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Effect of Robot-Assisted Phonological Awareness Training on Invented Spelling for Children with Reading Disabilities

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Objectives: In order to teach spelling effectively to children with reading disabilities, they need to be taught to understand the phonological system. Phonological awareness training has been conducted using various methods and media; following current technological trends, robots have been introduced to aid this training. This research looks at the effectiveness of using robots to train children with reading disabilities in order to identify the robots' potential for improving spelling. **Methods:** Fourteen 6- to 8-year-old children with reading disabilities were divided into three groups: traditional phonological awareness training, robot-assisted phonological awareness training, and control groups. Phonological awareness tests and spelling tests were used in this study. It was conducted through pre- and post-tests for the three groups with an additional test in the middle of training for the experimental group. A maximum of 23 sessions for phonological awareness training were conducted biweekly and each session took about 30 minutes. **Results:** First, the results showed significant differences in the total number of correct responses for spelling among the three groups. Second, children with reading disabilities who were taught phonological awareness training showed significant differences across the test periods for the number of correct responses for words with phonological rules of invented spelling. **Conclusion:** This result suggests that intervention using a robot could be an effective intervention method for children with reading disabilities. In addition, the results showed that the more children with reading disabilities received phonological awareness training, the more invented spelling skills on words with phonological rules are improved.

Keywords: Robot-based, Phonological awareness training, Reading disability, Invented spelling

With the development of information and communication technology, many aspects of society and personal life are changing. As a result of these changes, expectations for new teaching methods have increased in education fields and various changes have been attempted and have progressed to promote effective teaching and study. As part of the national policy to reflect this trend, the Ministry of Education and Science Technology (MEST) in Korea established 'Smart Education Promotion Strategy' in 2011 and is promoting a plan in order to realize education paradigms of information and technology geared toward our 21st century society (Lee, Choi, Jung, Kim, & Gye, 2012). Computer-based education media (CAI, WAI, e-learning, etc.) are widely used, and different uses for next generation media (e.g., digital textbook, augmented reality contents, IPTV, mobile or PMP, robot, etc.) are being researched constantly (Kim, Son, et al., 2009). With the development of smart media and information and communication technology, various intervention methods using smart media are being developed for children with communication disorders. Thus, as times change, it is necessary to establish studies for disorders using various media. There is some research that utilizes robots for disorder studies, and studies on the use of robots have been increasing in many different countries. Since 2003, use of robots has been the center of research for many studies on disorders (Kang, Lee, & Kim, 2013). Also, because the use of robots has been integrated into children education institutes, interests in the effect and applicability of intelligent robots has been growing since 2008 (Kwon & Park, 2013). However, study on the use of robots in Korea still remains in the primary stage. Studies for education or therapy using robots in special education are also in the beginning stage (Kwon & Park, 2013). Although researches for treatment, interaction, and intervention effects on disorders using robots are gradually increasing, only a small fraction of studies on autism disorders touches on the interaction between an autistic child and a robot. However, before an intelligent robot can become an effective tool for education and treatment, it is important to examine the effect and feasibility of robots in special education (Diehl, Schmitt, Villano, & Crowell, 2011).

Reading disabilities are usually found in school-aged children with learning disabilities. The core cause of reading disabilities is phonological deficit. These phonological deficits might delay development of phonological awareness which is based on reading and spelling, and consequently, the child's difficulty continues in reading (Scarborough, 2009; Stanovich & Siegel, 1994). While reading requires decoding to understand words based on received cues, spelling is a process of symbolizing those words without optical stimulus (Cho, 2008). In order to spell, children read the words and need to remember the sound of words and then connect the right words to the right pattern (Thomson & Watkins, 1993). Thus, children with reading disabilities are generally poor at spelling and these problems can be continued for a long time (Kim et al., 1997). However, in Korea, there is no spelling or dictation education after the 2nd grade in elementary school. Spelling is a necessary skill that influences school and everyday life, but further opportunity for spelling education is not given to children with reading disabilities because most classes in school are focused on reading. In addition, children with reading disabilities in early elementary school have difficulty correcting orthography, because it is difficult for them to understand phonological rules.

Analyzing phonological word structure may be needed for checking spelling in order to effectively improve spelling skills (Gaskins, Ehri, Cress, O'Hara, & Donnelly, 1997; Murray, & Steinen, 2011). Some researchers suggested that remembering spelling by analyzing the phonological word structure is better for children with spelling difficulties than memorizing the words' letters (Murray & Steinen, 2011). Some researchers have revealed that phonological awareness training improves children's spelling ability (Ehri et al., 2001) as well as children's reading ability. Previous studies have demonstrated that spelling skills are promoted by phonological awareness (Ball & Blachman, 1991; Bruck & Treiman, 1990; Cunningham, 1990). These studies suggested that the lack of phonological awareness might influence writing skills, and be closely connected to spelling (Stahl & Murray, 1998). Thus, these individuals may require continuous treatment and instructions focused on spelling, including phonological awareness and coordination of phonological and orthographic word forms (Berninger, Nielsen, Abbott, Wijsman, & Raskind, 2008).

