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Influence of perceptual factors on preschool children's visual attention in flat panel display systems

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ABSTRACT

This study investigates the influence of perceptual elements—including color schemes, graphic design, text readability, sound, and motion graphics—on the visual attention of preschool children using flat panel display systems. Adopting a quantitative approach, data were gathered through online questionnaires completed by parents and preschool educators. Structural equation modelling using SmartPLS 4 was employed to analyze the relationships among these variables. The results indicate that sound integration and motion graphics have the strongest positive effects on children's visual attention, highlighting the importance of multisensory and dynamic features in maintaining engagement. Color schemes and graphic design also showed positive but smaller effects, while text readability had no significant impact. These findings underscore the value of incorporating auditory and animated elements in the design of educational tools for young children and suggest directions for future research on their application across various learning environments.

1. Introduction

An enormous shift has been witnessed in every sector, owing to the irrationality of sophisticated artificial intelligence (AI) technologies, particularly in preschool education. In this fluid environment, educators and researchers are also turning their attention to the application of AI-enabled tools to the education of preschool children. This is one of the new approaches being focused on and is on the rise to afford special interactions with preschool children through interactivity and visual stimulation—the flat-panel visual systems. Such systems, which incorporate bright colors, animations, and sound effects, incorporate some systems speculated to enhance young people's understanding. Surveys have demonstrated that toddlers with autism spectrum disorders exhibit increased concentrations in class when visual imagery is presented on prominent surfaces (Wang et al., 2021). In addition, flat-panel displays used in parenting practices, such as book-sharing between children and caregivers, have been demonstrated to enhance visual attention as well as nonverbal engagement between children and caregivers (Liu et al., 2022). Such soliciting technologies have also been used to improve the interaction skills of preschool children, as they enable them to actively perform interaction activities with their peers, particularly by simply engaging them in visual scene displays on systems (Laubscher et al., 2020).

With the increase in the use of flat panel display devices in preschool classrooms, it becomes necessary to appreciate children's vision as an important perceptual dimension. Studies thus far have made significant contributions to several factors, including color schemes (Ivančić Valenko et al., 2019), graphic designs (Yanchus et al., 2022), text readability (Ren et al., 2024), sound integration (Hagtvedt and Brasel, 2016), and the effects of motion graphics (Ivančić Valenko et al., 2019). Nevertheless, there is a major deficiency in research on the integration of these elements in graphic design for preschool children with respect to the usage of enhanced aids, especially AI tools. Current studies have pinpointed some isolated factors; however, the assessment and analysis of the interaction of such factors in a systematic manner remain unexplored.

The present research focuses on the impact of five prominent visual factors—color schemes, graphic designs, text readability, sound integration,

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and motion graphics—on preschool children, highlighting their influence on children's visual perception and cognitive activity. With respect to this analysis, the present study also tends to investigate the application of visual warnings within flat-panel displays in educational settings to improve both the learning process and safety using teaching techniques learned from these elements. By solving such issues, this research not only aims to add something valuable to the existing body of knowledge but also aims to establish a comprehensive approach for the conception, design, and deployment of AI-integrated educational applications that would be effective in engaging learners and considering the specific visual characteristics of young learners.

The relevance and implications of this research study are that it can be used in both theoretical and practical contexts in the areas of early childhood education and educational technology. By understanding them and their interrelations, this research seeks to guide the design of appropriate educational tools driven by artificial intelligence that will ultimately optimize the learning experience of the preschool age group. It is further anticipated that the outcomes will recommend useful strategies to strengthen visual systems designed for interactive learning to meet young learner segments, including polarly contrasting kids, and provide suitable opportunities for their mental growth.

To achieve these objectives, the study also employed a quantitative technique with the help of SmartPLS-4 to perform SEM analysis to study the factors influencing vision. This study is guided by the following research questions: (1) What perceptual factors are the most important for the visual engagement of preschool children in flat panel visual systems? (2) How do these factors combine with one another, and what effects do they have on the flat-panel visual system? This study, therefore, addresses these research questions with the hope of shedding light on the perceptual factors that influence how young learners visually experience the environment and how modern technologies can be enhanced in the context of education.

Consequently, this study attempts to supplement the existing knowledge regarding the perception-related aspects of preschoolers' interactions with flat panel displays in an artificial intelligence-based learning environment. The outcomes of the research are likely to be broad in terms of both improving educational technology designs and helping the abilities and perceptions of children in the 21st century.

2. Hypothesis development

2.1. Color schemes and children's visual attention

In planning any experience for preschool children, the use of color schemes is paramount. This can be explained by the fact that visual attention is critical for this age group's learning and participation. The deliberate incorporation of visual imagery is known to affect children's attention to visual displays and their reactions to them. Thistle and Wilkinson (2009) reported that color, especially in the front part of preschool children's taxis, makes it easier for them to find target objects within a short period. This implies that color, when used appropriately, has a way of attracting attention and enhancing the effectiveness of search tasks, which is very important for children who have not yet matured cognitively.

Furthermore, the findings of Cho and Son (2016) concerning the incorporation of color ordinal scales in visual orientation were highlighted, as they reported that young children are more sensitive to color contrasts than older children or adults are. Thus, where children are part of the audience in a particular visual attention study, color contrast was found to strongly influence the distribution of children's visual attention. Such an observation of sensitivity to contrast in young subjects suggests that color is not merely an option for decoration. Instead, it is a weapon that can manipulate and maintain the focus of the younger audience. This has important consequences for educational environments, especially as the right color contrasts can be used to attract children's attention to the critical information required for optimal learning.

Furthermore, separate colors have been demonstrated to improve search performance, as indicated by Maule et al. (2023). According to their research, preschool toddlers identify symbols more effectively and rapidly when presented with multiple colors than when presented with a single color. This clearly demonstrates the advantages of the cognitive use of color variations in educational resources. Lessening the cognitive processing effort required to discriminate between different visual features of information enables children to respond to information more readily, which in turn improves attention.

