour complementary contrast, on visual images will increase the mean duration of the participants' attention span. Conversely, the null hypothesis states that the specific manipulation of colours, using colour complementary contrast, on visual images will have no effect on the mean duration of the participants' attention span. The statistical formulate are as follows:

$$H_0: \bar{x}_{\text{exp}} = \bar{x}_{\text{base}}$$

$$H_1: \bar{x}_{\text{exp}} \neq \bar{x}_{\text{base}}$$

The null hypothesis (H_0) states that there is no difference in the mean duration of the attention span between the Baseline group and the Experimental group. The alternative hypothesis (H_1) states that there is a difference in the mean duration of the attention span between the Experimental group and the Baseline group. For this study, the independent variable (IV) is the colour complementary contrast, whereas the dependent variable (DV) attention span.

1.1 Problem Statement

In early childhood education, sustaining children's attention is essential for supporting cognitive development, language acquisition, and long-term learning. While colourful illustrations are widely used in picturebooks to capture visual interest, their ability to sustain attention over time has not been adequately investigated—especially in the Malaysian preschool context. Although bright and saturated colours have been shown to attract initial attention [11] [12] [13], their effectiveness in maintaining attention is highly dependent on how colours are combined. Poor colour harmony may cause visual discomfort and disengagement, particularly in children whose perceptual sensitivities are still developing [11][14].

In Malaysian KEMAS preschools, which primarily serve children from socioeconomically disadvantaged backgrounds, the picturebooks used often lack intentional, evidence-based visual design. Although visual storytelling plays a central role in supporting literacy and imagination [15][3], most educational materials are not developed with reference to perceptual design principles, such as Itten's complementary colour contrast theory. This is a significant oversight, particularly given that visual attention is closely linked to early reading interest and information retention [16]. The underperformance of Malaysian students in international literacy benchmarks such as PISA [17] highlights the broader urgency of improving engagement strategies from the preschool level.

Despite advances in visual research technologies, tools like the Tobii T120 eye-tracker are rarely applied in Malaysian design or early childhood studies to empirically evaluate children's attention. There remains a lack of local research exploring whether scientifically grounded colour strategies—specifically complementary colour contrast—can effectively sustain visual attention. Therefore, this study addresses a critical gap by examining how colour manipulation in picturebook illustrations may enhance Total TFD among preschool children, contributing toward more sustainable learning through intentional, low-cost visual design. This study examine whether the use of complementary colour contrasts in picturebook illustrations increases the TFD of preschool children, as an indicator of sustained attention.

2. Literature Review

2.1 Children's Attention

Sustained attention, defined as the ability to focus on a stimulus over an extended period, is fundamental in early childhood learning. It supports memory, language development, and comprehension. In early learners, attention span is particularly fragile and easily influenced by environmental and sensory factors [1]. Research categorizes attention processes into bottom-up (stimulus-driven) and top-down (goal-directed) mechanisms. In the context of this study, bottom-up processes are most relevant, as they involve the automatic allocation of attention to visually salient elements such as colour and contrast.

Children's attention is also connected to their developmental readiness. Studies show that children between the ages of 4 and 6—the core demographic of this study—are particularly responsive to novel, vibrant, and emotionally resonant visual stimuli [18]. However, although bright colours initially attract attention, maintaining that attention requires well-structured visual strategies. Hidi and Renninger (2006) argue that interest development depends on the duration of attention. Therefore, the ability to *sustain* visual engagement through design has direct implications for reading interest and literacy development.

2.2 Picturebook as a Learning Medium

Picturebooks are essential pedagogical tools in early education, serving not only to convey narratives but also to foster language acquisition, imagination, and emotional development. Research indicates that the combination of textual and visual storytelling enhances comprehension and recall in young children [15][19]. In Malaysia, picturebooks used in KEMAS preschools often feature Malay folk tales and cultural values, yet many of them overlook the importance of visual design principles in promoting sustained engagement.

The visual components of picturebooks—particularly bright colour, and spatial composition—are responsible for attracting attention [19] and therefore could sustain the attention span. However, in current practice, illustrations in many Malaysian picturebooks do not strategically employ visual contrast to sustain children's attention. This study addresses this gap by applying a structured colour strategy to optimise the attention span of young readers.

2.3 Tobii T120 Eye-Tracking Technology

Advances in eye-tracking technology have greatly enriched research in visual communication design, offering valuable insights into how young children perceive and engage with picturebook illustrations. By accurately capturing gaze patterns and measuring fixation duration [20], [21], [22], eye-tracking helps bridge the gap between the intended design of educational materials and the actual attentional responses of preschool viewers. Understanding how children attend to visual materials requires precise and non-intrusive methods. Eye-tracking technology, particularly the Tobii T120, enables researchers to record TFD—a critical metric for sustained attention—without interfering with the natural viewing behaviour of participants. The Tobii T120 operates at a sampling rate of 120 Hz, providing high-resolution data on eye movements including gaze location, fixation duration, and gaze path [23] .