Invented spelling occurs by connecting letters systematically although a child pays attention to pronunciation and spelling using informal methods. The critical factor used for invented spelling is a child's phonological awareness of language. Some researchers propose that invented spelling is a proxy for phonological awareness (Mann, 1993; McBride-Chang & Ho, 2005). Children's understanding of segmental structure of speech is based on proficient spelling and is a critical factor for early spelling study (Liberman, Rubin, Duques, & Carlisle, 1985). Invented spelling involves children in listening carefully and thinking about sounds in a very purposeful way (Richgels, 2001). Furthermore, these activities can produce valuable practice with phonemes, word analysis, and letter-sounds correspondence (Chomsky, 1979). Children's invented spellings do not become permanent misspellings and follow the normal phase of child's spelling development (Watt, 2001). Invented spelling is not an independent phase but encourages children to think of the relationship between letters and sounds. Long-term developmental sequences are demonstrated while children move from their own spelling system to the standard system (Richgels, 2001). They move on their way to more a standard system by broadening and deepening their invented system (Beers & Henderson, 1977). Invented spelling is systematic even though it does not follow the same path as conventional spelling (Richgels, 2001). Inventive spellers have their own rules representing how a word is sounded out.

Visual and auditory stimulus, which was provided to children during phonological awareness training, influence how children take cognizance of syllables and phonemes (Kim, 2008a). Previous studies have shown that children's performance improves more when visual and auditory stimulus were provided together rather than alone (Torgesen, Waters, Cohen, & Torgesen, 1988). Also, some studies have shown that when intelligent robots are used, children show high level of attention, learning interest, and achievement compared to multimedia (Han, Jo, Jones, & Jo, 2008; Kim, Lee, Hyun, & Park, 2011). In addition, robots can help students with disabilities interact with others (peers or adults) with the robot performing the mediating role because robots can operate programs and produce structured therapy (Robins, Dautenhahn, Te Boekhorst, & Billard, 2005). However, there is limited work comparing the effects of robot usage to the traditional training methods for children with reading disabilities. In this research, differences in word spelling skills of children with reading disabilities are examined. Three different groups are considered in this research: a group who received traditional phonological awareness training, a group who received robot-assisted phonological awareness training, and a control group who did not receive any training.

The research questions are as follows: (1) Are there significant differences in the total number of correct responses for words among the three groups (traditional, robot-assisted, and control) depending on the test period (pre- and post-tests)? (2) Are there significant differences among test period (pre-, mid-, and post-tests) on the number of correct responses for words with phonological rules of invented spelling depending on the training methods of the group (traditional and robot-assisted)?

METHODS

Participants

Fourteen 6- to 8-year-old children with reading disabilities were selected from elementary schools in Seoul or Gyeonggi-do. All subjects scored over 85 on a non-verbal intelligence (IQ) sub-test of the Korean-Wechsler Intelligence Scale for Children-third edition (K-WISC-III; Kwak, Park, & Kim, 2001) or the Kaufman Assessment Battery for Children (K-ABC; Moon & Byun, 2003). Their reading performance level was under the 15th percentile on the Basic Academic Skills Assessment (BASA)-Reading (Kim, 2008). Also, their reading and spelling difficulties were not caused by another disability (e.g., blind, deafness, emotional disorders, etc.).

Children were divided into three groups: traditional phonological awareness training, robot-assisted phonological awareness training, and control group. Four children received robot-assisted phonological awareness training and three had traditional phonological awareness training and the remaining seven belonged to a control group that did not receive any intervention. Seven children in the control group were included in the existing intervention group after 2 months. They were also divided into robot phonological awareness training and traditional phonological awareness training. So, three of the seven children in the control group received robot-assisted phonological awareness training and the other four received traditional phonological awareness training. In other words, as children in the control group were included in the existing intervention group after 2 months, each intervention group included seven children's data. The average age of children who received traditional phonological awareness training was 84.7 months (SD = 8.0), and the average age of children in robot-assisted phonological awareness training group was 86.0 months (SD = 6.8), and control group's average age was 84.4 months (SD = 7.9). The average non-verbal IQ score of the traditional group was 100.1 (SD = 6.5), of the robot-assisted group is 96.7 (SD = 6.1), and of the control group was 98.1 (SD = 5.0). Receptive & Expressive Vocabulary Test (REVT; Kim, Hong, Kim, Jang, & Lee, 2009) test was used to investigate the children's vocabulary. The average receptive vocabulary score of children who received traditional phonological awareness training was 68.9 (SD = 11.1), the average receptive vocabulary score of robot-assisted group was 72.4 (SD = 12.7), and of the control group was 71.9 (SD = 14.1). The average expressive vocabulary score of the traditional group was 65.6 (SD = 8.1), of the robot-assisted group was 70.3 (SD = 10.5), and of the control group was 66.6 (SD = 9.2). Table 1 summarizes the participants' chronological age, non-verbal IQ and vocabulary scores.