Pomerleau et al. (2014) reported that certain colors, especially red and blue, are more efficient at attracting children's attention than green and yellow colors are. There are several eye movements toward red and blue rather than toward other colors on average, suggesting that some colors act on us faster than others do. This is important in the context of developing educational materials, as the choice of some colors may greatly broaden the child's range of attention and perception of visual information. A study by Morey et al. (2015) on the color-sharing effect revealed that vocalizing repeated colors in a visual display enhances audience attention to the picture. This implies that the strategically planned repetition of the colors in the graphic presentation can also help improve the recall of the information presented while keeping the user engaged. In the realm of education design, it is crucial to emphasize that selecting colors is not solely based on their initial display; it also involves considering their order of appearance and various combinations,

which serve as attention-grabbing and retention strategies.

Thus, the evidence underscores the profound influence that color schemes have on preschool children's visual attention. From improving the speed and accuracy of visual searches to enhancing perceptual organization and memory retention, color is a powerful tool in shaping how young learners engage with visual information. Therefore, the following hypothesis is proposed:

H1: Color schemes in flat-panel visual systems positively affect preschool children's visual attention.

2.2. Graphic designs and children's visual attention

Graphic design has significance in guiding visual attention, which is potentially equal in importance to any other aspect, especially in curriculum environments where there are visual elements that need to receive the attention of children. The effectiveness of graphic design in governing visual attention can be broken down into structural factors such as the arrangement of different visual features within a frame, the aesthetics of graphics and images, and attributes or extras.

Chakraborty et al. (2022) developed a model that helps in evaluating the visual attention given to graphic design documents during the nonlinear reading of the documents, which revealed that graphics that were logically organized and had an appeal changed the direction of attention as well as the order of aspects of a visual layout that were fixed upon. The fact that this model works on webpages, comics, posters, and other graphic designs that cut across various mass media further reiterates the basis and constructs of good graphic design that transcends mass media. This means that in the spirit of education, particularly in preschool-aged children, attention-focusing ability may be improved and further sustained by paying attention to the graphics.

Undeniably, this is supported by Godwin et al. (2022), who attempted to study children's behaviors in classrooms with elaborate visual designs. They reported that even after a long time, Horizons is delighted to know that there are different strategies that can help children return to work, even if they sometimes gaze at other things. Considerable weight is then placed on the use of visual ads in instructional materials, which increases the need as well as for those designs that are not only elaborate and beautiful but also organized to eliminate excess visuals and help focus on the necessary visuals.

More insights are reported by Smith et al. (2021), who explain how some elements of graphic novelization are significant for how well children with dyslexia commit to memory. Their study indicated that the use of appropriate imagery, which is normally artistically designed within the pages of a comic book, improved the visual attention and retention of the children. This is critical for the development of teaching aids that are intended to open children's view of learning and consider the fact that children learn differently, which means that the introduction of designs that are simple yet alluring can enhance learning.

Zheng (2022) contributed to the understanding of the visual influence of graphic design by building a neural network model for classifying and tuning graphic arts. In this study, cartograms made available to viewers through appropriate algorithms were established to greatly improve visual focus and impressions. This indicates that it is essential to do more than just make the content attractive; it should also be organized according to how people's brains work to attract their attention and engage.

O'Neill et al. (2019) studied visual attention in complex AAC visual scenes and found that participants focused more on the 'meaningful' parts of the design, such as the visual scene and navigation bars. Their findings suggest that when visual elements are clearly organized and well designed, they can help draw attention to key information, making it easier for young children to notice and understand important messages.

Finally, Arslan-Ari and Ari (2022) applied the techniques of eye tracking in the analysis of how pre-K children use e-books, specifically with respect to the attention afforded to the graphics incorporated within their design. Therefore, it is worth having a proper graphical endeavor and using it wisely to focus children on crucial aspects such as text. Graphic design focuses on how best to use children's vision within educational systems. This notion further strengthens the fact that effective graphic designs are useful in that the attention of preschool children is captured and maintained for even better learning. Hence, the above studies support the following hypothesis:

H2: Graphic designs in flat-panel visual systems positively affect preschool children's visual attention.

2.3. Text readability and children's visual attention

According to Arslan-Ari and Ari (2022), preschool children tend to use images more than written facts in e-books owing to their age and image preferences. Their research has also shown that when children's auditory stimuli are synchronized with visual illustrations, children's motivation towards the written text improves greatly. This information clearly highlights the need for readable text and the effective placement of picture cue systems to assist young children in reading for comprehension.

The study investigating the impact of visual enhancements on text readability conducted by Ikeshita et al. (2018) is particularly relevant here because these authors investigated the effect that text highlighting synchronized to the narration audio could have on children with developmental dyslexia.

The results revealed that using styles of highlighting increased text clarity, which means that such techniques can improve attachment to reading activities for children, including those with learning difficulties. The study exemplifies the possibility of increasing both the readability of text and its attractiveness to learners by employing visual aids.

In the same manner, Skibbe et al. (2018) reported that preschoolers look at printed text when it is read aloud, along with highlighting, much more than when the text is presented without sound. This opening of the auditory and visual systems simultaneously enables children to focus on the text in a more increased manner, facilitating literacy acquisition. The study also highlights the need to combine such text with audio-video as much engaging with young learners, as written material is entertaining, to help capture and maintain attention.

Valdois et al. (2019) presented evidence showing that visual attention span, which plays a key role in understanding written texts, is a strong predictor of reading fluency in children. Their findings suggest that when text readability is improved to an optimal level, children are more likely to visually engage with the text, even if they may not necessarily enjoy the process of acquiring reading skills. This highlights the link between clearer, more accessible texts and better reading performance in children, supporting the need to consider readability when designing educational materials.

Fong et al. (2019) conducted a study to evaluate whether colored overlays could help improve the reading performance of preschool children with autism spectrum disorder (ASD). Although the immediate effects on visual attention were not statistically significant, the researchers observed that using these overlays might support better text decoding and visual attention over time, especially with regular use. This finding suggests that interventions aimed at enhancing text focus in children with learning difficulties may be effective in the long term, gradually helping these children engage more successfully with written material.