In this study, the T120 was used to measure how long children fixated on Target Areas (TAs) in the picturebook illustrations before and after colour manipulation. TA refers to specific parts of a picturebook illustration where children's eye fixations were most concentrated, as identified using eye-tracking data. These areas were selected for colour manipulation and used to compare attention span before and after applying complementary colour contrast. The TFD data helped identify whether the applied visual design strategy—complementary colour contrast—successfully increased attention span. The use of eye-tracking represents a novel application in Malaysian preschool design research, offering an empirical way to assess how visual design affects young learners' engagement.

2.4 Colour Complementary Contrast

Among various graphic design elements, colour plays a central role in shaping how young children process and interact with visual information. Beyond its decorative function, colour has been found to directly influence cognitive load, attention control, and emotional engagement in early learners [11][7]. Johannes Itten's (1973) colour theory identifies complementary colours—those located opposite each other on the colour wheel—as producing the most intense perceptual contrast. This form of contrast creates simultaneous visual tension and balance, which can amplify visual salience and perceptual clarity, making it a compelling strategy for directing attention in instructional materials. Prior work by Camgöz et al. [14] and Schieber et al. [24] supports the use of strong colour contrast in increasing initial visual fixation, but the application of these principles within static, educational visual media—like picturebooks—remains underexplored.

In early learning contexts, especially for pre-literate children, illustrations are not merely supportive visuals but function as narrative anchors, guiding comprehension and emotional interpretation. Therefore, colour choices in illustrations carry pedagogical implications, influencing how children follow and interpret stories [2]. However, many educational materials—particularly those used in public or underfunded preschools—lack intentional application of perceptual design principles. The absence of empirically grounded visual strategies, such as complementary colour contrast, can limit the potential of picturebooks to sustain attention and scaffold learning.

From a design-for-learning perspective, integrating complementary colour contrast into picturebooks aligns with the principles of universal design and sustainable education. It offers a practical, low-cost solution for enhancing engagement without requiring technological infrastructure, thus making it particularly beneficial for low-resource preschool environments. This approach also resonates with the goals of inclusive, equitable education under frameworks such as UNESCO's Education for Sustainable Development [10], highlighting how visual design—when informed by theory—can contribute meaningfully to learning equity and quality in early childhood education.

3. Methodology

A quasi-experimental quantitative-method approach was employed in this study to examine the effect of colour complementary contrast on sustaining attention among preschool children. The sample comprised 54 children aged 4 to 6 years, enrolled in KEMAS preschools. Ethical approval for this study was granted and informed consent was obtained from parents or legal guardians through clear information sheets, and participation was entirely voluntary. The use of the Tobii T120 eye-tracking system was non-invasive and designed to be child-friendly. All data were anonymised and handled in accordance with ethical guidelines on privacy and protection. These procedures aligned with ethical principles of respect, beneficence, and justice, ensuring the rights and safety of participants were fully protected throughout the research process.

To investigate the influence of colour complementary contrast on sustaining children's visual attention, the study selected a culturally appropriate picturebook titled *Ratu yang Berani* (*The Brave Queen*), which is officially listed by Malaysia's Ministry of Education for KEMAS preschool reading. The picturebook was first digitised to allow for precise manipulation and presentation on screen-based eye-tracking equipment. To ensure that attention was directed solely at the illustrations and not influenced by text, all written content was removed from the images. This created a purely visual stimulus that focused participants' gaze on image-based storytelling elements.

The colour manipulation process employed Johannes Itten's (1973) complementary colour contrast theory, which involves pairing colours from opposite sides of the colour wheel (e.g., red-green, blue-orange, yellow-violet). Using Adobe Illustrator, these complementary colours were applied either next to or in place of dominant colours within the identified images. The adjustments were made carefully to maintain the logical and perceptual coherence of the illustrations. For example, a leaf originally rendered in green was retained, while the adjacent environment (e.g., a character's clothing or background object) was altered using its complementary counterpart, such as red. The colour choices were converted into the RGB colour model (Figure 1) to ensure accuracy and consistency on digital display screens used during testing.

Fig. 1. The pairs of colour complementary contrast with RGB codes

Figure 1 depicts the RGB codes for the complementary pairs, orange-blue, red-green, and yellow-violet. The pair of colours were changed into identified RGB colour codes as it is important to avoid colour variables due to their different colour values (shades and tone). The colour manipulations of the visual images had used these colour codes throughout the experiment. Additionally, it is important to note that the study will not attempt to identify which colour, or which complementary pair will garner more attention span. Rather, it aims to investigate whether a pair of complementary contrast colour can prolong the participants' attention span towards the picturebook.

Importantly, the manipulation avoided creating unnatural or culturally inappropriate visuals—such as altering human skin tones to blue or green—which could distract or confuse young viewers.

The goal was to isolate colour contrast as the variable under investigation without introducing novelty or absurdity that might independently influence visual fixation. Furthermore, the structural composition, drawing style, and illustrative content of the picturebook were kept entirely intact to ensure a fair comparison between the original and manipulated versions.