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Table 1. Participants' characteristics

	Traditional group (N=7)	Robot-assisted group (N=7)	Control group (N=7)	*F*	*p*-value
Chronological age (mo)	84.7 (8.0)	86.0 (6.8)	84.4 (7.9)	.085	.919
Non-verbal intelligence	100.1 (6.5)	96.7 (6.1)	98.1 (5.0)	.598	.561
Receptive vocabulary	68.9 (11.1)	72.4 (12.7)	71.9 (14.1)	.160	.853
Expressive vocabulary	65.6 (8.1)	70.3 (10.5)	66.6 (9.2)	.495	.618

Values are presented as mean (SD).

One-way ANOVA was conducted to identify whether there was any significant difference among three groups. Table 1 shows no significant difference in chronological age among the three groups ($F_{(2,18)}=.085$, $p>.05$). Also, there was no significant difference in non-verbal IQ for the three groups ($F_{(2,18)}=.598$, $p>.05$). There was no significant difference in receptive vocabulary score ($F_{(2,18)}=.160$, $p>.05$) and on expressive vocabulary score ($F_{(2,18)}=.495$, $p>.05$) for the three groups. Thus, there were no significant differences in participants' chronological age, non-verbal IQ and vocabulary scores among the three groups.

Materials

Phonological awareness test

A phonological awareness sub-test of Basic Academic Skills Assessment-Early Literacy (BASA-EL; Kim, 2011) was used to measure children's phonological awareness. The test consisted of four factors which are discrimination, blending, deletion, and substitution at the phoneme and syllable level. A phonological awareness score was calculated on the sum of each factor's score and the total score was 46. One-way ANOVA was conducted to identify whether there was any significant difference among the three groups. During the pre-test there was no significant difference on phonological awareness among the three groups ($F_{(2,18)}=.831$, $p>.05$).

Word spelling test

The word spelling test was comprised of 15 two-syllable real words and 16 two-syllable non-words. These stimuli are listed in Appendix 1. The word spelling test in this study was organized by selecting various types of words. Fifteen two-syllable real words were divided into two parts, which were seven words with no phonological rules and eight words with phonological rules. Non-word stimuli were composed of eight non-words of high similarity and eight non-words of low similarity for real words with no phonological rules. The task included only noun words of two syllables because noun words in Korean constitute a majority of the two-syllable words and words comprised of more than three syllables might be compound words (Lim & Kim, 2008).

Word stimuli consisted of words with and without phonological rules. In words with no phonological rules, words with no final consonant (CVC'V'), words with one syllable support from two syllables (CVC'C''V', CVC'V'C''), and words with complete support from two syllables (CVC'C''V'C''') were distributed evenly. Words applying phonological rules (e.g., lenition, nasalization, aspirated sound, and liquidization) were chosen evenly. Also, real words were selected by adjusting the ratio of words beginning with a vowel.

Non-word stimuli based on the study of Lee, Kim, Yeon, Park and Park (2013) were comprised of high and low similarity for words with no phonological rules. The high word similarity items were designed to change only the initial phoneme of words with no phonological rules. The variation of an initial consonant was changed into a consonant with the same manner of articulation or same place of articulation. Meanwhile, the low word similarity item included the same consonant of high word similarity stimuli. So the low word similarity item was produced as an initial consonant of each syllable for the high word similarity item which was reversed in order to balance vocally, but the vowel and an initial consonant of the high word similarity items were not changed.

Experimental design

This research was conducted with pre-, mid-, and post-tests. The pre-test was completed before phonological awareness training and the post-test was conducted after intervention. The mid-test was conducted before phonological awareness training for words with phonological rules. All tests and interventions were conducted by a researcher.

Phonological awareness training

Training words

Training words contained word stimuli, which were comprised of real words with and without phonological rules and non-word stimuli, which were made up of high/low similarity for words with no phonological rules. Real word and non-word stimuli were chosen in the same way. However, training words were selected not to include pre/post word spelling test items. The training words list is presented in the Appendix 2.