Scaltritti et al. (2019) investigated how typographic features such as font size and spacing affect children's visual processing when reading digital text. Their study found that these design elements significantly influence visual attention and reading performance. They emphasized that improving text readability is crucial for sustaining children's attention during reading. This suggests that typographic choices should be made carefully to enhance readability, which in turn supports better visual attention and reading outcomes.

Based on this evidence, it can be concluded that improving text readability, whether through visual design, typography, sound quality, or motion, helps attract and hold children's visual attention. These findings support the following hypothesis:

H3: Text readability in flat-panel visual systems positively affects preschool children's visual attention.

2.4. Sound integration and children's visual attention

Endowing sound to computer interfaces is especially important for enhancing and directing visual attention.

Fleming et al. (2020) reported that visual processing and visual search times increased when auditory information was presented within the same spatial location as visual information. When auditory information is added to a visual stimulus, it improves the efficiency with which visual information is processed, as seen in reaction times as well as event-related potentials. This illustrates that not only does sound integration aid the child's visual focus, but it also enhances it. This is a very important factor to consider in education design for attention-sensitive age groups such as children.

Ren et al. (2020) further delved into the notion of audio–visual integration under different conditions of visual attentional load. The outcome of their study was that sound integration works well in terms of visual attention enhancement if the children have already engaged in tasking, implying that sound is beneficial in maintaining and, at times, increasing visual attention to a task even when the task loads change. For this reason, it is necessary to use sounds in educational areas to help children maintain concentration over a task that involves attention for long periods of time.

Hutton et al. (2019) performed functional magnetic resonance imaging scans and analyzed the functional connectivity related to the attention, visual, and language networks of preschoolers when various story formats were engaged, including those that have sounds. Their studies suggested that audio-embedded illustrated storybooks may promote visual attention better than simple picture books, as many cognitive networks are used simultaneously. Therefore, it is possible to realize that using sounds in such tasks as storytelling cannot attract only a child's attention; however, fully completing such activities would become more interesting and involve a greater cognitive load as well.

Flynn et al. (2019) evaluated the specific screen-based pedagogical support of an SBPS that uses a combination of visual and sound effects to focus children's attention. The use of eye-tracking technology, in their case, allowed the investigation of sound effect occurrence and its influence, which contributed significantly to the attention preschool children paid to the educational media. This finding indicates that sound can indeed be embedded within educational content as an operational strategy, directing and maintaining children's visual focus within activities that involve more than one mode of representation, such as multimedia.

Finally, Li et al. (2022) addressed the issue of whether sounds, when present in omnidirectional videos, have an important influence on how attention is distributed visually. Their findings demonstrate that sound, so if one clear sound is presented, you can pay attention to the visual

components that are supported by the audio. This implies that sound is a very useful and effective way of manipulating visual attention; thus, its application should be emphasized in the development of interactive multimedia educational materials for preschoolers.

To summarize, auditory and visual elements work hand in hand to improve the visual attention of preschool children. Sewing clip art to the recorded narrative, using stereophonic narration, or simple yet effective sound effects can enhance the attentional and perceptual aspects of visual stimuli. This leads to the following hypothesis:

H4: Sound integration in flat-panel visual systems positively affects preschool children's visual attention.

2.5. Motion graphics and children's visual attention

Motion graphics have emerged as an essential way of drawing and holding the attention of the eyes, especially in the case of the education of preschoolers. Since motion graphics, by definition, involve moving visual graphics, they are an essential factor in attracting the attention of young learners and keeping their attention on learning activities.

On the other hand, Aprilliani et al. (2022) reported that, for preschool children, learning via motion graphics video media is a more effective way to capture attention than learning via traditional media. This means that they emphasized, among other findings, that the motion graphics inertia features were very effective in keeping the attention of children during teaching classes. This finding indicates that when motion graphics are used, kids not only focus but are also more involved, both effectively and cognitively, in the learning activity. It just tells us how useful it is in early childhood education.

This finding is further corroborated by Sun et al. (2019), who examined motion as a factor that enhances children's visual attention, which was evaluated with animated eBooks used to teach preschoolers to learn language. There was high and low motion, which was found to lead to greater visual attention and word recognition of target words among preschoolers. This is to emphasize that rather than being allowed to drift, moving images of visuals integrated with tertiary education augment receptors and learning results.

Pitt et al. (2023) conducted a study examining the different motion techniques in a brain–computer interface for children and reported that there was a notable difference in the attention responses to more complex animations compared with simpler animations. This indicates that even within the category of motion graphics, not all are optimally effective, as they should be there is room for more enticing and functional graphics. These findings clearly demonstrate the need to move beyond creating good-looking graphics for children to the creation of attention-grabbing motion graphics that are engaging cognitively in young learners.

Such performance can guide attention towards an area due to motion onset (both natural and animated), suggesting that Smith and Abrams (2018) motivated this investigation, but to move further. Their study supports the proposition that devices of attention, including children, can be harnessed by motion graphics using moving objects. This is consistent with existing knowledge in that motion is an attractive force, and it cannot be left out when developing educational materials for preschool children.

To conclude, the infusion of motion graphic elements substantially enhances preschool children's attention to educational media page content. The attention span that every animation and motion graphic has achieved entails better learning of the intended objectives by the end users. Therefore, these findings lead to the following hypothesis:

H5: Motion graphics in flat-panel visual systems positively affect preschool children's visual attention.

3. Methodology

3.1. Research design

The current study utilizes a quantitative research design that seeks to determine the relationship between how preschoolers perceive several factors, such as color schemes, graphic designs, text readability, sound integration, motion graphics and children's visual attention. The questionnaire survey approach was selected since it allows the collection of objective and quantifiable information that can be manipulated statistically while seeking relationships among the various components.

For this process, the SmartPLS-4 application of structural equation modelling was used, as it allows the exploration of complex structural relationships between observed and latent variables in a convenient way that meets the research objectives. This is because SEM allows the examination of more than one dependent and independent variable at the same time, allowing the researcher to obtain a holistic understanding of how the factors interact to direct visual attention to the children.

