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# Effects of the Speech Therapy Program Based Augmented Reality on Improving Naming and Functional Communication Ability of the Patients with Expressive Aphasia*

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ABSTRACT

The central goal of language therapy for aphasia should be to improve the patient's everyday language competence. However, the functional communication approach is difficult to apply in the clinical field, so most treatments are symptom-oriented. The purpose of this study was to investigate whether the speech therapy program based augmented reality is effective in improving the naming and functional communication ability of the patients with expressive aphasia. Five patients with expressive aphasia participated in the experiment where the naming and functional communication scores were compared before and after treatment. For treatment, the augmented reality contents similar to those of the home environment (room, living room, bathroom, and kitchen) were produced and presented to the patient in the form of a script. Then, when the subjects recognized such marks with a camera, three-dimensional models corresponding to the marks were indicated in the relevant card presenting the image to the subjects on the monitor. The study result showed that All of the subjects' response scores were improved. According to the results of the study, the post-treatment Naming Ability scores (38.4) were higher than the pre-treatment (26), whereas the post-treatment Functional Communication Ability scores (48.4) were higher than the pre-treatment (33). The speech therapy program based augmented reality can complement the symptom-oriented treatment and make the functional communication approach possible.

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## 1. Introduction

Aphasia is an acquired language disorder characterized by difficulties across various areas such as expressing or understanding language in everyday life due to damage to one's central nervous system after learning a normal language. Aphasia can be classified into fluency aphasia and non-fluent aphasia based on fluency. Typically, fluency aphasia includes Wernicke's aphasia and anomic aphasia, and non-fluent aphasia has Broca's global aphasia. The most common language disorder that manifests in patients with aphasia is the naming deficit. It is a persistent symptom of chronic aphasic patients, and there are many reports on the impaired naming abilities of the various types of aphasic patients.

During rehabilitation, it is of utmost importance to improve the communication function of the patients with aphasia in their daily life. Their aphasia should be treated systematically and intensively during the initial period, so that the patients would recover naturally after the aphasia occurs; after this period, it is important to provide training that emphasizes interaction as natural as that in everyday life. In addition, high frequency also shows a high success rate during rehabilitation when repeated naming and conversation training are provided. The key to such a rehabilitation therapy is that it requires the integration of speech therapy with the patient's daily life.

Nonetheless, differences between training in the therapy room and that in a conversational situation should be recognized from the perspective of communication in daily life. As different neural networks are activated in different conditions of speech therapy, research should be performed in various interventional contexts, and it has been reported that the intervention methods similar to daily life activates the neural network identical to that activated in the actual situation. Accordingly, with regard to speech therapy for the aphasia patients, it is important to aim for functional communication, rather than a speech intervention focused on symptoms. Due to the patients' limitations in terms of motor function or location in most clinical settings, however, it is difficult to approach functional communication.

To address such problems, therapies using various forms of media have been created. Among them, augmented reality (AR) is a branch of virtual reality, and a compound word of augmentation, a computer graphic technique that makes objects look like they exist in the real world by combining virtual objects, places, and other information in the real environment, and reality, referring to an actual world that unfolds before one's eyes. (Figure 1) In other words, as it allows the user to share virtual information, which is generated by the computer, in the real world, AR can be combined with many different types of virtual learning contents used in therapies. Since AR can provide a natural situation related to the user's life without constraints on location, using the AR contents would help supplement therapies focused on symptoms and make a functional approach possible.

The following are the previous studies that used AR. A study found that an AR-based therapy made progress like the traditional textbook method and was even more effective than the textbook-based therapy for general motivation and involvement. In addition, another previous study confirmed that an AR-based testing system for articulation and phonological disorders was effective in improving the subjects' concentration on the test, and implemented functions required to test articulation and

phonological disorders using the system. Emotional awareness, gaze, and eye training were performed through the augmented reality application using smart glasses, and abnormal behaviors of children with the autism spectrum disorder (ASD) decreased. In a study comparing the quality of experience (QoE) of a conversational immersive language evaluation implemented with augmented reality and virtual reality, both had similar quality ratings, but the users were more likely to adapt to the augmented reality (AR) environment than the virtual reality (VR). Another study also reported that storytelling with picture books using AR were effective in enhancing memory abilities, and AR is used in healthcare areas such as therapies for managing the patients' symptoms after a stroke and rehabilitation for upper extremities.