The training words list was produced from words with no phonological rules and words with phonological rules. Words with no phonological rules and non-words were used in the following order: words with no final consonant (CVC'V'), words with one syllable support by two syllables (CVC'C''V', CVC'V'C''), and words with complete support by two syllables (CVC'C''V'C'''). The training non-word stimuli were implemented while a participant attended criteria prepared by the researcher. Furthermore, in the case of training non-word stimuli, it was conducted by including both high and low word similarity items. Words with phonological rules were tested in the order of highest incidence (lenition, 3.1%; nasalization, 0.82%; aspirated sound, 0.57%; and liquidization, 0.35%) following the study of Lee (1990) on occurrence frequency of phonological awareness rules among modern Korean grammar.

Training material

The two treatment groups needed different training materials. The traditional phonological awareness training group required picture cards, word cards, and magnetic letters. Picture cards for target words were used for the invented spelling section. Word cards were used to discriminate and blend syllables, and magnetic letters were used for the phoneme blending section.

Meanwhile, robot-assisted phonological awareness training group utilized iRobiG as an education tool. The iRobiG is presented in the Figure 1. iRobiG is a small, intelligent robot developed by Yujin Robot Co. Ltd., Seoul, Korea. It can move its head, arms, and wheels, and express its emotions using face lamps. Also, it can take a picture using the built-in camera and can be connected to the Web in real time. So, it can download various educational content and upload children's activities as well. The specifications of the iRobiG are as follows: dimension (450 mm × 320 mm × 320 mm), weight (7 kg), display (7 inch, 800 × 480 / TV Out), and battery (charge time 3 hours, use time 3 hours).

Training program

A maximum of 23 sessions of phonological awareness training was conducted twice a week. The phonological awareness training program was comprised of invented spellings, discrimination of final syllables, and blending of syllables and phonemes. All four factors were included in one session and one session took about 30 minutes.

Figure 1. Education robot 'iRobiG' by Yujin Robot Co. Ltd.

Phonological awareness training progressed according to criteria established by the researcher. Even if participants did not meet the criteria, the researcher progressed to the next task if the maximum number of sessions was reached.

The criterion used in this study was as follows. To move on from real word stimuli to non-word stimuli, a child had to exhibit more than 90% positive reactivity. In order to move on to other word stimuli (e.g., moving from non-words with no final consonant (CVC' V') to real words with one syllable support by two-syllables (CVC' C''V', CVC'V'C'') or from lenition to nasalization), a child had to demonstrate more than 80% positive reactivity.

The maximum number of sessions was 23 for the phonological awareness training program in this study. In words with no phonological rules, the maximum number of session for real words and non-words with no final consonant (CVC'V') was 6, for real words and non-words with one syllable support by two syllables (CVC'C''V', CVC'V'C'') was 5, and for real words and non-words with complete support by two syllables (CVC'C''V'C''') was 4. Also, the minimum number of sessions for non-words was 2 sessions in order to treat both real-words and non-words. In words with phonological rules, the maximum number of sessions was 2.

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Traditional phonological awareness training

Traditional phonological awareness training used picture cards, word cards, and magnet letters. The specific content of traditional phonological awareness training was as follows.

During the invented spelling section, a researcher showed picture cards of target words and spoke the target words twice and then a child was required to write the target words on paper. If a child used nonconventional spelling during the invented spelling stage (e.g., when the target word was '놀이', a child spelt /노리/ as the way it sounds), the researcher reinforced the child's response. Although the invented spelling section was included in the phonological awareness training program as a component, each child was taught the correct, conventional spelling for the corresponding invented spelling at the end of the activity.

For the final syllable discrimination section, a researcher told three words and the participant was required to find a word with a different final syllable among the three words. If the subject responded with a wrong answer, the subject was given a second chance where the researcher said the three words one more time and showed the word cards.

For the syllable blending section, as a researcher told a target word and then presented each word's syllables using syllable cards, the child listened to the target word carefully and put the cards in the correct sequence. When the syllable cards were presented, obstructive syllable cards were displayed together besides syllables of the target word.

The blending activity of phonemes is similar to the syllable blending, but magnetic letters were used instead of syllable cards. Only correct responses were used from this activity

Robot-assisted phonological awareness training

During robot-assisted phonological awareness training each participant listened to sounds told by the robot and viewed materials displayed on the robot monitor. The functions of 'Baeumteo' and 'Gallery' were used, and the program of Letter popcorn that was developed for phonological awareness training was utilized. The Baeumteo is a function where a robot explains and exhibits images saved in the robot's memory. The Gallery function takes a picture of the outcome of a child's activities using the built-in camera. The Letter popcorn program was specifically made for final syllable discrimination and blending of syllables and phonemes. The Letter popcorn program shows scattered letters with each letter hidden or covered by a popcorn shaped icon.

