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A pilot study of children with dyslexia and learning foreign languages using 3D letters

Bio data

Hanae Ikeshita is an associate professor at Sagami Women's University. She received her Ph.D. in Global Information and Telecommunication Studies from Waseda University in 2011. She has developed literacy-learning methods for children with developmental dyslexia using 3D technology. Her recent research interests include accessible digital media and bilingual digital books to help children with dyslexia learn foreign languages.

Abstract

Children with developmental dyslexia find it challenging to learn a foreign language, as they often also have difficulties reading and writing their native language. In this study, we examined and assessed the intuitive recognition of the structures of Roman alphabetical letter expressions in children with developmental dyslexia to support their English learning. In the assessment, 18 participants who displayed difficulties in reading or writing English were examined in a comparative study of six types of 3D alphabetical letter expressions. The results suggest that the background color and the letter color combined in letter expressions affect the ease of recognizing the stroke orders of alphabets. Additionally, a questionnaire-survey was conducted among children with dyslexia to understand difficulties faced while learning native and foreign languages at school. Ten participants' parents were asked about their children's difficulties when learning native and foreign languages at school. Based on the relationship between Japanese and English acquisition, the survey showed that children with difficulties in reading and writing Japanese Kanji in elementary and junior high school also found it difficult to acquire English. Our results suggest that children who have difficulty acquiring Kanji, especially writing, also face difficulty learning English. Identifying children who experience difficulties in learning Kanji may allow them to receive English-learning support at an early age.

Conference paper

Introduction

Dyslexia is a neurological disorder characterized by difficulties in acquiring reading and writing skills, regardless of a child's age, intelligence, or motivation (Ferrer et al., 2010; Lyon et al., 2003). The comorbidity of attention-deficit hyperactivity disorder (ADHD) and dyslexia is among the common developmental disorders during childhood (Gilger et al., 1992; Kronenberger & Dunn, 2003). In approximately 4% of children with a learning disability (LD), dyslexia and ADHD coexist (Pastor & Reuben, 2008).

A new curriculum was officially implemented in Japanese public elementary schools in April 2020; foreign language (English) became a mandatory subject for students in the fifth and sixth grades. Previously, English was categorized as a foreign language activity,

and its classes included only speaking and listening, but in the new curriculum, reading and writing skills have also been included. Additionally, a foreign language is not easy to learn for children with dyslexia, who also have difficulties reading and writing their native language. Special education classes are conducted in Japanese public elementary schools, but children with dyslexia are often enrolled in regular classes. Hence, they receive education in the same learning environment as other children.

The Japanese writing system consists of three scripts: Hiragana, Katakana, and Kanji. In Japanese public elementary schools, students learn to read and write 46 Hiragana and Katakana characters and 1,006 Kanji characters. A case study of Japanese bilingual children reported that they could read Japanese accurately and fluently but faced difficulties in English reading and spelling (Wydell & Butterworth, 1999). Thus, typically developing children might face similar difficulties learning English as children with dyslexia.

Individuals with dyslexia are likely to have superior levels of various abilities despite problems with the acquisition of reading and writing skills. For example, enhanced visual-spatial recognition has been associated with dyslexia (von Károlyi et al., 2003). Visual-spatial recognition is required to understand the three-dimensional (3D) position of objects; 3D objects contain more information than two-dimensional (2D) objects. Foreign language teaching for children with dyslexia often employs a multi-sensory approach involving the visual and auditory senses. For example, multimedia learning incorporating tablet computers is being widely used in Japanese public schools. Multimedia learning also consists of assistive technology with audio support for children with dyslexia. Knoop-van Campen et al. (2020) suggested that adding audio support compensates for reading difficulties but eventually hampers the learning of students with dyslexia.