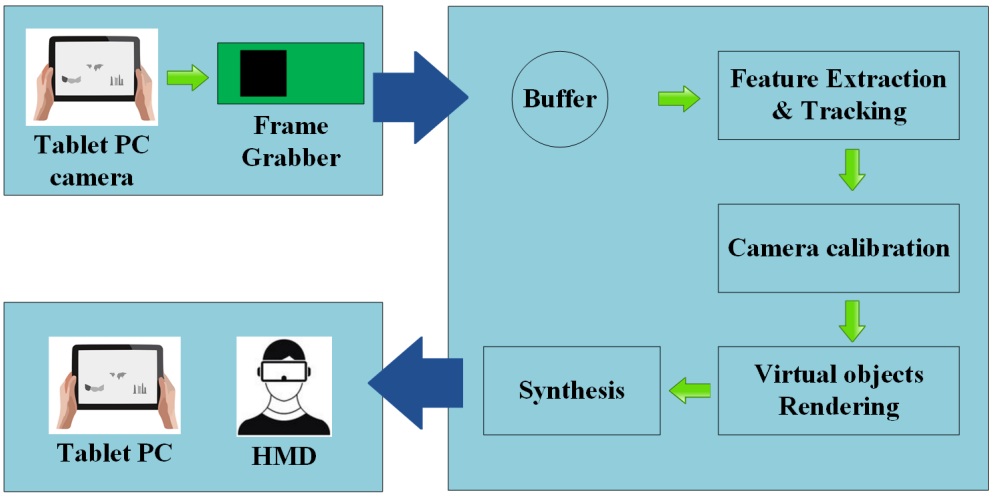


**Figure 1.** Block diagram of the augmented reality based speech therapy system

As described above, a new medium has emerged with advances in computer engineering, and a new challenge of converging it with other specialized fields has been presented. With regard to the speech therapy, however, there are very few studies on the AR-based interventions. Using an information generated virtually to supplement the actual environment is an innovative approach that can help complement the traditional aphasia therapies under clinical settings.

Functional communication also refers to the ability of an individual to communicate efficiently in his or her daily life regardless of the communication skill. In other words, it requires language skills in various situations from informal social interactions to formal educational tasks. In many studies on functional communication, it was reported that interventions using scripts were effective in improving routine and functional communication. It was revealed that scripts could ease cognitive burden in intervention situations, and scripts with a higher degree of familiarity used more complex and longer sentences and produced more developed communication abilities. Accordingly, this study aimed to determine the effect of an AR-based speech therapy program on improving the expressive aphasia patients' naming and functional communication abilities.

## 2. Materials and methods

### 2.1 Subjects

This study was conducted on 5 expressive aphasia patients who were outpatients or admitted to Pusan National University Hospital in Busan. As for the inclusion criteria, those who were found to have expressive aphasia by the Korean version, the Western Aphasia Battery (K-WAB), no auditory or visual problems, no history of developmental defects or psychological and mental disorders before the occurrence of the expressive aphasia, and no left neglect were selected for this study (Table 1).

Table 1. Descriptive information of aphasia patients

| Case | Age | Sex | Edu | Type of CVA (aphasia type) | AQ[a] | TPO[b] |
|---|---|---|---|---|---|---|
| 1 | 57 | F | 16 | Lt. MCA inf. (Anomic) | 87.2 | 1 |
| 2 | 27 | F | 16 | spont. ICH (Anomic) | 82.4 | 1 |
| 3 | 27 | F | 12 | Lt. MCA inf. (broca) | 61.8 | 1 |
| 4 | 45 | M | 16 | Lt. MCA inf. (broca) | 54.4 | 1 |
| 5 | 56 | M | 16 | Lt. MCA inf. (broca) | 51.3 | 1 |

K-WAB, Korean version-the Western Aphasia Battery; AQ, aphasia quotient; TPO, time post-onset; CVA, cerebrovascular accident; MCA, middle cerebral artery; ICH, intracerebral hemorrhage.

### 2.2 Experiment methodology

#### 2.2.1 Procedure

This study used a pre/post-test design in order to identify the effect of an AR-based speech therapy program on improving expressive aphasia patients' naming and functional communication.