The invented spelling section was conducted using the functions of Baeumteo and Gallery. Using the program of Baeumteo, a picture of the target word was shown through the monitor on the robot and the robot told the direction and a target word, and then the child was required to write the target word on paper. After the activity, the child took a picture of his invented spelling with a camera on the robot and checked it through Gallery. If the child used non-conventional spelling at the invented spelling stage, the researcher reinforced the child's response. Although the invented spelling section was included in the phonological awareness training program as a component, each child was taught the correct, conventional spelling for the corresponding invented spelling at the end of the activity.

For the final syllable discrimination activity, a discrimination item in the Letter popcorn program was used. The robot spoke three words and the child was required to find the word with a different final syllable among the three words. If the child responded with a wrong answer, the robot said the words again with letters and popcorn symbols, and then the child tried once more.

The blending of syllables activity was conducted using blending syllable items in the Letter popcorn program. The robot spoke a target word and then presented each word's syllables on the monitor. The child listened to the target word carefully and touched the letter popcorns in the correct sequence. When the letter popcorns were presented, obstructive syllables' popcorns were displayed together besides syllables of the target word.

The blending activity of phonemes was conducted in the same way as the blending of syllables and with phoneme blending items in the Letter popcorn program. Only correct responses were used from this activity

Data analysis

For each child 1 point was assigned for correct word spelling in real words with no phonological rules and non-words. With real words with phonological rules, 1 point was awarded for phonologically correct invented spelling and 2 points for conventional spelling. The maximum score for the 15 word stimuli was 23 and for the 16 non-word stimuli the maximum score was 16. The total maximum score on the word spelling test was 39.

Meanwhile, the invented spelling score on words with phonological rules was scored differently. Phonologically correct invented spelling or conventional spelling for words with phonological rules were each scored as 1 point. The maximum score for invented spelling was 8.

Statistical processing

Two-way mixed ANOVA was conducted to identify whether there were significant differences among the total number of correct responses for words among the three groups depending on the test period.

Also, two-way mixed ANOVA was conducted to identify whether there were significant differences on the number of correct responses for invented spelling on the words with phonological rules among test periods (pre, mid, and post) depending on the training methods of the group.

RESULTS

Comparison of the total number of correct responses for words among three groups

The study intended to identify statistically significant differences among the total number of correct responses for words among the two groups and the control group depending on the test period. First, the total number of correct responses for words in pre-/post-test of the three groups is presented in Figure 2 and Table 2.

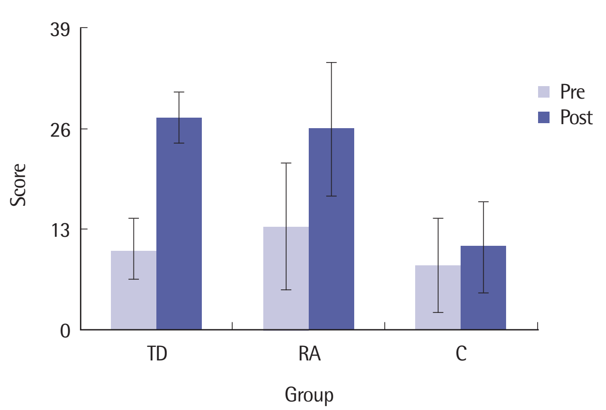

Figure 2. The total number of correct responses for words with and without phonological rules in pre-/post-test of three groups. TD = traditional group; RA = robot-assisted group; C = control group.

Figure 2 and Table 2 show that the total number of correct responses for words in all of the three groups at the post-test increased from the pre-test. In order to identify whether this variation was significantly different or not, two-way mixed ANOVA was conducted; the results are in Table 3.

The results from two-way mixed ANOVA show that the main effect for the groups is statistically significant ($F_{(2,18)} = 5.916$, $p < .05$). Accordingly, the post-hoc comparison was conducted using Bonferroni correction.

As shown in Table 4, pairwise comparisons with Bonferroni correction reveal that there are significant differences between the traditional and control groups ($p < .05$). Therefore, children in the traditional group were performed significantly better than those in the control group. Also, there were significant differences between robot-assisted and control groups ($p < .05$). So, children who received the robot-assisted phonological awareness training received higher scores than children who did not receive any phonological awareness training. However, there were no significant differ-

Table 2. Descriptive statistics of three groups on the total number of correct responses for words

	Pre-test	Post-test
Tradition group (N = 7)	10.29 (3.90)	27.43 (3.31)
Robot-assisted group (N = 7)	13.29 (8.18)	26.00 (8.64)
Control group (N = 7)	8.29 (6.08)	10.71 (5.91)

Table 3. Result of two-way mixed ANOVA on the total number of correct responses for words

	Type III sum of squares	df	Mean square	*F*
Between group	891.571	2	445.786	5.916*
Error	1,356.429	18	75.357	
Within test period	1,216.095	1	1,216.095	270.243**
Test period × group	398.905	2	199.452	44.323**
Error	81.000	18	4.500	

*$p < .05$, **$p < .001$.