In Hiragana, each character represents one of 46 unique syllables. Yamazoe [Ikeshita] et al. (2009) developed a literacy-learning system to illustrate Hiragana using a stereoscopic 3D display; results suggested the possibility of using stereoscopic vision to help individuals with developmental dyslexia write Hiragana characters. However, some studies have found that participants show symptoms such as asthenopia or headaches after viewing a 3D display (Kooi & Toet, 2004; Lambooi et al., 2009; Read & Bohr, 2014); further, stereoscopic displays are difficult to use and thus are rarely used in schools. Primary schools in Japan have recently introduced tablets in class, but little is known about adding 3D visual support in multimedia learning of foreign languages for Japanese children with dyslexia.

In the present study, we explored how this visual support affects children with dyslexia in their ability to recognize stroke order. We attempted to resolve these challenges by using a tablet computer that does not require special equipment to test the efficacy of 3D English learning as a tool in foreign language education. We examined the advantages of 3D alphabetical letter expressions in a comparative study of six types of these expressions to support English education for children with dyslexia. Additionally, we conducted a questionnaire-survey among children with dyslexia to understand the difficulties they face while learning native and foreign languages at school.

Methods

Participants

Participants comprised 18 students with dyslexia and other LDs who had difficulties reading or writing English (aged 12 to 20 years; seven cases with ADHD, 11 cases with autism spectrum disorders). Written informed consent was obtained from adult participants and children's parents. This study was approved by the Ethical Review Committee at Sagami Women's University (No. 19052).

Materials

We used a 3D modeling software (The Foundry MODO 10.2v1, Autodesk Maya 2016) to model 3D Roman alphabetical letters (hereafter “3D letters”), which were exported in COLLADA format for display on tablets. Each 3D letter was divided into strokes positioned at regular intervals in depth according to the stroke order. The 3D letters were developed so that learners could operate them by touching the screen with a finger and rotating them 360 degrees (Figure 1). The 3D letters used Helvetica (Gothic) for the font. To move the 3D letter, the user had to tap the letter with a fingertip; the 3D letter could be moved up, down, left, or right in a 360-degree arc. Each letter stroke was displayed in the order they were to be drawn in.

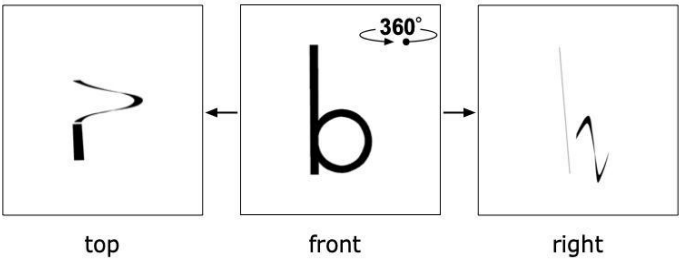


Figure 1. Example of a 3D letter

3D letter expressions were set to the color values of white (RGB: 255, 255, 255), black (RGB: 0, 0, 0), gradation 1 (black to white), and gradation 2 (white to black); white and black were used for background colors. The color settings for two gradations were applied from the beginning of the first stroke to the end of the last stroke. Six types of 3D letter expressions were created (Table 1).

Table 1. Six types of 3D letter expressions

Type	Letter color	Background color
A	White	Black
B	Black	White
C	Gradation 1 (RGB value 255-0)	White
D	Gradation 2 (RGB value 0-255)	White
E	Gradation 1 (RGB value 255-0)	Black
F	Gradation 2 (RGB value 0-255)	Black

Setting

The experiment was conducted in a private room with a table on which the tablet was placed and a chair for the participant to sit on. The stimuli were displayed on a 9.7-inch tablet (Apple iPad Air) at a 50 cm distance. Participants’ behavior during the experiment was recorded using a digital camera. Stimuli constituted the six types of 3D letter

expressions, as shown in Table 1. The letters “b” and “d” were selected, as children with dyslexia often confuse them.

Procedure

First, participants were informed of the experimental procedure and asked to practice the operation of 3D letters to be presented on the screen beforehand. The two 3D letters were presented simultaneously on the tablet screen, and participants were instructed to move each letter from side to side and up and down using a finger. After watching and comparing the 3D letters, participants were asked, “Which letter’s writing order is understandable?”; they selected a letter by pointing a finger. This was regarded as one trial, and a set of 15 trials were performed. The presentation order of the 3D letter types was randomized across participants, and it varied for each of the 15 trials. This experiment examined how to easily recognize the correct stroke order. In addition, the participants were interviewed and asked to comment on the 3D letters.