In the pre-test, K-BNT and the Communicative Effectiveness Index (CETI) were adopted and revised by two professors of speech-language pathology to measure the subjects' naming ability and communication function before the AR-based speech therapy program was provided.

During the intervention, the AR-based speech therapy program was implemented with the subjects individually, and the intervention was performed thrice per week for two months for the total of 24 sessions. In the post-test, the same tools used in the pre-test were used for evaluation. In terms of the retention period, this study had a one-week break for evaluating how long the intervention's effect would last after the intervention terminated, and then the subjects were reevaluated without any intervention or clue under the same conditions as in the pre-test.

### 2.2.2 Intervention program

This study's intervention program was developed to see if activities using an AR-based speech therapy program improved the patients' naming ability and functional communication. This study's system had the AR function that recognized markers through a tablet PC camera and a three-dimensional video on the display (Figure 2).

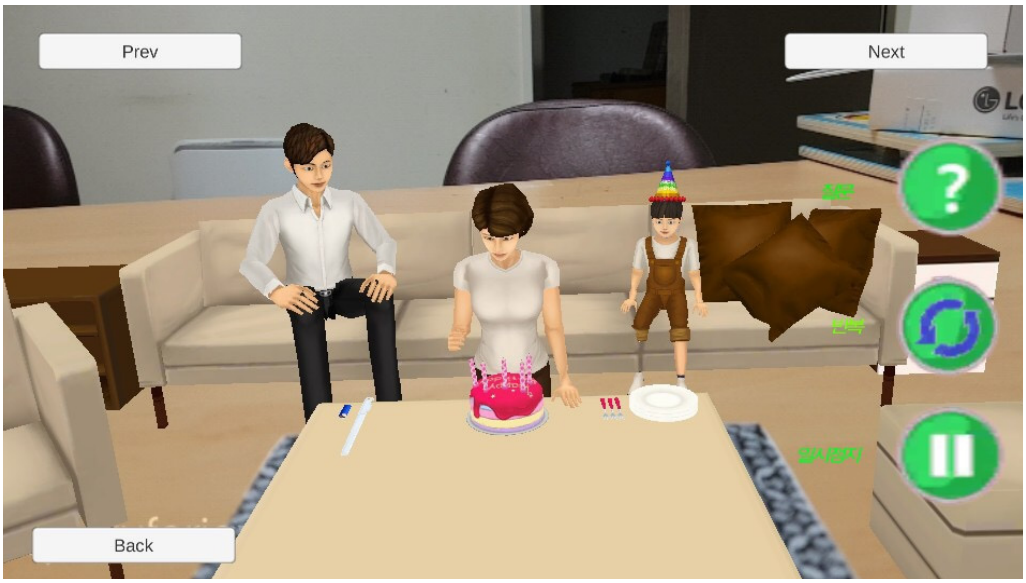


**Figure 2.** Augmented reality based speech therapy applications

For markers, 68 three-dimensional actions and 90 background objects were designed in household environments such as the room (24 items), living room (31 items), bathroom (7 items), and kitchen (6 items), which were constructed to be presented in the form of a script. Furthermore, the system provided a training mode, practice mode, evaluation mode, and a system configuration interface to support naming therapies for object names or actions.

The intervention program used in a session implemented three-dimensional actions and background objects in AR on a desk in a therapy room for the subjects.

In this study, subjects were asked to report on the actions that characters were taking on the screen, which were implemented in the form of a script, and the names of the background objects. When the subjects could not answer a question, they were provided with step-by-step clues to lead them to a target word.

The following were the step-by-step clues: first, clues for the target word's function or meaning; second, clues for the target word's category; third, clues for completing a sentence in which the target word is used; fourth, gesture clues; fifth, clues regarding the first sound of the target word, and; sixth, clues for the first letter of the target word. These clues were presented step-by-step. If the subjects could not find the target word even after the last clue was provided, the researcher

articulated the target word and led them to imitate it. (Figure 3)