Participants were divided into two groups: Baseline group, who were exposed to the unmodified version of the picturebook *Ratu yang Berani*, and the Experimental group, who viewed the same picturebook with selected illustrations digitally manipulated using complementary colour pairs, such as red-green and blue-orange. To measure sustained visual attention, eye-tracking technology (Tobii T120) was used to record the TFD on predefined TA within the illustrations. These TAs were identified based on areas of high visual engagement during the baseline phase. Data were collected during both the pre-manipulation and post-manipulation stages, and will be compared to identify whether the colour complementary contrast can affected to the duration span.

3.1 Pre-Manipulation Stage

During the pre-manipulation phase, eye-tracking data collected using the Tobii T120 system was used to identify specific TA. The setup of the classroom shown in Figure 2. During this process, the TAs will be identified, that is the parts of the image that receive the most attention from children, based on eye fixation data and heatmap visualisations (Figure 3). These TAs will then undergo colour manipulation. Applying complementary colour contrast to these areas will help assess whether it can further hold the children's attention. Furthermore, by focusing on areas that already draw attention, the study will explore whether colour changes can make children look at them for a longer period.

Fig. 2. Baseline group–the actual setup of the T120 (left) and the secondary screen (right) in the classroom

Figure 2 illustrates one of the 27 Baseline group participants whose performance was video recorded and continuously monitored in real-time via a second screen using a remote live viewer. All participants viewed the digital picturebook (visual stimulus) for approximately 10 minutes. This TA consisting of two images next to each other, where the researcher placed the pair of colour complementary contrast. The duration spans on the TA were measured.

As illustrated in Figure 3, the example from page 1 of the picturebook (cover) shows the original picturebook illustration on the left. Adjacent to it is the visualisation of participants' eye fixation areas, next to it displays the heatmap, where red areas indicate longer fixation durations. These frequently fixated regions were identified as the TA. These TAs were then compared between the pre-manipulated and post-manipulated stages to determine whether the application of complementary colour contrast would result in a longer attention span. The last picture presents the illustration after the colour manipulation was applied and later will be exposed to the Experimental group. This picturebook consisted of 25 pages, and the process of the colour manipulation was done throughout the picturebook.

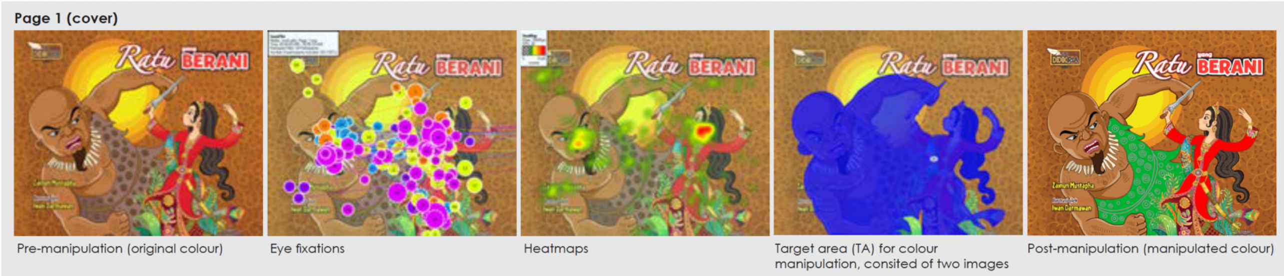

Fig. 3. The process of colour manipulation on the cover page

In Figure 3 illustrates the colour complementary pair of red and green was applied to the main characters; the protagonist (queen) and the antagonist (giant) characters in the picturebook. The complementary colours were applied to the target area that consisted of the two images located immediately next to each other. In order to standardise the colours used for this experiment, the RGB colour code was used throughout. Since the queen, in the original picturebook, was already in red, the red colour was changed to RGB red code, R:255 G:0 B:0, whereas the colour of the giant's costume was changed to green RGB code R:0 G:178 B:50, from its original brown colour. Moreover, if there were more than one target area, where there were no specific complementary colours (i.e., red and green, blue and orange, and yellow and purple), the colour manipulation would follow the closest complementary colour for the image (Figure 4a&4b).