Table 4. Result of post-hoc comparison for three groups on the total number of correct responses for words

Group	Tradition	Robot-assisted	Control
Tradition			
Robot-assisted			
Control	*	*	

*$p < .05$.

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ences between traditional and robot-assisted groups on the total number of correct responses for words ($p>.05$).

Meanwhile, a main effect for pre-/post-test was statistically significant ($F_{(1,18)}=270.243$, $p<.001$). That is, the total number of correct responses at the post-test was higher than at the pre-test. Also, a two-way interaction between group and test period was statistically significant ($F_{(2,18)}=44.323$, $p<.001$). Accordingly, the post-hoc comparison was conducted using one-way between-subject ANOVA for each test period among the three groups. There were no significant differences among the three groups at the pre-test ($p>.05$). However, there were significant differences among the three groups at the post-test ($p<.001$). Accordingly, the post-hoc comparison was conducted. There were significant differences between the traditional and control groups ($p<.001$) and between the robot-assisted and control groups at the post-test ($p<.05$). However, there were no significant differences between traditional and robot-assisted groups at the post-test ($p>.05$).

Comparison of the number of correct responses for invented spelling on words with phonological rules among test period

The study intended to establish statistically significant differences among the number of correct responses for invented spelling on words with phonological rules among pre-/mid-/post-test scores depending on the training methods of the groups (traditional and robot-assisted groups). Descriptive statistics for the number of correct responses for invented spelling on words with phonological rules among test period (pre-, mid-, and post-tests) are presented in Table 5 and Figure 3.

Table 5. Descriptive statistics for the number of correct responses for invented spelling on words with phonological rules

	Pre-test	Mid-test	Post-test
Tradition group (N=7)	2.29 (1.113)	4.00 (1.155)	6.43 (.535)
Robot-assisted group (N=7)	2.71 (1.799)	4.00 (2.517)	6.00 (1.732)

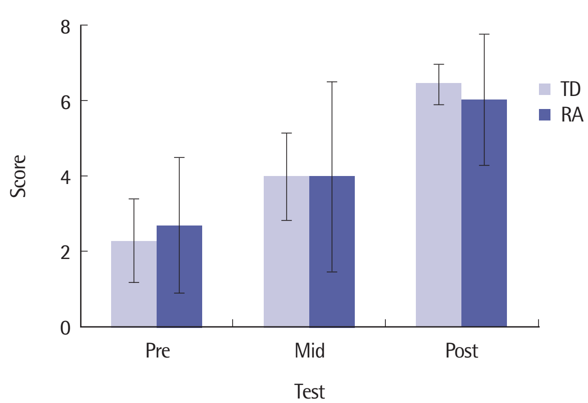

Figure 3. The number of correct responses for invented spelling on words with phonological rules among test period. TD=traditional group; RA=robot-assisted group.

The number of correct responses for invented spelling on words with phonological rules in all of experimental groups increased gradually. In the traditional group, the number of correct responses for invented spelling on words with phonological rules at the mid-test was higher than at the pre-test, and the post-test score was higher than the mid-test. Also, the robot-assisted group showed better performance on the number of correct responses for invented spelling on words with phonological rules at the mid-test than at the pre-test. They scored higher on the number of correct responses for invented spelling on words with phonological rules at the post-test than at the mid-test.

Two-way mixed ANOVA was conducted to identify whether there were significant differences among the number of correct responses for invented spelling on words with phonological rules among test periods (pre, mid, and post) depending on the training methods of the group.

According to Table 6, there was not statistically significant difference for the main effect of the group ($F_{(1,12)}=.000$, $p>.05$). However, the main effect for test period was statistically significant ($F_{(2,24)}=54.264$, $p<.001$). Accordingly, the post-hoc comparison was conducted using Bonferroni correction as shown in Table 7. Pairwise comparisons with Bonferroni correction reveal that the post-test is significant different from the pre-test ($p<.001$) and mid-test ($p<.001$), and the mid-test is also significantly different

Table 6. Result of two-way mixed ANOVA for the number of correct responses for invented spelling on words with phonological rules

	Type III sum of squares	df	Mean square	*F*
Between group	.000	1	.000	.000
Error	70.952	12	5.913	
Within test period	97.762	2	48.881	54.264**
Test period × group	1.286	2	.643	.714
Error (test period)	21.619	24	.901	

$^{**}p<.001$.