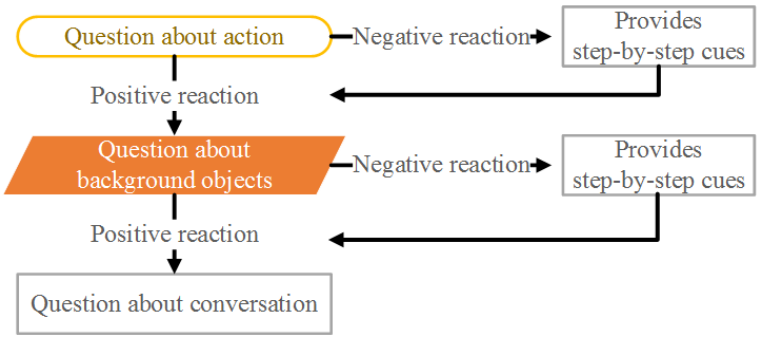


**Figure 3.** Process of the augmented reality based speech therapy

In addition, in this study, subjects were asked about what they did in their room, living room, bathroom, or kitchen so that they could speak the target or other words, which led them to naturally talk about things related to daily life. In this study, the subjects' wrong reactions to the last questions were overlooked.

**Statistical analysis**

Wilcoxon signed-rank test was used to evaluate the effect of speech therapy; *P* values of $< 0.05$ were considered significant. All statistical analyses were performed using R, version 3.4.1 (The R Foundation for Statistical Computing, Vienna, Austria) and RStudio 1.0.143 (RStudio Inc., Boston, MA, USA).

## 3. Results

### *3.1 Effect on improving the naming performance*

The K-BNT test was performed to examine whether the naming score increased as a result of the AR-based speech therapy program's intervention with the 5 expressive aphasia patients. (Figure 4) The results indicated that the scores of 5 participants in this study improved by 12.4 points, from an average of 26 before the therapy to 38.4 after the therapy, and the score from the retention period was 36.6, which was similar to the post-therapy (Table 2). Overall, the post-therapy naming score significantly increased compared to the pre-therapy ($p<0.01$). The post-therapy score yielded no significant difference vis-à-vis that from the retention period, and the naming performance was maintained very well ($t=0.46$, $p=0.66$).

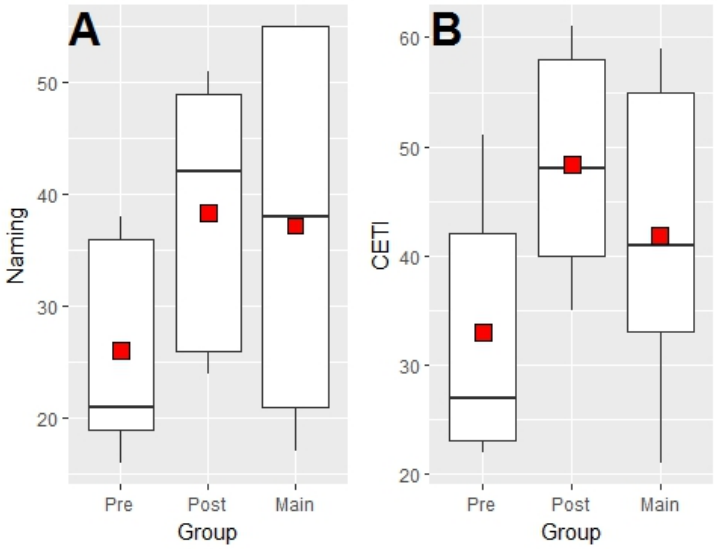


**Figure 4.** Results of K-BNT and CETI following the intervention procedures

**Table 2.** Results of the pre- and post-speech therapy naming test based on AR

| Case | Pre-test (Score) | Post-test (Score) | T | p | Maintained (Score) |
|---|---|---|---|---|---|
| Case 1 | 36 | 49 | | | 52 |
| Case 2 | 38 | 51 | | | 55 |
| Case 3 | 21 | 42 | | | 38 |
| Case 4 | 16 | 26 | | | 21 |
| Case 5 | 19 | 24 | | | 17 |
| Mean | 26 | 38.4 | -4.76 | 0.008** | 36.6 |

t, t-value; p, p-value.
** Significant at 0.01 level (two-tailed).

### *3.2 Effect on improving the communication function*

A revised and updated CETI questionnaire survey was used to assess whether the functional communication score improved as a result of the AR-based speech therapy program's intervention with the 5 expressive aphasia patients.(Figure 4) The results showed that the CETI score, which represented the patients' functional communication, increased by 15.4 points, from an average of 33 points before the therapy to 48.4 after the therapy, and it was also found that the score was maintained at 41.8 during the retention period (Table 3). However, the functional communication score of Subject 5 increased after the therapy yet declined during the retention period, and was lower than the score immediately after the speech therapy. Overall, the post-therapy communication score represented a significant increase compared to the pre-therapy ($p<0.01$). The post-therapy

score yielded no significant differences compared to that from the retention period, and the communication performance was maintained fairly well (t=2.04, p=0.11).