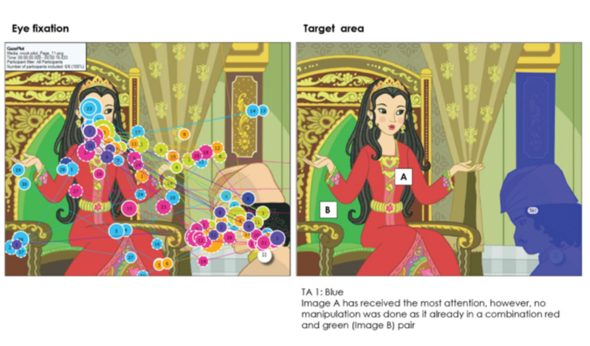

Fig. 4a. The TA was identified during the pre-manipulation stage

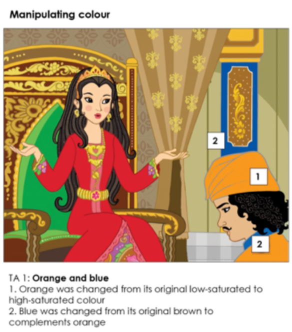

Fig. 4b. Colour manipulation was conducted on the TA

As shown in Figure 4a, eye-tracking data indicated that participants' fixations were primarily concentrated on the areas labelled A, B, 1, and 2. Since images A and B already featured a red-green complementary colour pair, no further manipulation was applied. It is however, in the images labelled 1 and 2 (Figure 4b), colour adjustments were made: area 1, originally brown, was replaced with orange (RGB: 255, 153, 0), as brown is considered a darker shade of orange; area 2 was changed to blue, thereby establishing a complementary colour pairing with orange in accordance with Itten's colour theory.

The colour-manipulated version of the picturebook was then used as the stimulus material for the experimental group during the post-manipulation phase. This design enabled a controlled comparison of both TFDs between the original and manipulated illustrations, ensuring that any observed increase in sustained visual attention could be attributed specifically to the application of complementary colour contrast.

3.2 Post-manipulation stage

After the colour manipulation was completed, the next step was to conduct the post-manipulation stage, that is, to use the colour manipulated picturebook as the stimuli to measure the attention span of the Experimental group. Figure 5 below illustrates the setup on the post-manipulation stage.

Fig. 5. The actual setup in the classroom. The T120 (in front of the participants) and the secondary screen (laptop) for the author to monitor the participant's eye fixations

Data extraction and analysis of the eyetracking method using the Tobii Studio 3.4.8 (TS) software. After the data had been collected during both, the pre- and post-manipulations stages, next step is examined using a five-step process derived from Bojko [20]in their book, *Eye tracking the user experience*, as illustrated in Figure 6 below.

Fig. 6. The steps to analyse the data collected during the eye-tracking task

There were five steps in the analysis of data, beginning with data collection by the Tobii Studio (TS) software through to the statistical analysis using SPSS. As per Figure 6, the procedure began with the identification of the TA. The TAs was identified by the researcher via the heat maps generated by the software of the eye tracker. Once the TAs had been identified, the data had to be cleansed before it could be analysed. This meant that only the fixation duration within these specific areas of the stimulus would be included in the calculations. For the third step, the author extracted the data of the TFD measures from the TS software, which were then imported into a Microsoft Excel 14.2.0

spreadsheet, in order to reorganize the data easily. Finally, the data were exported to the SPSS Version 25 Statistics software for statistical analysis. These five steps were applied throughout, for both pre-and post-manipulations tasks.

Mean differences of both groups

The first step of the statistical analysis was to calculate the mean differences of the TFD for the stimuli (the pre- and post-manipulations of the 25 pages of the picturebook). The formula to calculate the above is as follows,

$$\bar{x}_{\text{exp}} - \bar{x}_{\text{base}} = \text{mean differences}$$

Table 1 below shows the mean differences that are used to find the sample characteristic, i.e., normality test.

Table 1

means differences between the Experimental and Baseline groups of all 25 pages

TFD	pg1	pg2	pg3	pg4	pg5	pg6	pg7	pg8	pg9	pg10	pg11	pg12	pg13
Experimental	284.52	158.58	194.2	168.12	156.38	183.28	133.13	140.59	131.1	138.99	134.87	148.36	128.74
Baseline	269.94	126.1	121.85	109.07	147.79	132.36	106.79	104.25	91.94	93.15	87.82	109.6	103.63
	14.58	**32.48**	**72.35**	**59.05**	**8.59**	**50.92**	**26.34**	**36.34**	**39.16**	**45.84**	**47.05**	**38.76**	**25.11**

TFD	pg14	pg15	pg16	pg17	pg18	pg19	pg20	pg21	pg22	pg23	pg24	pg25
Experimental	167.22	142.73	124.21	136.92	142.14	146.57	163.54	148.08	183.32	174.5	189.05	184.65
Baseline	102.65	105.11	99.41	99.43	118.86	106.94	129.02	109.5	131.43	130.06	124.8	165.29
	64.57	**37.62**	**24.8**	**37.49**	**23.28**	**39.63**	**34.52**	**38.58**	**51.89**	**44.44**	**64.25**	**19.36**

Table 1 illustrates the mean of total fixation durations between the Experimental group in the post-manipulation task and the Baseline group in the pre-manipulation task data. The mean difference, highlighted in yellow, was used for the normality test.

3.3 Results

The analysis showed a statistically significant increase in TFD among participants in the experimental group compared to the baseline group. On average, children in the experimental group spent 30%–45% longer fixating on target areas enhanced with complementary colour contrast. Some pages recorded an increase in TFD of up to 2.5 seconds per area, indicating a clear improvement in sustained visual engagement. Heatmaps corroborated the numerical findings, visually illustrating prolonged attention to colour-manipulated regions.