3.2. Participants

This included preschool educators and parents of preschool children aged 3-5 years who acted as primary respondents. Owing to the preschool age of the respondents, those direct responses from the children themselves were not attainable; therefore, the input from parents and educators was used to collect data on the visual attention and interaction of the children with the visual system. The participants were recruited through an online China-wide

advertisement that used digital media to reach out to natives in their respective regions to encourage the wide participation of various populations. This guaranteed that the participants were from different backgrounds, which in turn facilitated the transferability of the results of the study.

The inclusion criteria required that participating parents or educators had closely interacted with the children in educational or related settings. Children with known visual or cognitive impairments that were not accounted for in the study were excluded, as such conditions could significantly affect their attention. Additionally, participants needed internet access to view the study materials and use the data collection platform. Informed consent was obtained from all participating parents and educators. They were fully informed about the study's purpose, procedures, and their right to participate voluntarily. Confidentiality of their responses and the protection of personal data were ensured. Measures were also taken throughout the study to ensure that the children did not experience any discomfort or distress during observations.

3.3. Instruments and data collection

In this study, a structured questionnaire was used as the primary instrument for data collection (Table 1). The questionnaire was designed to measure factors that are hypothesized to influence preschool children's visual attention. The items for two of these variables (color scheme and graphic design) were adopted directly from the literature, whereas the items for the other four variables (text readability, sound integration, motion graphics and children's attention) were adapted from related studies.

Table 1: Variable measurement items

Variable	Items in literature	Items in this study	Reference
Color scheme	1. Do you like the color scheme of the office?	CS-1. Do you like the color scheme of flat panel visual systems?	Öztürk (2010)
	2. Do you prefer this color scheme for your office?	CS-2. Do you prefer this color scheme for the flat panel visual systems?	
	3. Do you think this color scheme is appropriate for an office environment?	CS-3. Do you think this color scheme is appropriate for flat panel visual systems?	
Graphic design	1. Colors, images, and icons help to understand and identify the messages and concepts of each of the visual creations.	GD-1. Colors, images, and icons help to understand and identify the educational content in the flat panel visual systems.	Vallverdu-Gordi and Marine-Roig (2023)
	2. Colors, images, and icons draw attention to the campaign.	GD-2. Colors, images, and icons draw attention to the educational content in the flat panel visual systems.	
	3. The campaign design as collectable badges/medallions draws attention and encourages the reading of the messages.	GD-3. Visual design encourages interaction and reading of the educational content in the flat panel visual systems.	
Text readability	——	TR-1. The text is easy to read and understand for preschool children in the flat panel visual systems.	Crossley et al. (2008) and Sun et al. (2020)
	——	TR-2. The font size and spacing are appropriate for preschool children in the flat panel visual systems.	
	——	TR-3. The text layout helps in maintaining visual attention in the flat panel visual systems.	
Sound integration	——	SI-1. The sound effects are synchronized well with the visual content in the flat panel.	Peeraer and Van Petegem (2012), Buongiorno et al. (2019), and Gray and Kathleen (2000)
	——	SI-2. The sound enhances the educational value of the content in the flat panel visual systems.	
	——	SI-3. The sound helps in maintaining children's attention on the visual content.	
Motion graphics	——	MG-1. The motion graphics capture and hold children's attention effectively in the flat panel visual systems.	Hapsari and Hanif (2019)
	——	MG-2. The animations are engaging and support educational content in the flat panel visual systems.	
	——	MG-3. The movement of visual elements helps in guiding children's focus to key information in the flat panel visual systems.	
Children's visual attention	——	CVA-1. The child can focus on the visual content for extended periods in the flat panel visual systems.	Prieler et al. (2018) and Costescu et al. (2019)
	——	CVA-2. The visual content helps maintain the child's attention throughout the activity.	
	——	CVA-3. The child is less distracted when visual content is engaging and interactive in the flat panel visual systems.	

Data were collected through an online questionnaire distributed to parents and preschool educators across China. The questionnaire included 5 Likert scale items ranging from "Strongly Disagree" to "Strongly Agree" (Graphic Design, Text Readability, Sound Integration, Motion Graphics) and "No" to "Yes" (Color Scheme). The use of an online platform facilitated broad participation and allowed for the efficient collection of data from a geographically diverse sample.

The responses were automatically recorded and stored in a secure database, ensuring both the confidentiality of the participants and the integrity of the data. The data collection process was conducted over a period of [insert time frame], during which reminders were sent to encourage participation and increase the response rate. The collected data were then prepared for analysis via SmartPLS 4, which focuses on the relationships between the identified perceptual factors and children's visual attention. The questionnaire design, combined with the use of reliable and validated items from literature, ensures that the data collected are both robust and relevant to the research objectives.

3.4. Procedure

The questionnaire was filled out by parents and educators, who provided their observations based on their regular interactions with their children. Given that the children were unable to complete the questionnaire themselves, the parents and educators served as proxies, offering insights into how the children responded to various visual stimuli.

The data collection was conducted entirely online, with participants accessing and completing the questionnaire through a web-based platform. This approach allowed for broad participation across different regions, ensuring a diverse and representative sample. Participation in the study was entirely voluntary, and participants were informed about the purpose of the study and their rights, including the confidentiality of their responses and the option to withdraw at any time.

As the data collection was web-based, it facilitated the efficient gathering and secure storage of responses in a password-protected database. The process was conducted over a defined period, during which reminders were sent to encourage participation and ensure a high response rate. This structured and web-based approach to data collection ensured that the study's findings would be both robust and reliable, providing valuable insights into the impact of perceptual factors on children's visual attention in educational contexts.

3.5. Data analysis

The data collected from the online questionnaire, which was completed by parents and educators, was analyzed via SmartPLS 4, a powerful tool for structural equation modelling (SEM). SmartPLS 4 was employed to conduct a comprehensive analysis that included assessing the volatility and reliability of the constructs, examining the relationships between the key variables (color scheme, graphic design, text readability, sound integration, motion graphics, and children's visual attention), and evaluating the overall model fit. The analysis began with the assessment of the measurement model to ensure that the constructs were reliably and validly measured, followed by structural model analysis to test the hypothesized relationships between the perceptual factors and children's visual attention. Model fit was evaluated via key indices such as the standardized root mean square residual (SRMR) to ensure that the SEM accurately represented the data. This approach allowed for a detailed examination of how the different perceptual factors influenced visual attention, providing robust empirical support for the study's hypotheses.