Second, ten participants’ parents were asked four questions (Table 2) regarding difficulties their children faced in acquiring native and foreign languages in school.

Table 2. *Question items about the process of children acquiring native and foreign languages in schools*

Theme	Question item
Process of acquiring children’s native language (Japanese)	1) Do you think your child could read and write Japanese (Hiragana, Katakana, and Kanji) in elementary school? 2) Do you think your child experienced distress while learning Japanese in elementary school?
Process of acquiring a foreign language (English)	3) Do you think your child could read and write English in elementary or junior high school? 4) Do you think that your child experienced distress while learning English in elementary or junior high school?

Data analysis

To compare the 3D letters, participants’ perceptions of readability were analyzed using Thurstone’s law of comparative judgment (Thurstone, 1927). Thurstone’s method provides one-dimensional data based on preference judgments for two items and can be used to transform rank-ordered data. The most popular simplification is Thurstone’s Case V model, which was used in this study because children were able to select stimuli easily. The Case V model assumes all response options have equal variance and zero correlations. The results of the interval scores were plotted on an interval scale.

In the questionnaire-survey, the response data were analyzed to determine the correlation between participants’ acquisition of native and foreign languages. Correlations with acquiring different languages were analyzed with Fisher’s exact test and Cramer’s V.

Results

Results of understanding stroke order

Figures 2 and 3 show the rank-order results for 3D letter expressions. The horizontal axis shows the understanding of stroke order; levels of understanding increase from right to left. The ranking order for understanding stroke order of 3D letters was type A, B, D, E, F; C for the letter "b"; and type A, B, E, D, F and C for the letter "d."

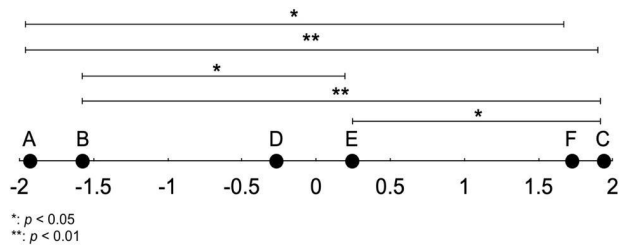


Figure 2. Results of understanding stroke order for "b"

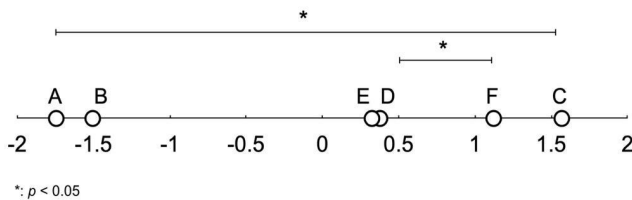


Figure 3. Results of understanding stroke order for "d"

We used the binomial test, to check for significance in the comparison between types of 3D letter expressions. Understanding the stroke order of 3D letters was significant for both letters "b" and "d." Analysis of "b" revealed significant differences between types A and C, and B and C ($p < 0.01$); as well as A and F, B and E, and C and E ($p < 0.05$). Regarding "d," significant differences were noted between A and C, and D and F ($p < 0.05$).

In the interviews regarding 3D letters, participants mentioned, "I think it is easier to learn the alphabet using the 3D letter," "I will be able to memorize the letter more easily with the 3D letter," "It is easy to understand how to rotate the letter," and "I think that the 3D letter makes it enjoyable to learn English."

Results of correlations with learning native and foreign languages in school

Figure 4 presents survey responses regarding acquisition of reading. For Japanese (Hiragana, Katakana, and Kanji), participants sometimes misread Kanji but were able to read Katakana and Hiragana. Ten and nine participants could read Katakana and Hiragana, respectively. Six participants were unable to read English.