3.3.1 Normality test

The Shapiro-Wilk (SW) test is the preferred test of normality because of its good power properties as compared to a wide range of alternative tests [25][26][27]. In Table 2, the Shapiro-Wilk's test shows the p-value as ($p>.05$) [28], which indicates that the data is normally distributed. In addition, visual inspections of their histograms (Figure 7), normal Q-Q plots (Figure 8), and box plots (Figure 9) support the notion that the attention spans, based on the TFD, between the Experimental and Baseline group scores, were approximately normally distributed with skewness of 0.218 (SE =

0.464) and kurtosis of 0.195 (SE = 0.902), where the z-values in between was in the span of -1.96 to +1.96.

Table 2
Shapiro-Wilk analysis is used for achieving sufficient power at smaller sample size less than 50 [29]

TESTS OF NORMALITY

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Difference	.126	25	.200*	.980	25	.883

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

DESCRIPTIVES

			Statistic	Std. Error
Difference	Mean		39.0800	3.17232
	95% Confidence Interval for Mean	Lower Bound	32.5327	
		Upper Bound	45.6273	
	5% Trimmed Mean		38.9454	
	Median		38.5800	
	Variance		251.590	
	Std. Deviation		15.86160	
	Minimum		8.59	
	Maximum		72.35	
	Range		63.76	
	Interquartile Range		23.26	
	Skewness		.218	.464
	Kurtosis		-.195	.902

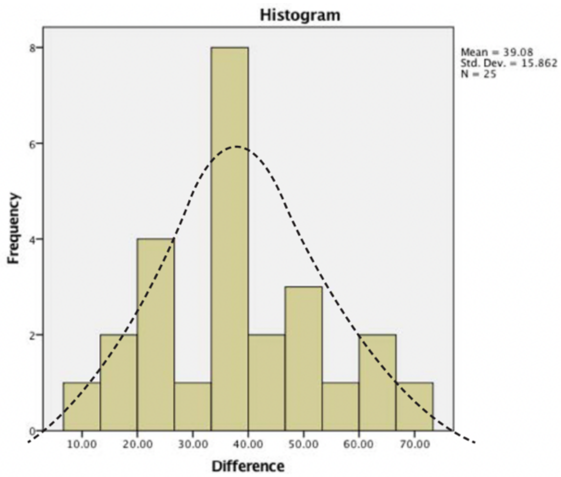

Fig. 7. Histogram in bell curve shaped that supported the notion that data points are normally distributed

When inspecting the box plot, it was observed that there were no outliers indicated as there were no points spotted above the upper whisker (line extending from the top and bottom of the box) and below the lower whisker. The whiskers represent the minimum and maximum values as they are within 1.5 times the interquartile range from either end of the box [30]. It is important to note that any score greater than 1.5 times the interquartile range will appear out of the boxplot and are considered to be outliers, while those which are greater than 3 times the interquartile range are deemed to be extreme outliers. A boxplot that is symmetrical, with a median line which is approximately at the centre of the box and where the symmetric whiskers are slightly longer than the subsections of the centre box, suggests that the data may have come from a normal distribution [31].

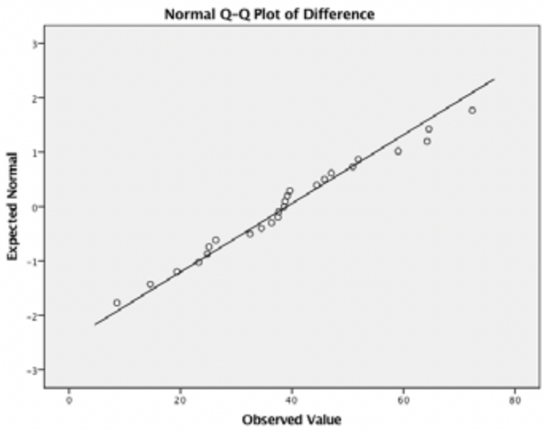

Fig. 8. Q-Q plots (Quantile-Quantile Plot). The data points are fairly closely distributed along the line, suggesting that the data are normally distributed. In a condition when the data scattered points lying away from the line are suspected outliers that may cause the sample to fail a normality test.

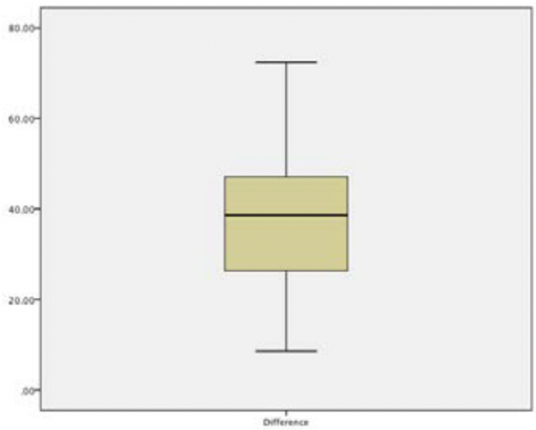

Fig. 9. A boxplot provides an excellent visual summary of many important aspects of distribution. The figure on the left shows the median as a horizontal line inside the box and the interquartile range (range between the 25th to 75th percentiles) as the length of the box