4. Results

The sample for this study consisted of 452 respondents, comprising two primary groups: preschool educators (183 participants) and parents of preschool children (269 participants). The participants were drawn from five key regions in China, including Beijing, Guangdong, Hubei, Hunan, and Sichuan, providing a geographically diverse representation. This demographic diversity adds robustness to the study's findings, as it reflects a broad range of educational and cultural contexts across these major provinces. The inclusion of both educators and parents ensures that the data offers comprehensive insights into children's visual attention from the perspectives of both formal education settings and home environments.

As shown in Table 2, the reliability and validity of the constructs were assessed via Cronbach's alpha, composite reliability (rho_a and rho_c), and average variance extracted (AVE). Children's vision showed strong reliability, with a Cronbach's alpha of 0.847 and composite reliability values (rho_a = 0.849, rho_c = 0.907), whereas the AVE of 0.766 confirmed good convergent validity. The color scheme, however, had a lower Cronbach's alpha of 0.595, suggesting moderate internal consistency. To address this, the interpretation of measurement items for the color scheme was revisited, emphasizing dimensions such as contrast and appropriateness to better align with its theoretical definition. Despite the moderate reliability, the composite reliability (rho_a = 0.703, rho_c = 0.752) and AVE of 0.511 met the minimum threshold for validity.

Table 2: Reliability and validity

Variables	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	AVE
Children's vision attention	0.847	0.849	0.907	0.766
Color scheme	0.595	0.703	0.752	0.511
Graphic design	0.790	0.793	0.877	0.703
Motion graphics	0.657	0.734	0.811	0.598
Sound integration	0.880	0.880	0.926	0.806
Text readability	0.868	0.870	0.919	0.791

The graphic design demonstrated satisfactory reliability (Cronbach's alpha = 0.790), with strong composite reliability (rho_a = 0.793, rho_c = 0.877) and an AVE of 0.703. Motion graphics had moderate reliability, with a Cronbach's alpha of 0.657. The presentation of measurement items for this construction was also refined to emphasize elements such as animation fluidity and engagement, ensuring closer alignment with its theoretical framework. The composite reliability (rho_a = 0.734, rho_c = 0.811) and AVE of 0.598 remained acceptable for construct validity. Sound Integration showed excellent internal consistency (Cronbach's alpha = 0.880) and strong composite reliability (rho_a = 0.880, rho_c = 0.926), with an AVE of 0.806, indicating high validity. Text readability also performed well, with a Cronbach's alpha of 0.868 and strong composite reliability (rho_a = 0.870, rho_c = 0.919), alongside an AVE of 0.791. Table 3 presents the path coefficients, which demonstrate varying levels of influence from the perceptual factors on children's vision. Sound integration has the strongest positive impact on children's visual attention, with a path coefficient of 0.555, indicating that auditory elements play a significant role in enhancing visual engagement. Motion graphics also positively influence children's

vision, with a path coefficient of 0.184, emphasizing the importance of dynamic visual elements. Graphic design has a moderate positive effect (0.135), indicating that well-designed visual imagery aids in maintaining children's attention. The color scheme, with a path coefficient of 0.091, has a smaller but still positive impact on visual attention. Interestingly, text readability has a slightly negative path coefficient (-0.049), suggesting that text readability may not significantly contribute to children's visual attention in this context, possibly because of the young age of the participants and their developing reading skills. Overall, these results highlight the importance of sound integration and motion graphics in enhancing children's visual engagement, whereas the role of color, design, and text may vary in influence.

Table 3: Path coefficients

Path	Path coefficients
Color scheme > children's vision attention	0.091
Graphic design > children's vision attention	0.135
Motion graphics > children's vision attention	0.184
Sound integration > children's vision attention	0.555
Text readability > children's vision attention	-0.049

The results shown in Table 4 indicate the statistical significance of the relationships between perceptual factors and children's vision. Sound integration has the strongest and most significant effect on children's vision, with a path coefficient of 0.555, a T-statistic of 10.676, and a P-value of 0.000, confirming a highly significant positive influence. Motion graphics also positively influence children's vision, with a path coefficient of 0.184, a T-statistic of 2.307, and a P-value of 0.021, indicating a statistically significant effect. The graphic design has a moderate positive effect, with a path coefficient of 0.135, a T-statistic of 3.306, and a P-value of 0.001, indicating strong statistical significance. The color scheme has a weaker positive effect (path coefficient = 0.091) but still shows statistical significance, with a T-statistic of 2.239 and a P-value of 0.025. On the other hand, text readability does not have a statistically significant effect on children's vision, as indicated by its negative path coefficient of -0.049, a T-statistic of 0.621, and a P-value of 0.534, suggesting that text readability may not significantly impact children's visual attention in this context. Overall, the analysis highlights the strong impact of sound integration, motion graphics, and graphic design on children's visual attention, while the color scheme plays a smaller but still significant role, and text readability has no significant influence.

Table 4: Statistical significance of path coefficients

	Original sample	Sample means	Standard deviation	T-statistics	P-values
Color scheme > children's vision attention	0.091	0.093	0.040	2.239	0.025
Graphic design > children's vision attention	0.135	0.136	0.041	3.306	0.001
Motion graphics > children's vision attention	0.184	0.184	0.080	2.307	0.021
Sound integration > children's vision attention	0.555	0.554	0.052	10.676	0.000
Text readability > children's vision attention	-0.049	-0.050	0.079	0.621	0.534

The results of this study partially support the hypothesis that color schemes positively affect preschool children's visual attention. While color schemes had a positive influence, the effect was relatively weak compared with that of other factors, with a path coefficient of 0.091. This suggests that although color can create an engaging environment, it is not as significant in sustaining children's attention as other dynamic elements, such as sound and motion graphics.

The hypothesis regarding the positive impact of graphic design on children's visual attention is supported by the results. The graphic design demonstrated a moderate effect, with a path coefficient of 0.135. These findings indicate that well-organized and visually appealing designs contribute to maintaining children's focus, supporting the idea that attractive and structured visuals help guide children's attention in educational content.