**Table 3.** Results of the pre- and post-speech therapy CETI based on AR

| Case | Pre-test (Score) | Post-test (Score) | t | p | Maintained (Score) |
|---|---|---|---|---|---|
| Case 1 | 42 | 58 | | | 55 |
| Case 2 | 51 | 61 | | | 59 |
| Case 3 | 23 | 48 | | | 41 |
| Case 4 | 22 | 35 | | | 33 |
| Case 5 | 27 | 40 | | | 21 |
| Mean | 33 | 48.4 | -5.96 | 0.003** | 41.8 |

t, t-value; p, p-value.
** Significant at 0.01 level (two-tailed).

## 4. Discussion

This study intended to examine whether an AR-based speech therapy program's intervention with expressive aphasia patients improved their naming ability and communication function. The results are summarized as follows.

First, the AR-based speech therapy program's intervention was effective given that the scores of the subjects' naming performance and functional communication abilities increased after the intervention vis-à-vis that before the intervention. This finding is consistent with those of the previous studies such that AR was a good method to train the patients on naming tasks repeatedly and helped them to interact with personal objects in the household via an AR application and create extremely natural training situations. Furthermore, it is also consistent with the findings of other studies in that the conversational script method facilitated participation in daily life activities and was effective in the functional communication, which enabled easier linguistic expressions. Integrating virtual objects with real ones based on the AR technology was reported to help children and adults with physical and mental challenges in better interacting with intuitive learning methods and assistive technologies. If the current strategy applied to the subjects were effective, this study suggests that it would receive positive feedback.

Second, the AR-based speech therapy program's intervention was effective in retaining the subjects' performance considering that their naming performance and functional communication abilities during the retention period were similar to those after the intervention. The AR-based rehabilitation training was reported in another study to have provided a high degree of motivation to the subjects and encourage them to express positive feelings. In addition, it seems that the subjects' improved naming and functional communication abilities worked as a factor triggering them to evaluate their communication abilities even more positively. These might have contributed in maintaining the subjects' performance at a certain level.

As demonstrated in the results above, the AR-based speech therapy program had a positive effect on the expressive aphasia patients' naming and communication functions. Moreover, it is believed that the AR-based intervention would address the limitations of the traditional picture cards, and to some degree, help supplement functional communication-focused therapies that are difficult to perform in the setting of therapy room.

There is no doubt that the AR technology is an attractive method using the actual environment such that patients can have a new experience of storytelling. Furthermore, it is suitable for training very personal experiences or memories through the actual setting by remembering or telling a story about particular places associated with personal experiences or stories.

The limitation of this study is that it is necessary to obtain a larger number of samples because of the difficulty of generalization of the results due to the small number of samples. As a disadvantage of the augmented reality based language therapy program, most of the training using the augmented reality is training for naming, and it is difficult to apply the augmented reality training for the syntax and form of language. The augmented reality based language therapy programs across various language forms are still being implemented. In addition, there is a limitation in that the augmented reality-based language therapy performance would vary depending on cognitive function, physical sensations, and exercise function of the subjects. Subjects 2 and 3 were in their 20s and more interested in the AR therapy tasks than the other subjects. Meanwhile, even though Subject 1 had the mildest aphasia, this patient was not able to concentrate adequately while performing tasks due to problems with the visual and motor functions.

Based on the results, this study affords the following suggestions for the future studies.

First, this study was conducted with only the expressive aphasia patients, and it is necessary to develop a better structured and efficient system by conducting research with the patients with various types of aphasia.

Second, it is important to develop AR contents that will enable patients to experience not just household situations but also other varying situations within their local community.

Third, it is crucial to design and develop not just naming training but also an AR therapy system based on the participants' personal experiences or memories.

Fourth, it is necessary to develop a glasses device to address difficulty in control due to sensory or motor problems accompanying aphasia.

## 5. Conclusion

The augmented reality-based speech therapy programs are promising approaches to the successful language rehabilitation, complementing symptomatic therapy and enabling functional communication approaches.

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