There is a need to ascertain whether the difference between the two groups is statistically significant, i.e., there is a likelihood that a relationship between the variables was caused by the colour manipulations and not by chance. Statistical significance is used to accept or reject the null hypothesis, where there is no relationship between the measured variables. Additionally, the data set is statistically significant when the set is large enough to accurately represent the phenomenon or population sample being studied. When the test result exceeds the p-value ($p \leq 0.05$), the null hypothesis is accepted. When the test result is less than the p-value ($p > 0.05$), the null hypothesis is rejected [32]. In other words, the statistical significance is determined by the p-value. The lower the p-value, the lower the probability of obtaining a result like the one that was observed if the null hypothesis was true. Thus, a low p-value indicates that there is decreased support for the null hypothesis.

Thus, examining the significant difference between the means of the attention span, based on the TFD, between the Experimental and Baseline groups, required a parametric procedure where the dataset was found to be normally distributed [28]. Parametric procedures are typically more powerful and flexible than their non-parametric (not normally distributed) counterpart [33].

3.3.2 Paired samples t-Test

Paired sample t-test or also known as dependent t-test, is used when comparing two means that come from conditions consisting of the same related subjects [34]. In a paired sample t-test, each subject or entity is measured twice, resulting in pairs of observations. In statistics, a two-tailed test is a method in which the critical area of a distribution is two-sided and tests whether a sample is greater than or less than a certain range of values [32]. It is used in null-hypothesis testing and testing for statistical significance.

Table 3 shows that the two-tailed paired samples t-test revealed that the manipulation of colours had an effect on the time taken for the eye gaze of the participants and therefore, the null hypothesis is rejected, t (24) = 12.32, p < .000 at 0.05 alpha level. However, if the p value is very small, then p<0.0001 should be used instead [33]. The mean of the time taken for the post-manipulation of colour manipulations (manipulated picturebook) was statistically and significantly higher than the mean of the time taken for the pre-manipulation (original picturebook). A graphical representation of the means and adjusted to a 95% confidence interval [35].

Table 3
Paired samples test of Experiment and Baseline group shows there is a significant difference between both groups

Paired Samples Test									
		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Experiment - Baseline	39.08000	15.86160	3.17232	32.53265	45.62735	12.319	24	.000

In Table 3, after finding the AOI data between both groups to be statistically significant, the next step was to ascertain the effect size of the study, as the significance does not convey the importance of the effect. Effect size quantifies the size of the difference between two groups [34]. From Table 3, the magnitude size of the effect between the Experimental group and the Baseline group is large, Cohen's = $(d = \frac{\mu exp - \mu base}{SD})\, d$ 2.46, as Cohen [36] suggested on what constitutes a large, medium or small effect: d < 0.2 (small), 0.2 < d < 0.5 (medium), and d > 0.8 (large). This also indicates that the power to reject the null hypothesis is greater, as the larger the value of d, the larger the effect is on the population [37]. For this study, the manipulation had a large effect size on the attention span of the Experimental group.

Overall, the analysis of data suggested that the manipulation had a significant effect on the Experimental group. This manipulation has the potential to have a bigger size effect on the population [36]. It also indicated that there was a constructive impact on the Experimental group's attention span to the visual images during the post-manipulation. As a result, the study accepted the hypothesis that specific colour manipulation using complementary contrasts increases the mean duration of participants' attention span, while rejecting the null hypothesis.

4. Discussion and Conclusion

This study uncovered a new and novel methodology in graphic design research. Although it has been in existence since the 1940s, eyetracking technology has not been widely employed in the research of attention span. As such, there are no prior studies, to the knowledge of the author, that use this technology to study the effects of design on attention span. Although there were existing studies on the use of the complementary colour contrast approach, most of them primarily focused on the attraction of attention. This study, however, expanded upon those researches by exploring how attention can be sustained. This can only be done using the eyetracking technology that is able to pinpoint the actual area of focus of the attention, but also to measure the duration of the attention span. This may benefit future research efforts as researchers are now able to measure attention qualitatively and with precision. This has implications for researchers who want to seek advancements in the field of design by investigating the effectiveness and the optimisation of the design process. It is especially beneficial in specialised contexts such as design within the medical and educational fields. The use of eye-tracking technology may prove to be useful to investigate and extend the findings from previous research.

Furthermore, this study provides clear empirical evidence that complementary colour contrast, grounded in Johannes Itten's [4] colour theory, significantly enhances the fixation duration in preschool children when viewing picturebook illustrations. Using the Tobii T120 eye-tracking system, results showed that participants in the Experimental group, exposed to digitally manipulated illustrations with high-contrast colour pairs (e.g., red-green, blue-orange), exhibited longer and more sustained visual attention compared to the Baseline group. The results, supported by a highly significant t-value and a large effect size confirm that colour contrast has a direct impact on visual engagement—extending previous works [24][14] who found colour to influence fixation but did not explore sustained attention in early learning contexts.