However, the hypothesis that text readability positively affects children's visual attention was not supported. The data revealed a negative and statistically insignificant effect, with a path coefficient of -0.049. This finding suggests that for preschool-aged children, text readability is not a critical factor in capturing attention, possibly because their developing reading skills lead them to focus more on visual and auditory elements than text. The strongest support was found for the hypothesis that sound integration positively influences children's visual attention. With a path coefficient of 0.555, sound integration had the most significant effect, highlighting the importance of multisensory engagement in maintaining children's focus. When sound is effectively synchronized with visual content, it enhances children's ability to concentrate and engage with the material.

Finally, the hypothesis regarding the positive impact of motion graphics was also supported. Motion graphics had a significant positive effect on children's visual attention, with a path coefficient of 0.184. The dynamic nature of motion graphics effectively captures and sustains attention, making it a valuable tool in educational content for young children. Overall, the study supports most of the hypotheses, emphasizing the importance of sound and motion in engaging children's attention, whereas text readability plays a minimal role in preschool learners. These findings provide valuable insights into how each perceptual factor contributes to children's visual attention, forming the basis for the subsequent discussion of their broader implications and alignment with existing educational theories.

5. Discussion

The results suggest that children's visual attention is most positively affected by sound integration, which is reflected in the considerable

path coefficients and statistical significance. This result agrees with the findings of past studies, which emphasize the role of multisensory integration in learning. It has been proven that sound can be effectively combined with pictures in such a way that cognitive activity is improved, and children's attention is limited, confirming multimedia learning theories based on a dual coding system of auditory and visual information (Fleming et al., 2020). Building on the significance of sound integration, it is equally important to explore the role of motion graphics as another dynamic multisensory element that captures and sustains children's attention. The integration of multisensory elements aligns with dual coding theory, which suggests that combining visual and auditory stimuli enhances cognitive processing and memory retention by activating multiple pathways (Mir et al., 2023). Moreover, these elements reduce the cognitive load, making it easier for children to focus on critical information. In addition to providing immediate benefits, multisensory design fosters inclusivity, accommodating diverse learning preferences and supporting children with sensory or learning challenges. These principles also resonate with constructivist approaches, which advocate engaging in interactive environments to facilitate deeper learning. By adopting multisensory strategies, educational systems can enhance not only attention but also overall learning outcomes, contributing to the development of innovative, child-centered instructional tools.

Motion graphics were also found to positively affect visual attention and were statistically significant, indicating that a strong belief is held that children's attention can be captured and sustained by dynamic elements. Using motion graphics as tools, such as animations and e-books, in educational settings aligns with previous research indicating that motion enhances attention capacity, which is more common in younger children (Sun et al., 2019). In addition to motion graphics, effective graphic design strategies contribute to children's visual attention by creating visually appealing and organized content that supports engagement and understanding.

The influence of children's graphic design strategies was found to be moderate yet significant in terms of visual attention. Visual engagements are likely to be of better performance since the exposures contain appealing and organized images, which children normally love because they are 'user-friendly'. While effective graphic design is central to directing attention and enhancing understanding of the findings, particularly when such understanding is needed together with some images, the existence of this knowledge confirms the importance of graphical designs in educational content materials (Vallverdu-Gordi and Marine-Roig, 2023). Although graphic design and color schemes contribute to visual engagement, the relatively small influence of color schemes compared with other aspects necessitates a deeper exploration of their interactions with dynamic features such as motion and music. While the color scheme was favorable, it had comparatively weaker effects than some of the other variables, but was still statistically significant. This finding indicates that although colors contribute greatly to the attractiveness of visual design, they may not be as effective as moving images or sounds in holding the audience's attention. The limited effect of using color schemes is an indication that color alone is not enough to attract attention and must be used in conjunction with other elements, such as movement or sound (Öztürk, 2010).

Curiously, however, text readability had a strong negative but statistically insignificant effect on children's visual attention. One might regard the result as being the reading proficiency of preschool children, who are out of the stages of comprehension and actively concentrating on written words. Their attention may be captured better with pictures and movement than with text. This further supports research that also discusses the dynamic in which children pay close attention to visual images rather than focus on the text during early education (Crossley et al., 2008).

The discussion highlights the critical roles of sound and motion in driving children's visual attention, supported by the moderate contributions of graphic design and color schemes. These insights pave the way for the conclusion, which summarizes the study's findings and their implications for educational resource development. While graphics and color combinations are identified as underpinning factors, the results indicate that the relevance of looking at text is minimal at this stage of development. These findings emphasize the importance of adopting multisensory strategies, as sound and motion have been shown to enhance not only attention but also learning outcomes. Multisensory approaches reduce cognitive load, engage diverse learners, and align with educational theories advocating for interactive and engaging environments. This understanding enhances educational resource development, helps eliminate the reliance on traditional teaching methods, and supports cognitive development in preschool children. Such content, which aids in cognitive structure and interfaces, will also aid in understanding how educational images function and why children require such representations of the learned material. Roughly, some of these lines may even work for instructional materials for older children and adults, at least in aspects concerning cognitive rather than motivational factors.

6. Conclusion

This study sought to evaluate the effects of five aspects, namely, color scheme, graphic design, text readability, sound integration, and motion graphics, on children's visual attention to educational settings. The results of the study showed that children's attention and involvement have improved the most through sound integration and motion graphics, which stresses the necessity of multisensory feature

designs of educational materials. Although graphic design and color schemes also positively impact visual attention, their influence is less pronounced, which indicates that these elements are more effective in conjunction with movement and sound. The infographics, however, had the least impact on focused attention, which can be attributed to the toys of preschool children, who are more responsive to images and sounds than to letters and words.

These findings have salient implications for the construction of educational materials, particularly for younger children. For the optimal engagement of children, the design of the material must be visually attractive, with a focus on the combination of sound and motion graphics. In addition, attention must also be given to graphic design and color so that the materials are both visually attractive and systematically organized. Such text-level features may not be very important for preschool-aged learners; thus, the design of educational content should focus less on reading and more on graphics and sounds.

