

Applying Mobile EEG to Measure Attention and Reading Time for Picture Books

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Abstract. People use the five senses to receive external information. These senses are used to communicate with the external world during reading development in children. Picture books with various types of sensory stimuli are frequently used as reading materials to help children learn effectively. The objective of this study is to examine various types of sensory stimuli of picture books, including visual perception (i.e. Conventional Book), and auidial and visual perceptions (i.e. Talking Book). In addition, this study attempts to explore the relationship among attention, sensory stimuli and reading time of children with different ages. A mobile electroencephalography (EEG) device has been adopted in this experiment to analyze the correlation between attention and reading time of children who are reading various types of sensory stimuli of picture books. The result reveals that the students in lower grades exhibit spend a significantly longer time reading Conventional Book (visual sensory) than the students in upper grades do. Furthermore, age significantly influences attention and reading time in visual perception. Attention and reading time of the upper grades are significantly and positively correlated, indicating that the executive function of attention and reading ability improve with age. This study has provided a useful mechanism to examine the attention and sensory stimuli in reading that could be as a reference on how to improve the reading performance.

Keywords: Children; Sensory stimuli; Attention; Reading time; Age; Picture book; EEG.

1 Introduction of Various types of Sensory Stimuli

People use the five senses to receive external information, and sensory information reception probably involving attention. The senses are used to communicate with the external world during early reading development in children. Various types of sensory stimuli help children construct a reading context, which enables children to learn independently (Holt, 2005). Tang and Posner (2009) indicate that sensory stimuli can change the physical and psychological responses of children, thereby enhancing their interest and attention.

Picture books often exhibit varying layouts and are published using various multimedia and textures to directly expose children to sensory stimuli, such as visual, acoustic, and tactile perception, thus facilitating children's reading (Briggs & Elkind, 1973; Ma & Wei, 2015). However, published picture books feature diverse forms of reading. Researchers should explore which sensory stimuli of picture book most effectively improve children's attention. In cognitive development theory, Piaget proposes that the development stages executive functions related to cognition and attention in children vary based on age (Bruner, 1996). Therefore, researchers also examine whether children with different ages demonstrate differing attention performance in response to picture books using various types of sensory stimuli.

According to Bednarek et al. (2004), children require longer time to read because of decreased abilities to focus their attention and inhibit distraction. Numerous scholars have indicated that ages differ in their attention span and state during reading (Buchholz & Aimola Davies, 2008; Van Petten et al., 2006; Wei & Ma, 2016). On the basis of the aforementioned literature, the relationship between attention and reading time of students in the lower grades and the upper grades will be further illustrated in this study.

2 Visual and Acoustic Sensory Stimuli of Picture Books

In the area of product design, sensory dominance can be defined as the relative importance of different sensory modalities for product experience (Fenko et al., 2010). Therefore, in the current mature publication market, because of reader sensory requirements and improved multimedia technology, the content of picture books is presented through text, illustration, multimedia (e.g. various book materials, sounds, music, and animation), and diverse sensory stimuli and reading methods are used to attract children's attention and interests.

In this study, we select two types of sensory stimuli of the most common picture books in currently market, are (a) Conventional Book (visual perception), which is the most common book format and involves the simple behavior of page turning when visual reading; (b) Talking Book (acoustic and visual perceptions), which offers a multimedia presentation of the traditional storybook format, including the addition of speech feedback (e.g. CD and MP3 formats) so that children can elect to hear the story read to them (Wood et al., 2010).

3 Experimental Design: Tools and Participants

We use the mobile EEG device MindBand developed by NeuroSky as the experimental tool in this study. MindBand is a type of head-mounted EEG device that features a transducer installed at the position of the frontal lobe of the cerebral cortex to measure the α - and β -waves in the brain. The frontal lobe is the site of the attention network (Gevins et al., 1997). The advantages of MindBand are its light weight, compactness, stability, and ease of use. Therefore, it has attained considerably high acceptance among participants. In the attention EEG experiment, we collect the EEG data of the participants while they read the picture books. The data is ranged from 0 to 100 (0 being the lowest and 100 being the highest), enabling the collection of real-time information and analysis of EEG signals.

In this study, we adopt the same story content but different sensory stimuli of picture books as the experimental tool for reading, namely, *Guess How Much I Love You* (McBratney, 2010). 24 children aged 8-9 years in the lower grades of elementary school students and 24 children aged 11-12 years in the upper grades of elementary school students are recruited as participants. Based on the experimental design, the participants at different ages are divided into two groups of reading picture books in two types of sensory stimuli: (a) visual perception: Conventional Book, and (b) acoustic and visual perception: Talking Book. The participants have not previously read the sample picture book.