From a cognitive standpoint, prolonged TFD implies deeper visual processing, which is essential for language development, memory retention, and narrative understanding in pre-literate children [16] [38]. Since preschoolers rely primarily on images to decode meaning in picturebooks, guiding their attention through intentional colour application offers a developmentally appropriate and accessible strategy to enhance learning outcomes. This reinforces the argument that visual design in educational materials must move beyond aesthetics and engage with perceptual psychology to support children's emerging cognitive skills.

In terms of broader implications, the study presents a sustainable and low-cost intervention for early education—particularly valuable in under-resourced preschool environments such as Malaysia's KEMAS centres. Colour manipulation using established design theory requires minimal resources and infrastructure but yields measurable improvements in engagement. As such, this approach aligns with UNESCO's Education for Sustainable Development [10] framework, which promotes inclusive, equitable, and quality education through contextually relevant practices.

Building on these findings, several recommendations are proposed. First, future research should explore the effects of other visual variables—such as hue intensity, brightness, saturation, and spatial layout—to develop a more comprehensive understanding of how different design elements influence children's attention and comprehension. Second, similar studies should be conducted using multilingual or multicultural picturebook**s**, to assess the cross-cultural generalisability of the results. Third, extending this work into interactive or digital media environments, including mobile applications or augmented reality storybooks, could offer insights into how colour contrast operates in multimodal learning contexts.

Additionally, educators and designers should consider collaborating to integrate visual design principles into national curriculum materials, ensuring that picturebooks and visual aids are not only culturally appropriate but also perceptually optimised. Finally, training modules or design guidelines for publishers, illustrators, and early childhood educators could help translate research findings into everyday classroom practice, contributing to long-term improvements in educational equity and early literacy development.

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Reference
[1] M. M. McClelland, A. C. Acock, A. Piccinin, S. A. Rhea, and M. C. Stallings, "Relations between preschool attention span-persistence and age 25 educational outcomes," *Early Child Res Q*, vol. 28, no. 2, pp. 314–324, Apr. 2013, doi: 10.1016/J.ECRESQ.2012.07.008.
[2] G. Woolley, "Using Visualisation and Imagery to Enhance Reading Comprehension BT - Literacy in the Arts: Retheorising Learning and Teaching," G. Barton, Ed., Cham: Springer International Publishing, 2014, pp. 215–234. doi: 10.1007/978-3-319-04846-8_13.
[3] R. N. Carney and J. R. Levin, "Pictorial Illustrations Still Improve Students' Learning from Text," *Educ Psychol Rev*, vol. 14, no. 1, pp. 5–26, 2002, doi: 10.1023/A:1013176309260.
[4] J. Itten, *The Art of Color: The Subjective Experience and Objective Rationale of Color*. Reinhold Publishing Corporation, 1973. [Online]. Available: https://books.google.com.my/books?id=gSRmwQEACAAJ
[5] M. Lacour and L. Tissington, "The effects of poverty on academic achievement," *Educational Research and Reviews*, vol. 6, Jul. 2011.
[6] OECD, *OECD Regions at a Glance 2016*. Paris: OECD Publishing, 2016. doi: https://doi.org/10.1787/reg_glance-2016-en.
[7] T. L. Stone, AdamsMorioka, S. Adams, and N. Morioka, *Color Design Workbook: A Real World Guide to Using Color in Graphic Design*. Rockport Publishers, 2008. [Online]. Available: https://books.google.com.my/books?id=CjuLl_bNO9UC
[8] N. Olguntürk, C. Yener, and D. Köksal, "Effects of Hue, Saturation, and Brightness: Part 2 - Attention," *Color Res Appl*, vol. 29, pp. 20–28, Dec. 2003, doi: 10.1002/col.10214.
[9] S. Becker, C. Valuch, and U. Ansorge, "Color priming in pop-out search depends on the relative color of the target," *Front Psychol*, vol. 5, p. 289, Apr. 2014, doi: 10.3389/fpsyg.2014.00289.
[10] U. Nations, "THE 17 GOALS." Accessed: Jun. 26, 2025. [Online]. Available: https://sdgs.un.org/goals
[11] J. Krause, *Illustrations, Color for Designers: Ninety-five things you need to know when choosing and using colors for layouts and*. New Riders, 2015.
[12] H.-J. Suk and H. Irtel, "Emotional response to color across media," *Color Res Appl*, vol. 35, pp. 64–77, Feb. 2010, doi: 10.1002/col.20554.
[13] L. Wilms and D. Oberfeld, "Color and emotion: effects of hue, saturation, and brightness," *Psychol Res*, vol. 82, Sep. 2018, doi: 10.1007/s00426-017-0880-8.
[14] N. Camgöz, C. Yener, and D. Güvenç, "Effects of hue, saturation, and brightness: Part 2: Attention," *Color Res Appl*, vol. 29, no. 1, pp. 20–28, Feb. 2004, doi: https://doi.org/10.1002/col.10214.
[15] K. Fletcher and E. Reese, "Picture book reading with young children: A conceptual framework," *Developmental Review*, vol. 25, pp. 64–103, Mar. 2005, doi: 10.1016/j.dr.2004.08.009.
[16] S. Hidi and K. A. and Renninger, "The Four-Phase Model of Interest Development," *Educ Psychol*, vol. 41, no. 2, pp. 111–127, Jun. 2006, doi: 10.1207/s15326985ep4102_4.
[17] OECD, "PISA 2022 Results (Volume I and II) - Country Notes: Malaysia," 2023.
[18] H. F. Neville, *Is This a Phase? Child Development & Parent Strategies, Birth to 6 Years*. Parenting Press, 2007.
[19] Y. N. Yum, N. Cohn, and W. K. W. Lau, "Effects of picture-word integration on reading visual narratives in L1 and L2," *Learn Instr*, vol. 71, p. 101397, Feb. 2021, doi: 10.1016/J.LEARNINSTRUC.2020.101397.
[20] A. Bojko, *Eye Tracking the User Experience: A Practical Guide to Research*. New York: Rosenfeld Media, 2013.
[21] A. T. Duchowski, "Gaze-based interaction: A 30 year retrospective," *Computers and Graphics (Pergamon)*, vol. 73, pp. 59–69, 2018, doi: 10.1016/j.cag.2018.04.002.
[22] A. T. Duchowski, K. Krejtz, J. Zurawska, and D. H. House, "Using Microsaccades to Estimate Task Difficulty during Visual Search of Layered Surfaces," *IEEE Trans Vis Comput Graph*, vol. 26, no. 9, pp. 2904–2918, 2020, doi: 10.1109/TVCG.2019.2901881.
[23] T. Technology, "Tobii T60 & T120 Eye Tracker," Danderyd, 2011.
[24] F. Schieber, N. Willan, and B. Schlorholtz, "Fluorescent Colored Stimuli Automatically Attract Visual Attention: An Eye Movement Study," *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, vol. 50, Oct. 2006, doi: 10.1177/154193120605001625.
[25] M. SHAIK, "Normality Tests and its Power against Alternative Distributions: An Empirical Analysis on Emerging Asian Stock Index Returns," *The Journal of Prediction Market*, vol. 16, no. 1, 2022, doi: https://doi.org/10.5750/jpm.v16i1.1852.