Compliance with ethical standards

Ethical considerations

This study was conducted in accordance with the ethical standards outlined in the Declaration of Helsinki. Informed consent was obtained from all participants (parents and educators), and participation was voluntary. The privacy and confidentiality of all data were maintained. As the study involved observations through adult proxies and no direct child interaction, no formal ethics board approval was required; however, care was taken to ensure no harm or distress occurred during the process.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

Aprilliani K, Adibah LM, Akyuni LZ, Khoerunnisa SR, Afifah JN, and Maranatha JR (2023). Motion graphics video as learning media to improve the empathy of preschool children. KINDERGARTEN: Journal of Islamic Early Childhood Education, 5(2): 227-235. https://doi.org/10.24014/kjiece.v5i2.18857

Arslan-Ari I and Ari F (2022). The effect of visual cues in e-books on pre-K children's visual attention, word recognition, and comprehension: An eye tracking study. Journal of Research on Technology in Education, 54(5): 800-814. https://doi.org/10.1080/15391523.2021.1938763

Buongiorno D, Longo A, Michelini M, Pagotto S, Ricci D, and Santi L (2019). APPs in sound measurements to gain a school-work experience. Journal of Physics: Conference Series, 1223(1): 012002. https://doi.org/10.1088/1742-6596/1223/1/012002

Chakraborty S, Wei Z, Kelton C, Ahn S, Balasubramanian A, Zelinsky GJ, and Samaras D (2022). Predicting visual attention in graphic design documents. IEEE Transactions on Multimedia, 25: 4478-4493. https://doi.org/10.1109/TMM.2022.3176942

Cho EK and Son KH (2016). A study on visual attention on color perception by visitors of children's hospital. Korean Institute of Interior Design Journal, 25(2): 50-58. https://doi.org/10.14774/JKIID.2016.25.2.050

Costescu C, Rosan A, Brigitta N, Hathazi A, Kovari A, Katona J, Demeter R, Heldal I, Helgesen C, Thill S, and Efrem I (2019). Assessing visual attention in children using GP3 eye tracker. In the 10th IEEE International Conference on Cognitive Infocommunications, IEEE, Naples, Italy: 343-348. https://doi.org/10.1109/CogInfoCom47531.2019.9089995

Crossley SA, Greenfield J, and McNamara DS (2008). Assessing text readability using cognitively based indices. Tesol Quarterly, 42(3): 475-493. https://doi.org/10.1002/j.1545-7249.2008.tb00142.x

Fleming JT, Noyce AL, and Shinn-Cunningham BG (2020). Audio-visual spatial alignment improves integration in the presence of a competing audio-visual stimulus. Neuropsychologia, 146: 107530. https://doi.org/10.1016/j.neuropsychologia.2020.107530 **PMid:32574616 PMCid:PMC8016516**

Flynn RM, Wong KM, Neuman SB, and Kaefer T (2019). Children's attention to screen-based pedagogical supports: an eye-tracking study with low-income preschool children in the United States. Journal of Children and Media, 13(2): 180-200. https://doi.org/10.1080/17482798.2019.1575887

Fong KN, Ma WY, Pang HK, Tang PP, and Law LL (2019). Immediate effects of coloured overlays on the reading performance of preschool children with an autism spectrum disorder using eye tracking. Research in Developmental Disabilities, 89: 141-148. https://doi.org/10.1016/j.ridd.2019.03.012 **PMid:30991307**

Godwin KE, Leroux AJ, Seltman H, Scupelli P, and Fisher AV (2022). Effect of repeated exposure to the visual environment on young children's attention. Cognitive Science, 46(2): e13093. https://doi.org/10.1111/cogs.13093 **PMid:35122312**

Gray L and Kathleen M (2000). Measuring sound in hospital nurseries. Journal of Perinatology, 20(1): S100-S104. https://doi.org/10.1038/sj.jp.7200440 **PMid:11190688**

Hagtvedt H and Brasel SA (2016). Cross-modal communication: sound frequency influences consumer responses to color lightness. Journal of Marketing Research, 53(4): 551-562. https://doi.org/10.1509/jmr.14.0414

Hapsari AS and Hanif M (2019). Motion graphic animation videos to improve the learning outcomes of elementary school students. European Journal of Educational Research, 8(4): 1245-1255. https://doi.org/10.12973/eu-jer.8.4.1245

Hutton JS, Dudley J, Horowitz-Kraus T, DeWitt T, and Holland SK (2019). Functional connectivity of attention, visual, and language networks during audio, illustrated, and animated stories in preschool-age children. Brain Connectivity, 9(7): 580-592. https://doi.org/10.1089/brain.2019.0679 **PMid:31144523 PMCid:PMC6775495**

Ikeshita H, Yamaguchi S, Morioka T, and Yamazoe T (2018). Effects of highlighting text on the reading ability of children with developmental dyslexia: A pilot study. International Journal of Emerging Technologies in Learning, 13(9): 239-251. https://doi.org/10.3991/ijet.v13i09.8736

Ivančić Valenko S, Cviljušac V, Zlatić S, and Modrić D (2019). The impact of physical parameters on the perception of the moving elements in peripheral part of the screen. Tehnički Vjesnik, 26(5): 1444-1450. https://doi.org/10.17559/TV-20190214125057

Laubscher E, Raulston TJ, and Ousley C (2022). Supporting peer interactions in the inclusive preschool classroom using visual scene displays. Journal of Special Education Technology, 37(2): 318-326. https://doi.org/10.1177/0162643420981561

Li J, Zhai G, Zhu Y, Zhou J, and Zhang XP (2022). How sound affects visual attention in omnidirectional videos. In the IEEE International Conference on Image Processing (ICIP), IEEE, Bordeaux, France: 3066-3070. https://doi.org/10.1109/ICIP46576.2022.9897737

Liu T, Schultz BG, Dai D, Liu C, and Lense MD (2022). Parent-child nonverbal engagement during spoken versus sung book-sharing in preschoolers with and without autism. Psychology of Music, 50(6): 1721-1739. https://doi.org/10.1177/03057356211058781 **PMid:36381385 PMCid:PMC9648075**

