Using a Computer Intervention to Support Phonological Awareness Development of Adults with Severe Speech and Physical Impairments

Ha Trinh
School of Computing
University of Dundee
Dundee, UK

hatrinh@computing.dundee.ac.uk

ABSTRACT
The present study investigates the effectiveness of a computer-based intervention to support adults with severe speech and physical impairments (SSPI) in developing their phonological awareness, an essential contributory factor to literacy acquisition. Three participants with SSPI undertook seven intervention sessions during which they were asked to play a training game on an iPad. The game was designed to enable learners to practice their phonological awareness skills independently with minimal instruction from human instructors. Results of post-intervention assessments showed that participants P1 and P2 achieved improvements on most phonological awareness and literacy tasks. Participant P3 only obtained higher scores for two tasks but was able to generate novel words using phonemes during the intervention. All participants reported highly positive feedback on the iPad training software. These results support the use of mainstream technologies to aid learning for individuals with disabilities.

Categories and Subject Descriptors
K.3.2 [**Computer and Information Science Education**]: Literacy

General Terms
Human Factors, Languages.

Keywords
Phonological Awareness, Literacy, Severe Speech and Physical Impairments, Computer-based Intervention.

1. PROBLEM & MOTIVATION
It is well documented that individuals with severe speech and physical impairments (SSPI) often experience difficulties in literacy acquisition [16]. In order to develop effective literacy instructional strategies for individuals with SSPI, much research promotes the inclusion of phonological awareness interventions in literacy training [1, 10]. Phonological awareness (PA) refers to the explicit attention to the sound structure of language, reflected by the ability to identify and manipulate individual phonological units of words [9]. PA encompasses a wide range of skills, from rhyming recognition, phoneme blending, to phoneme segmentation and phoneme manipulation. These skills, especially the phoneme blending and phoneme segmentation skills, play a critical role in the development of word decoding and spelling skills and thus are essential for literacy success [9].

Most PA interventions for individuals with SSPI reported to date utilize paper-based materials, such as storybooks and picture cards [10]. Speech and language pathologists often play a central role, having to present multiple tasks, from presenting auditory items, labeling picture cards orally, to checking the learner's answers and implementing correction procedures if needed. There is little research into how mainstream technologies can be employed to automate PA interventions for individuals with SSPI. Moreover, most studies to date have focused on evaluating the efficacy of PA interventions for children [3]. There is limited evidence on the effects of such interventions on adults with SSPI. To address these issues, the present study investigates whether mainstream computer technologies can be applied to develop PA interventions for adults with SSPI, and how these interventions influence the PA abilities and literacy skills of the target user group. It is hoped that the use of computer-based intervention with minimal instruction required from human instructors would help promote the learner's independent practice and reduce the workload imposed on the instructors.

2. BACKGROUND & RELATED WORK
2.1 PA Interventions for People with SSPI
A number of research studies have shown that many people with SSPI experience PA deficits compared to their typical developing peers [2, 6] and therefore may benefit from focused and explicit instruction on PA skills. Conventional PA instructional procedure typically requires the learner to produce oral responses, which is problematic for individuals with SSPI. To eliminate the needs for oral production, previous research has proposed a number of adaptation strategies to allow learners with SSPI to respond using alternative modes, such as pointing to a picture card or scanning through a set of response options to indicate the intended response. Light et al. [10] describes such an adapted procedure for the phoneme segmentation task, which enables learners with SSPI to practice matching an orally presented phoneme to a picture of a word that begins with the target phoneme. The success of this type of intervention has been evidenced by a number of case studies with children with SSPI [5, 10].

While PA interventions have been shown to be effective for children with SSPI, limited evidence has been reported on the effects of such interventions on low-literate adults, especially those with SSPI [13]. These adults might not have been exposed to PA instruction during the emergent literacy stage but might have acquired some literacy knowledge through other learning routes, such as sight word reading. The question arises

as to whether these adults could still improve their PA and literacy skills through PA interventions in the same way that children do.

2.2 Computer-based PA Interventions

Traditional PA interventions are often conducted on a one-to-one basis or within a small group, requiring significant time and human resources that are not always available. To address this problem, a number of computer software programs have been developed to facilitate PA training [17]. Several research studies have conducted to investigate the impact of such programs on the learner's PA and literacy skills [7, 12]. Results of these studies have demonstrated the effectiveness of computer-delivered instruction to enhance PA skills of learners across a variety of age levels, from kindergarten to school-aged students.