Table 7. Result of post-hoc comparison for test period on the number of correct responses for invented spelling on words with phonological rules

Test period	Pre	Mid	Post
Pre			
Mid	*		
Post	**	**	

*$p<.05$, **$p<.001$.

from the pre-test ($p<.05$). In other words, the number of correct responses for invented spelling on words with phonological rules at the mid-test was significantly higher than at the pre-test. The number of correct responses for invented spelling on words with phonological rules at the post-test was significantly higher than at the mid-test. Also, the number of correct responses for invented spelling on words with phonological rules at the post-test was significantly higher than at the pre-test. Meanwhile, a two-way interaction between group and test period was not statistically significant ($F_{(2,24)}=.714$, $p>.05$).

CONCLUSION

Comparison of the total number of correct responses for words among three groups

Children with reading disabilities were divided into three groups depending on the training method (or whether trained or not) and then their word spelling skills were examined. Children with reading disabilities showed that there are statistically significant differences in the total number of correct responses for words among the three groups. There were no significant differences between the two groups which received different phonological awareness methods. However, there were significant differences between the control group which did not receive the training and each of the two experimental groups. That is, children with reading disabilities who received the phonological training improved their word spelling skills. There were significant differences in the total number of correct responses for words between pre- and post-tests. These results support previous research which showed improved spelling skills through phonological awareness training (Gifford, 2004; Kim, 2008b).

Meanwhile, there were no significant differences on the total number of correct responses for words between traditional and robot-assisted groups. This means that use of a robot to assist a child in phonological awareness training improves the child's word spelling skills as much as the traditional method. These results support previous study that showed effective results of a toddler's phonological awareness and word recognition when using a robot (Kim et al., 2011). In fact, it is suggested that the increased number of educational activities using a robot for assistance has been proven to have a positive effect on toddlers' language development (Han et al., 2008; Hyun, Kim, & Jang, 2008; Kim et al., 2011). Furthermore, these previous studies' results provide a basis for language and communication intervention using robot assistance. Also, this study's results suggest that the use of robots can produce effective intervention for children with reading disabilities as well as normally developing children.

According to Srinivasan, Lynch, Bubela, Gifford, and Bhat (2013), using a robot for clinical assistance might reduce the burden on speech-language pathologists. Also, it might promote functional independence and provide a new opportunity for children with special requirements. In other words, a robot seems to be a promising tool to support speech-language pathologists and conventional training. Therefore, the results of this study suggest that a robot could be utilized to assist a speech-language pathologist in clinical language treatments. In addition, with the use of robots it is possible to automate and increase the frequency of language treatments and at the same time reduce the workload of pathologists.

Throughout the study, children who belonged to the traditional group showed consistent attitudes from the early to late stages of intervention. However, children who received robot-assisted phonological awareness portrayed quite different attitudes from the early to late stages of intervention. They had higher interest in the robot and concentrated on the training in the early stage of intervention, but their interest in the robot and concentration on the training decreased in the later stages of intervention. Therefore, when using a robot in language treatment, it is suggested that a short period of intervention is used and exposures to robots are established intermittently. However, follow-up studies are required to verify these suggestions.

Comparison of the number of correct responses for invented spelling on words with phonological rules among test period

The research intended to examine the number of correct respons-

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es for invented spelling on words with phonological rules among test period depending on the training methods of the group (traditional and robot-assisted groups). The results showed significant differences among pre-/mid-/post-tests. There were significant differences between pre- and mid-tests, between mid- and post-tests, and between pre- and post-tests. These results suggested that the more children received the phonological awareness training, they improved word spelling by applying their own informal rules relating letters systematically to sounds. These results support the study of Liberman et al. (1985), which suggested that the critical factor in invented spelling is a child's phonological awareness about language sounds and a child's insight into segmental structure of speech is based on proficiency of invented spelling which is critical for early spelling education. Also, a study showed that kindergarten children who received phonological awareness training used more invented spelling than a control group (Tangel & Blachman, 1992). These researchers also conducted a follow-up study, which indicated that as children followed alternative reading programs in first grade that emphasized phonological awareness, they performed better in terms of both invented spelling and standard spelling than a control group (Tangel & Blachman, 1995).

Meanwhile, there were no significant differences in the number of correct responses for invented spelling on words with phonological rules between the two experimental groups. This result suggests that when using a robot, children improved their invented spelling on words with phonological rules as much as the traditional group. Kim, Son, et al. (2009) presented that it is worthwhile to use a robot as a next generation educational medium since it is fun and leads to positive educational effects. One of the reasons is that robots can be used effectively for task centered learning. In other words, because a robot is able to manipulate programs and is unaffected by psychological and environmental influences, it has potential applications for diagnosis and mediation processes of speech-language pathology. In addition, a robot is suitable for construction of condition-centered learning structures. So, it is suggested that robot usage can improve treatment effects in language treatment programs by extending structured treatment programs to patients' living environments (home, school, community, etc.) (Lee et al., 2013).