[26] S. Korkmaz and Y. Demir, “Investigation of some univariate normality tests in terms of type-i errors and test power,” *Journal of Scientific Reports-A*, no. 052, pp. 376–395, 2023.
[27] M. Cavus, B. Yazici, and A. Sezer, “Penalized power properties of the normality tests in the presence of outliers,” *Communications in Statistics-Simulation and Computation*, vol. 52, no. 8, pp. 3568–3580, 2023.
[28] S. S. Shapiro and M. B. Wilk, “An Analysis of Variance Test for Normality (Complete Samples),” *Biometrika*, vol. 52, no. 3/4, pp. 591–611, Jun. 1965, doi: 10.2307/2333709.
[29] D. Kilic, “An Examination of Using Self-, Peer-, and Teacher-Assessment in Higher Education: A Case Study in Teacher Education,” *Higher Education Studies*, vol. 6, p. 136, Feb. 2016, doi: 10.5539/hes.v6n1p136.
[30] P. Jennifer, *Medical Statistics: A Guide to Data Analysis and Critical Appraisal*. Blackwell Publishing Ltd, 2005. doi: 10.1002/9780470755945.
[31] A. C. & W. A. W. Elliott, *Statistical Analysis Quick Reference Guidebook: With SPSS Examples*, 1st ed. SAGE Publications, Inc, 2006.
[32] J. Pallant, *SPSS Survival Manual: A step by step guide to data analysis using IBM SPSS (7th ed.)*, 7th ed. London: Routledge, 2020. doi: 10.4324/9781003117452.
[33] E. McCrum-Gardner, “Which is the correct statistical test to use?,” *British Journal of Oral and Maxillofacial Surgery*, vol. 46, no. 1, pp. 38–41, Jan. 2008, doi: 10.1016/J.BJOMS.2007.09.002.
[34] A. Field, *Discovering statistics using IBM SPSS statistics*. Sage publications limited, 2024.
[35] G. R. Loftus and M. E. J. Masson, “Using confidence intervals in within-subject designs,” *Psychon Bull Rev*, vol. 1, no. 4, pp. 476–490, 1994, doi: 10.3758/BF03210951.
[36] Jacob Cohen, “Statistical Power Analysis,” *Curr Dir Psychol Sci*, vol. 1, no. 3, pp. 98–101, Jun. 1992, doi: 10.1111/1467-8721.ep10768783.
[37] G. J. Privitera, *Statistics for the Behavioral Sciences Third Edition*. SAGE Publications, Inc, 2017.
[38] G. & I. H. Woolley, *Using imagery as a strategy to enhance students’ comprehension of read text*. NSW, Australia: Pearson Education Australia, 2004.