Most of the published computer-based intervention studies, however, have on focused on evaluating the effects of these interventions on children. To date, little research has examined the impact of computer-based instruction on individuals with SSPI, particularly adults with SSPI. The use of computer programs has the potential to provide the learner with independent practice opportunities, which are particularly valuable for adults with SSPI, who often have limited access to conventional literacy instruction in classroom settings. Moreover, computer-based PA intervention usually does not require oral responses from the learner, making it a promising option for individuals with severe speech impairments. However, there are a number of challenges in developing a computer-based intervention for adults with SSPI. First, the intervention software needs to be appropriately designed to accommodate the special needs of people with SSPI and minimize the learning demands. Second, the program design and content need to be age appropriate. Existing PA software programs often utilize animations and cartoon-like interface designs to motivate children, their major user group. Adult users, however, often perceive these designs as childish and distracting. Thus, it is important to evaluate the developed software with the target user group to ensure its usability and accessibility.

3. APPROACH & UNIQUENESS

A computer-based PA intervention program was developed to replace traditional paper-based materials. The intervention software was designed in consultation with a teacher and evaluated by a group of adults with SSPI to ensure that it was accessible and usable to the target user group. A longitudinal study was then conducted with three participants with SSPI to examine the impact of the intervention on the participants' PA and literacy skills.

3.1 PA Intervention Software Development

3.1.1 Targeted PA Skills and Procedure

Results of the meta-analysis of PA training studies conducted by the National Reading Panel revealed that PA intervention was more effective when focusing instruction on one or two skills than when focusing on multiple skills [14]. Thus, it was decided that the intervention software should provide focused and explicit training on the phoneme segmentation skill, which is critical for learning to read and spell.

Phoneme segmentation, which requires breaking spoken words into individual phonemes, is considered the hardest of PA tasks. To teach this skill, the software adopted the *Elkonin boxes* method [4], which has been successfully employed in many PA intervention programs. This method uses the concept of 'sound boxes' to graphically represent the process of segmenting words into phonemes. Typically, the sound boxes are connected squares drawn on a piece of paper or whiteboard, each of which represents a phoneme in a word. The typical procedure using Elkonin boxes is summarized below:

INSTRUCTOR: Says a word (which is often represented by a picture card) and presents the Elkonin sound boxes. The number of the boxes corresponds to the number of phonemes in the target word.

LEARNER: Articulates each phoneme while moving a counter (i.e. a poker chip or sticker) into the corresponding box in a left-to-right progression. He/she then says the target word after collecting all the required phonemes.

INSTRUCTOR: Repeats the word or the phonemes if the learner struggles and provides encouragement when the learner completes the word.

The intervention software was designed to simulate this procedure while eliminating the needs for oral responses from the learner and oral instruction from the instructor.

3.1.2 The Intervention Software

Over the last few years, there has been a growing trend of using mainstream technologies, such as Apple's iOS platform, to provide more affordable communication support for individuals with SSPI. The intervention software was, therefore, developed on the iPad. With its appropriate size and touchscreen display, the iPad could potentially provide a viable access method for individuals with severe find motor impairments who have difficulties accessing traditional PC-based platforms.

The software allows the learner to listen to the 42 spoken phonemes introduced in the Jolly Phonics, a systematic synthetic phonics program widely used in the UK for literacy teaching [11]. These phonemes are represented by the Jolly Phonics' picture cards, e.g. /d/ is represented by a picture of a 'drum', as it is the sound a drum makes and it is also the initial phoneme in the word 'drum'. The phoneme set is divided into 7 groups with 6 phonemes in each group. Each group is placed on a separate page (see Figure 1.a). The learner can listen to each phoneme by touching the corresponding picture, and can swipe through the phoneme pages.

A 'Word Creation' game is implemented for each phoneme group to enable the learner to practice segmenting spoken words into phonemes. There are 20 practice words for each group, which are arranged in increasing levels of complexity. The software starts by speaking a word then displays a set of Elkonin boxes (i.e. the blue boxes on the upper panel of the screen) and a set of 6 to 8 candidate phoneme cards (i.e. the picture cards on the bottom panel of the screen) (see Figure 1.b). The learner can touch the picture cards to hear the candidate phonemes, then drag-and-drops each correct card to the corresponding box in a left-to-right progression. If the learner chooses an incorrect phoneme, the phoneme automatically moves back to its original position. The software contains a 'Speak Word' button, which enables the learner to

repeatedly listen to the target word. It also has a 'Speak Phonemes' button, which allows the learner to hear all the phonemes in the target word in case he/she could not find the correct phonemes. Once the learner has selected all the required phonemes, the software repeats the phonemes in sequence, followed by the target word. This emphasizes how the phonemes are blended into spoken words, thereby reinforcing the learner's phoneme blending skill.