Figure 5 presents survey responses regarding acquisition of writing. For Japanese (Hiragana, Katakana, and Kanji), most participants were able to write in Katakana and Hiragana. Nine and eight participants could write in Katakana and Hiragana, respectively. Seven participants were unable to write in Kanji and English.

We used Fisher’s exact test and Cramer’s V as nonparametric statistical methods to test for correlation between difficulty in acquiring native and foreign languages. Cramer’s V varies between 0 and 1; a value greater than 0.25 is considered a very strong relationship. Both Kanji and English were strongly associated with writing difficulties, as confirmed by strong Cramer’s V correlations (1.00, $p < 0.01$). English writing and reading were strongly associated with writing and reading difficulties, as confirmed by strong Cramer’s V correlations (0.80, $p < 0.05$). Writing Kanji and reading English were strongly associated with writing Kanji or reading English difficulties, as confirmed by strong Cramer’s V correlations (0.80, $p < 0.05$).

Results of correlations with distress in learning native and foreign languages in school

Five participants selected “strongly agree” or “agree” regarding experiencing distress while learning Japanese and English in school (Table 3). The mean evaluation (SD) given for learning Japanese and English in school were high, 3.10 (1.37) and 3.50 (1.08), respectively.

We used the chi-square test and Cramer’s V to test for correlation between mental stress in learning native and foreign languages. There was no significant difference between learning Japanese and learning English in school ($\chi^2= 17.50$, $df=12$, n.s.). Both were strongly associated with distress, as confirmed by strong Cramer’s V correlations (0.76).

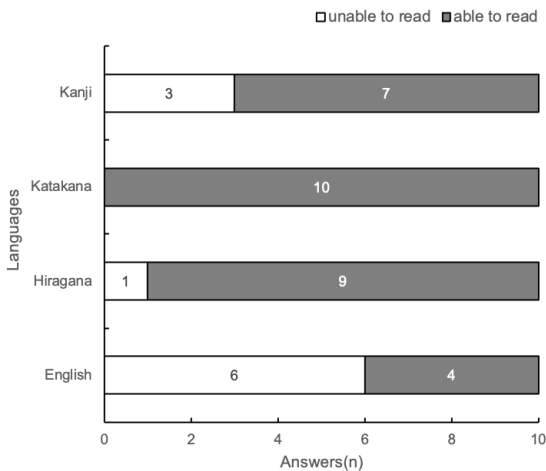


Figure 4. Acquisition of reading skills in Japanese and English (n = 10)

The vertical axis is Languages; Hiragana, Katakana, and Kanji are Japanese. The horizontal axis is Answers. □unable to read, ■able to read.

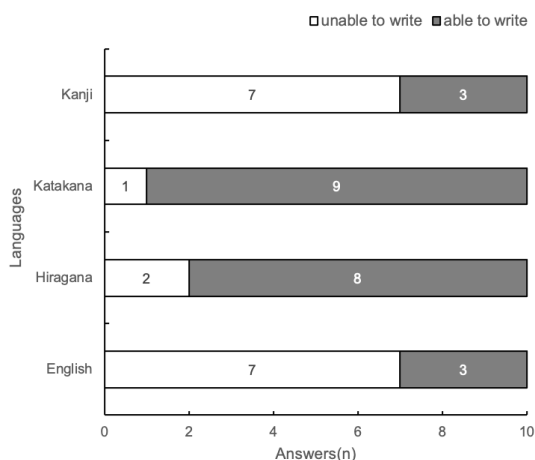


Figure 5. Acquisition of writing skills in Japanese and English (n = 10)

The vertical axis is Languages; Hiragana, Katakana, and Kanji are Japanese. The Horizontal axis is Answers. □unable to write, ■able to write.