Children with reading disabilities have an especially hard time with words with phonological rules because these words require an understanding and application phonological rules, compared to words with no phonological rules. However, including the invented spelling factor in phonological awareness training encourages children to think about the relationship between letters and sounds through phonological rules and helps them to move from their own intrinsic system to a standard system. Therefore, allowing and encouraging children to think carefully about spontaneously developed spelling (Paul, 1976) can encourage the development of an alphabetic system that can be used for word recognition, spelling, and segmentation of speech sounds (Chomsky, 1979).

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Appendix 1. The list of words on the word spelling test

Real word		Non-word	
Words with no phonological rules	Words with phonological rules	High word similarity	Low word similarity
기차	낙하	비차	치바
마디	입학	나디	다니
상처	진리	항처	창허
바람	관람	반세/반새	산베/산배
어항	녹음	다람	라담
동산	놀이	거항	허강
발톱	국물	봉산	송반
	정리	말톱	탈몹

Appendix 2. List of training words

Real word	Words with no phonological rules	보리, 소녀, 도로, 노래, 비누, 가지, 노루, 머리, 누나, 남자, 김치, 염소, 반지, 술래, 기둥, 사슴, 하품, 대문, 시골, 선물, 물통, 공책, 동굴, 반찬, 임금, 송편, 골목, 방문
	Words with phonological rules	군인, 담임, 단어, 먹이, 문어, 범인, 물음, 백인, 불안, 국민, 학문, 막내, 식물, 작문, 숙녀, 승리, 장롱, 왕릉, 축하, 북한, 직행, 국화, 녹화, 목화, 국회, 학회, 약혼, 전래, 난로, 분류, 산림, 신랑, 난리, 신라, 전략, 훈련
Non-word	High word similarity	모리, 호녀, 보로, 기누, 수나, 딤치, 만지, 훌래, 비둥, 나슴, 새문, 넌물, 농굴, 단찬, 밈금, 강문
	Low word similarity	로미, 노혀, 로보, 니구, 누사, 침디, 잔미, 룰해, 디붕, 사늠, 매순, 먼눌, 공눌, 찬단, 김믐, 망군

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국문초록

보조로봇활용 음운인식훈련이 읽기장애 아동의 창안적 글자쓰기에 미치는 효과

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배경 및 목적: 읽기장애 아동에게 철자를 보다 효과적으로 교수하기 위해서는 아이들이 단어의 음운적 구조를 분석하고 음운체계를 파악하도록 돕는 것이 필요하다. 음운인식훈련은 다양한 방법과 매체를 이용하여 이뤄지고 있으며, 과학기술이 발달함에 따라 지능형 로봇의 활용 가능성과 효과에 대한 연구가 점차 이뤄지고 있다. 따라서 본 연구에서는 언어 중재에 있어서 로봇의 활용 가능성을 확인하기 위하여 로봇을 이용한 음운인식훈련이 읽기장애 아동의 철자쓰기 능력에 미치는 효과를 살펴보고자 하였다. **방법:** 본 연구 대상은 초등학교에 재학중인 만 6-8세 읽기장애 아동으로 전통적 음운인식훈련집단, 로봇을 이용한 음운인식훈련집단, 통제집단으로 나뉘었다. 연구과제로는 사전, 사후검사로 음운인식검사와 단어쓰기검사를 실시하였으며, 훈련집단은 추가적으로 중간 검사를 실시하였다. 음운인식훈련은 최대 23회기로 주2회 진행되었으며 한 회기당 30분 정도 소요되었다. **결과:** 단어쓰기 점수는 세 그룹 간 유의미한 차이를 보였으며, 음운인식훈련을 받은 읽기장애 아동들은 음운변동이 있는 단어에 대한 창안적 글자쓰기 점수가 통계적으로 유의하게 향상되었다. **논의 및 결론:** 본 연구의 결과는 로봇을 활용한 음운인식훈련이 읽기장애 아동의 철자쓰기 능력에 긍정적인 영향을 미쳤음을 시사한다. 이러한 결과는 로봇을 활용한 중재가 읽기장애 아동들에게도 효과적인 중재를 제공할 수 있음을 의미한다. 또한, 읽기장애 아동들이 음운인식훈련을 받을수록 음운변동이 있는 단어에 대한 창안적 글자쓰기도 향상됨을 시사한다.

핵심어: 보조로봇활용, 음운인식훈련, 읽기장애 아동, 창안적 글자쓰기

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