a. Phoneme Groups **b. The Game**

Figure 1. The Intervention Software

Informal evaluation sessions were conducted with a teacher and a group of 3 adults with SSPI to ensure that the software was usable and accessible to the target user group, given their speech and physical impairments. All participants learned to use the software successfully after a brief instruction from the author. No major accessibility problems were found, however one of the participants commented that she would like the picture cards to be slightly bigger. All participants visibly enjoyed using the training game and indicated that they would like to use it in the future when asked by the author.

3.2 Study Design

Having implemented the intervention software, the next stage was to conduct a longitudinal multiple case study to investigate the effectiveness of the developed intervention.

3.2.1 Participants

Three cerebral palsied adults (2 females and 1 male), aged from 40 to 54 years old, with SSPI and varying degrees of literacy difficulties were selected for the study. Participants' cognitive ability was assessed using the Raven's Coloured Progressive Matrices test [15]. The working memory of the participants was assessed using an adapted version of the Digit Span test from the Wechsler Adult Intelligence Scale-III [18]. Results of these tests revealed that participants P1 and P3 possibly have working memory deficits.

3.2.2 Materials

3.2.2.1 PA and Literacy Assessment Battery

An assessment battery was prepared to assess the PA and literacy skills of the participants at pre- and post- intervention. The battery consists of 8 tests, including:

- 1- Letter name knowledge: A test of ability to identify printed letters from spoken stimuli. 26 test items (i.e. 26 letters).
- 2- Letter-sound correspondence: A test of ability to identify printed letters that correspond to spoken phonemes. 26 test items (i.e. 26 letters).
- 3- Spelling real words: A test of ability to spell orally presented words. 20 test items.
- 4- Reading real words: A test of ability to recognize printed words from spoken stimuli. 40 test items, including 20 words with regular spelling and 20 words with irregular spelling.
- 5- Blending real words: A test of ability to blend sequences of spoken phonemes into real words. 10 test items.
- 6- Blending non-words: A test of ability to blend sequences of spoken phonemes into non-words. 20 test items.
- 7- Phoneme analysis: A test of ability to identify individual phonemes in spoken words. 24 test items, including phonemes from initial, medial, and final positions, and phonemes that form part of clusters in initial and final positions.
- 8- Phoneme counting: A test of ability to count the number of individual phonemes in spoken words. 12 test items.

Tests 1-3 were created by the author whilst tests 4-8 were adapted from the APAR test [8], an assessment of PA and reading skills specifically designed for adults with SSPI. All the tests did not require any oral responses and were accessible to participants with severe physical impairments.

3.2.3 Procedure

Baseline assessment of PA and literacy skills of each participant was carried out prior to the intervention phase. The assessment was conducted in two sessions, each lasted 45-60 minutes. The participants then undertook 7 intervention sessions, one per week, each lasted 30-45 minutes. During each intervention session, the participants were introduced to a new group of 6 phonemes and practiced creating spoken words from the phonemes using the intervention software. These sessions were conducted either in a university lab or at the participants' home. Post-intervention assessment was started a week after the last intervention session.

4. RESULTS AND DISCUSSION

4.1 PA and Literacy Assessment

4.1.1 Participant P1

Table 1 shows the PA and literacy assessment results of Participant P1 prior- and post- intervention.

Table 1. Results of Participant P1 (Percent Correct)

Assessment Tasks	Pre-intervention	Post-intervention
Letter name knowledge	84.6	88.5
Letter-sound correspondence	72.0	100.0
Spelling real words	5.0	5.0
Reading real words	72.5	80.0
Blending real words	80.0	100.0

Blending non-words	70.0	65.0
Phoneme analysis	58.3	83.3
Phoneme counting	8.3	25.0

The results demonstrated an improvement in the participant's performance for all the assessment tasks except for the spelling and the blending non-word tasks. A maximum score was reported for the blending real words task while a noticeable improvement was shown on the phoneme analysis task. The participant also performed better on the phoneme counting task. However, this task proved to be very difficult for the participant as she only scored 25% post intervention. It is suspected that the participant's working memory deficit might partly account for this result. Although the spelling score did not increase, the participant achieved improvements in the reading and the letter-sound correspondence tasks, which was surprising considering that letters were not introduced in the intervention.