4 Data Analysis

In this section, the data obtained from the EEG experiment of attention are statistically analyzed and discussed using descriptive statistics, One-way ANOVA, Independent Samples *t* Test, and Correlation Analysis. To examine the influence of age and sensory stimuli in attention, students are divided into four groups: (1) visual perception: the lower grades, (2) visual perception: the upper grades, (3) acoustic and visual perception: the upper grades, and (4) acoustic and visual perception: the upper grades. Based on the average attention of each sensory group, children in the lower grades exhibit the highest performance in attention for Talking Book (52.92). By contrast, the students in upper grades exhibit favourable attention for Conventional Book (45.67). Moreover, regarding the performance of reading time, the lower grades spend a considerably longer time for reading Conventional Book than the upper grades ($250.25 > 149.83$).

4.1 Interaction of Age and Sensory Stimuli for Attention: One-Way ANOVA

One-way ANOVA is performed to analyze the relationships and differences of age and sensory stimuli in attention among the four groups. The result shows the lower grades and upper grades in groups to read picture books with varying sensory stimuli. The F

value is 1.43 and p value is 0.24 (>0.05), indicating that there is no significant difference. It implies that children's attention does not differ significantly among the four group.

Table 1. Attention and reading time of students in the lower and upper grades

Source	Grades	Sensory	Mean	N
Attention (unit: 0-100)	Lower Grades	Visual (Conventional Book)	39.58	12
		Acoustic & Visual (Talking Book)	52.92	12
	Upper Grades	Visual (Conventional Book)	45.67	12
		Acoustic & Visual (Talking Book)	37.08	12
Reading Time (unit: second)	Lower Grades	Visual (Conventional Book)	250.25	12
	Upper Grades	Visual (Conventional Book)	149.83	12

(* The Reading Time for Talking Book is all the same because of the length of the audio track)

4.2 Age Difference based on Reading Time in Visual Perception: Independent Samples t Test

To further examine the influence of age difference on reading time in visual perception (Conventional Book), an independent samples t test is conducted in groups based on age. Table 2 shows that a significant difference ($F=0.08$, $p=0.00 < 0.05$) is observed in reading time between the lower and upper grades. In addition, the t value is positive ($t = 5.42$), thus indicating the lower grades significantly spend longer time reading Conventional Book than the upper grades.

Table 2. Independent Samples Test for students in the lower and upper grades

Reading	F	t	df	Sig.	MD
Time	0.08	5.42	22	**0.00	100.42

4.3 Correlation Analysis of Attention and Reading Time

Table 3 presents the correlation coefficient matrix of attention and reading time of the upper grades while reading Conventional Book (visual perception). Attention and reading time of the upper grades is significantly correlated ($r= 0.73$, $p= 0.00 < 0.05$), whereas that of the lower grades is not significantly correlated ($r= -0.39$, $p= 0.081 > 0.05$). Specifically, attention and reading time of the upper grades is highly positively correlated, indicating that the upper grades pay more attention to reading Conventional Book for a longer time.

Table 3. Correlation analysis of attention and reading time of the upper grades

		Attention	Reading time
Attention	Pearson Correlation	1	0.73**
	Sig. (2-tailed)		0.01
	N	12	12
Reading time	Pearson Correlation	0.73**	1
	Sig. (2-tailed)	0.01	
	N	12	12

5 Conclusion

This study has investigated that children with different ages demonstrate differing attention performance in response to picture books using various types of sensory stimuli, and also examine the relationship between attention and reading time. A mobile EEG device has been adopted in this experiment to analyze the correlation between attention and reading time of children who are reading various sensory stimuli of picture books. The results of this study are shown as follows:

1. When reading, children in the lower grades exhibit superior attention in acoustic and visual perception (i.e. Talking Book), whereas the upper grades exhibit favourable attention in visual perception (i.e. Conventional Book), although their attention does not differ statistically significant.

2. The lower grades exhibit spend a significantly longer time reading Conventional Book (visual perception) than the upper grades do.
3. Attention and reading time of the upper grades are significantly and positively correlated, thus indicating that the executive function of attention and reading ability improve with age.

These results show students in the lower grades prefer Talking Book with acoustic and visual perception because young children may not have mature independent reading ability. Regarding the early reading experience of children, reading aloud, reading stories, and telling stories are indispensable processes for reading ability development in children (Dockett et al., 2006). Talking book with acoustic and visual perception is used to make picture books more interesting, and therefore, children can be attracted to the world constructed in picture books. In particular, young children have enhanced auditory comprehension ability that substantially surpasses their visual comprehension ability (Chall, 1996). Traditional paper picture books (Conventional Book) are the most common type of picture books, and these books are thin, light, portable, read at any time, and appropriate for readers of all ages. For children in the upper grades, Conventional Book constitutes a sequence of images with a narrative structure and brief text to convey stories and thus elicits the interests of children and attracts their attention, enabling them to focus on visual reading.

This study has provided a useful mechanism to examine the attention and reading performance. However, numerous factors affect attention and individual differences exist among children. In order to verify the experimental results, various important issues have to be investigated from different perspectives.

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