Table 3. Number of participants who experienced distress while learning languages in school (n = 10)

Responses	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Mean	SD
Japanese (n)	1	4	2	1	2	3.10	1.37
English (n)	2	3	3	2	0	3.50	1.08

Discussion

The present study examined 3D letter expressions for children and young adults with dyslexia and their intuitive recognition of letter structure in English learning material on a tablet. The results revealed that stroke order was most easily understood in letter expression type A (black) for both letters “b” and “d.” The data obtained suggest that depth and color expressions in 3D letters are key factors in recognizing alphabetical letters efficiently. The depth of information regarding a letter’s structure might be important to assist English learning for individuals with dyslexia. Stroke order of alphabetical letters may also be more easily recognized if letter color and background color have a high contrast ratio; letter expression type E (Gradation 1) was easily understood for “d” than type C (Gradation 1). Further, easy understanding of gradation of 3D letter expressions could vary individually. In the future, we plan to investigate the learning effect of 3D letters.

Children with dyslexia present difficulty learning English; our results are consistent with those of Wydell and Butterworth’s (1999) study, which examined the difficulty of learning English in school. We found participants struggled to learn English if they also struggled to learn Kanji. Kanji has different letter structures than Hiragana and Katakana, as well

as more strokes; participants were able to read Kanji but could not recall the order when writing it (Uno et al., 2009). Further, Kanji has ideographic characters, making their meaning easy to understand; hence, reading is not difficult. In the case of English, meaning-making is not possible based on the shape of its letters; hence, learning to read and write English is likely to be more difficult for Japanese learners.

Our survey results on the relationship between Japanese and English acquisition suggest that if students find it difficult to read and write Kanji in elementary and junior high school, it might also be difficult for them to learn English in junior high school. In Japanese education, English classes begin in the upper grades of elementary school, but the number of hours of English increases in junior high school, making the subject more difficult. Our results suggest that children who have difficulty acquiring Kanji, especially writing Kanji, also struggle to learn English. The early detection of children presenting difficulty in Kanji might lead to earlier support for English learning.

We found that half the participants experienced distress while learning languages in school. The most-used method for learning Japanese requires learners to write Kanji characters physically while looking at a model. Learners need to write the characters repeatedly until they master writing them correctly by themselves. In Japanese education, stroke order is important. This method has been adopted in the learning of English, as well. According to participants' responses, writing repetition and maintaining stroke order is very spiritual. Distress while learning languages in school may not only affect learning native and foreign languages but may also cause a loss of motivation for other learning. Educators must determine whether a child requires repeated learning for acquiring native or foreign languages.

Our study has not fully clarified our teaching materials' effect on learning English. In the future, once their effect has been clarified, our method may provide an easy learning strategy as compared to conventional iterative learning and may lead to long-term language retention.

Japanese children feel resistance toward learning English, regardless of dyslexia (Ministry of Education, Culture, Sports, Science and Technology, 2004). Therefore, more research is needed that examines all children in general. Since these aspects could not be clarified in this study, they should be focused on in future research. Learning a language requires a method that provides children enjoyment rather than struggle.

Conclusion

Recently, electronic devices have become widespread and have been applied in English learning environments. In this study, we examined 3D letters as a novel learning approach. The results point to the possibility that differences in letter expression may affect the ease of understanding letters' stroke order. A limitation of this study is its small sample size; future studies should examine the influence of 3D letters on English learning capabilities with a larger sample of children with dyslexia. The questionnaire-survey was conducted among children with dyslexia regarding difficulties in learning their native language and foreign language in school. The results indicate that difficulties in acquiring Japanese are also reflected in learning English in children with dyslexia. In addition, it might be necessary for teachers to consider the distress caused by English learning in children with dyslexia. If a child has difficulties in writing Kanji, it is quite possible they will also have trouble learning English; hence, learning support from elementary school to junior high school is important. The opportunity to learn should not be lost due to the distress of learning languages in school. Relieving this distress may be important for successful language learning. A method incorporating 3D technology may help alleviate this distress in children with dyslexia. In the future, we plan to investigate the effects of 2D and 3D learning techniques and potential distress during 3D learning. We also plan to investigate the detailed effect of 3D learning techniques on English reading and writing.

Acknowledgments

This work was supported by JSPS KAKENHI Grant Number JP 17K18195.

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