4.1.2 Participant P2

Pre-intervention assessment results of participant P2 showed that the participant had obtained maximum scores for three tasks, including the letter name knowledge, the blending real words, and the phoneme analysis tasks. This implies that the findings of this study are influenced by ceiling effects. At post-intervention assessment, the participant maintained the scores for these tasks while demonstrating an improved performance for all five remaining tasks (see Table 2). The participant achieved a noticeable improvement on the phoneme counting task, however her score for this task was still relatively low, at 41.7% post intervention. Similar to participant P1, P2 also performed better for the reading real words and the letter-sound correspondence tasks, reaching 100% for both of these tasks. Her spelling score also increased from 60.0% to 85% after the intervention.

Table 2. Results of Participant P2 (Percent Correct)

Assessment Tasks	Pre-intervention	Post-intervention
Letter name knowledge	100.0	100.0
Letter-sound correspondence	88.0	100.0
Spelling real words	60.0	85.0
Reading real words	97.5	100.0
Blending real words	100.0	100.0
Blending non-words	90.0	95.0
Phoneme analysis	100.0	100.0
Phoneme counting	16.7	41.7

4.1.3 Participant P3

In contrast to the results of participants P1 and P2, participant P3 showed a limited improvement in his PA and literacy skills (see Table 3). The participant obtained higher scores for two tasks, including the blending real words and the letter-sound correspondence tasks. However, the participant' scores for the phoneme counting and the spelling tasks remained unchanged while his scores for the phoneme analysis, the blending non-words, the letter name knowledge, and the reading real words tasks slightly decreased.

Table 3. Results of Participant P3 (Percent Correct)

Assessment Tasks	Pre-intervention	Post-intervention
Letter name knowledge	100.0	96.2
Letter-sound correspondence	88.0	100.0
Spelling real words	30.0	30.0
Reading real words	92.5	90.0
Blending real words	80.0	100.0
Blending non-words	100.0	90.0
Phoneme analysis	83.3	75.0
Phoneme counting	41.7	41.7

4.1.4 Summary of the PA and Literacy Assessment

Results of the PA and literacy assessment of the three participants demonstrated that the intervention had general positive effects on the PA and literacy skills of the participants. However, the degree of these effects varied from individual to individual. While the positive effects of the intervention were clearly evidenced by the results of participants P1 and P2, these effects appeared to be small in the case of participant P3. With a limited number of participants and the presence of ceiling effects, it is difficult to interpret and generalize the results. Other factors, such as the participants' cognitive ability or their conditions on the assessment days, might also contribute to the results. Thus, it is important to conduct further studies with a larger number of participants and a more rigorous study design to confirm the impact of the intervention.

4.2 User Feedback

All participants reported highly positive feedback on the iPad intervention software. Using various methods of communication, the participants stated that they liked hearing the sounds in words using the software and felt that it was helpful. In particular, participant P3, who showed limited improvements in his PA and literacy skills after the intervention, expressed a high interest in the software and asked to have a copy at home for further practice. Prior to the intervention, this participant indicated that he had difficulty saying the sounds in his head, which suggests that he might have problems with subvocal rehearsal. However, during the intervention, the participant was able to use the software to create novel words that did not appear in his word board (i.e. his primary means of communication). This greatly boosted his motivation and explained his highly positive attitude towards the software. All participants also displayed great excitement in using the iPad during the intervention. It appears that the 'cool' factor as well as the accessibility and mobility of this platform helped maintain their interest and motivation, which are essential for learning success. This highlights the importance of choosing an appropriate platform to deliver the intervention software.

One area that could be improved according to the user feedback was the use of pictures to represent the sounds. The participants occasionally showed confusion over some of the pictures and indicated the desire to change those pictures. Thus, future work is needed to improve the transparency of the picture set.

4.3 Observation

The author highlighted two observations that could be helpful for future research.

First, throughout the intervention, the participants often experienced difficulty in identifying vowels. Thus, it might be useful to add into future intervention more focused and explicit instruction to support vowel identification.

Second, participants P1 and P3, who have dysarthria, were observed to vocalize frequently during the intervention sessions, either to say the sounds or to repeat the words spoken by the software. The question arises as to whether this form of vocalization could have any effects on their speech production. Further research is needed to seek the answer for this question.

5. CONCLUSION

The results of this study suggest that PA intervention could potentially have positive effects on the PA and literacy skills of adults with SSPI. Moreover, the highly positive feedback on the iPad intervention software obtained from all participants supports the use of mainstream technologies to develop accessible PA intervention. However, further studies with a larger number of participants are needed to generalize these results.

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