Maule J, Skelton AE, and Franklin A (2023). The development of color perception and cognition. Annual Review of Psychology, 74(1): 87-111. https://doi.org/10.1146/annurev-psych-032720-040512 **PMid:35973406**

Mir KJ, Fatima SA, and Fatima ST (2023). Impact of dual coding strategy to enhance students' retention of scientific concepts in middle schools. Annals of Human and Social Sciences, 4(4): 655-666. https://doi.org/10.35484/ahss.2023(4-IV)63

Morey CC, Cong Y, Zheng Y, Price M, and Morey RD (2015). The color-sharing bonus: Roles of perceptual organization and attentive processes in visual working memory. Archives of Scientific Psychology, 3(1): 18-29. https://doi.org/10.1037/arc0000014

O'Neill T, Wilkinson KM, and Light J (2019). Preliminary investigation of visual attention to complex AAC visual scene displays in individuals with and without developmental disabilities. Augmentative and Alternative Communication, 35(3): 240-250. https://doi.org/10.1080/07434618.2019.1635643 **PMid:31305160**

Öztürk E (2010). The effects of color scheme on the appraisal of an office environment and task performance. M.Sc. Thesis, Bilkent Universitesi, Ankara, Turkey.

Peeraer J and Van Petegem P (2012). Measuring integration of information and communication technology in education: An item response modeling approach. Computers and Education, 58(4): 1247-1259. https://doi.org/10.1016/j.compedu.2011.12.015

Pitt KM, Cole ZJ, and Zosky J (2023). Promoting simple and engaging brain–computer interface designs for children by evaluating contrasting motion techniques. Journal of Speech, Language, and Hearing Research, 66(10): 3974-3987. https://doi.org/10.1044/2023_JSLHR-23-00292 **PMid:37696046**

Pomerleau VJ, Fortier-Gauthier U, Corriveau I, Dell'Acqua R, and Jolicœur P (2014). Colour-specific differences in attentional deployment for equiluminant pop-out colours: Evidence from lateralised potentials. International Journal of Psychophysiology, 91(3): 194-205. https://doi.org/10.1016/j.ijpsycho.2013.10.016 **PMid:24188915**

Prieler T, Wood C, and Thomson JM (2018). Developing a visual attention assessment for children at school entry. Frontiers in Psychology, 9: 2496. https://doi.org/10.3389/fpsyg.2018.02496 **PMid:30581408 PMCid:PMC6293024**

Ren H, Yan T, Chen X, Lyu R, and Liu Y (2024). Intelligent Chinese typesetting model based on information importance can enhance text readability. International Journal of Human–Computer Interaction, 41(10): 6266-6285. https://doi.org/10.1080/10447318.2024.2375799

Ren Y, Li S, Wang T, and Yang W (2020). Age-related shifts in theta oscillatory activity during audio-visual integration regardless of visual attentional load. Frontiers in Aging Neuroscience, 12: 571950. https://doi.org/10.3389/fnagi.2020.571950 **PMid:33192463 PMCid:PMC7556010**

Scaltritti M, Miniukovich A, Venuti P, Job R, De Angeli A, and Sulpizio S (2019). Investigating effects of typographic variables on webpage reading through eye movements. Scientific Reports, 9(1): 12711. https://doi.org/10.1038/s41598-019-49051-x **PMid:31481744 PMCid:PMC6722069**

Skibbe LE, Thompson JL, and Plavnick JB (2018). Preschoolers' visual attention during electronic storybook reading as related to different types of textual supports. Early Childhood Education Journal, 46: 419-426. https://doi.org/10.1007/s10643-017-0876-4

Smith KC and Abrams RA (2018). Motion onset really does capture attention. Attention, Perception, and Psychophysics, 80: 1775-1784. https://doi.org/10.3758/s13414-018-1548-1 **PMid:29971749**

Smith PL, Goodmon LB, Howard JR, Hancock R, Hartzell KA, and Hilbert SE (2021). Graphic novelisation effects on recognition abilities in students with dyslexia. Journal of Graphic Novels and Comics, 12(2): 127-144. https://doi.org/10.1080/21504857.2019.1635175

Sun H, Loh J, and Charles Roberts A (2019). Motion and sound in animated storybooks for preschoolers' visual attention and Mandarin language learning: An eye-tracking study with bilingual children. AERA Open, 5(2). https://doi.org/10.1177/2332858419848431

Sun Y, Chen K, Sun L, and Hu C (2020). Attention-based deep learning model for text readability evaluation. In the International Joint Conference on Neural Networks, IEEE, Glasgow, UK: 1-8. https://doi.org/10.1109/IJCNN48605.2020.9206633

Thistle JJ and Wilkinson K (2009). The effects of color cues on typically developing preschoolers' speed of locating a target line drawing: Implications for augmentative and alternative communication display design. American Journal of Speech-Language Pathology, 18(3): 231-240. https://doi.org/10.1044/1058-0360(2009/08-0029) **PMid:19332524**

Valdois S, Roulin JL, and Bosse ML (2019). Visual attention modulates reading acquisition. Vision Research, 165: 152-161. https://doi.org/10.1016/j.visres.2019.10.011 **PMid:31751900**

Vallverdu-Gordi M and Marine-Roig E (2023). The role of graphic design semiotics in environmental awareness campaigns. International Journal of Environmental Research and Public Health, 20(5): 4299. https://doi.org/10.3390/ijerph20054299 **PMid:36901306 PMCid:PMC10001648**

Wang Z, Liu J, Zhang W, Nie W, and Liu H (2021). Diagnosis and intervention for children with autism spectrum disorder: A survey. IEEE Transactions on Cognitive and Developmental Systems, 14(3): 819-832. https://doi.org/10.1109/TCDS.2021.3093040

Yanchus VE, Kheifits AE, and Borevich EV (2022). Study of the perception of graphic information in the human peripheral vision. Graphicon-Conference on Computer Graphics and Vision, 32: 937-946. https://doi.org/10.20948/graphicon-2022-937-946

Zheng Y (2022). Visual memory neural network for artistic graphic design. Scientific Programming, 2022(1): 2243891. https://doi.org/10.1155/2022/2243891