

A Speech Therapy Game Application for Aphasia Patient Neurorehabilitation – A Pilot Study of an mHealth App

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Abstract—A life without language – the human system of communication – is a life that couldn't be lived to the fullest. Aphasia, a multimodal neurophysiologic disorder that is manifested by a substantial communication restriction due to damage to the brain, is one of the many possible causes that can make life languageless. Fortunately, it can be treated by speech therapy to rehabilitate language skills and can even be improved by therapy via an app to supplement communication experiences as proven by recent studies. As a contribution to the gaming rehabilitation industry, this paper aimed to design and develop a speech therapy game application, as an additional neurorehabilitation modality for aphasia patients and assess its applicability as an adjunct to the traditional neuromuscular rehabilitation through a pilot study. Eight sessions of game-based speech therapy were applied to seven aphasic patients, 10–15 minutes per day, once a week, for 8 successive weeks. Aphasia assessment in stroke patients was performed with a multidimensional assessment tool, built-in to the therapeutic game, based from quick aphasia battery (QAB) before and after treatment. The comparison of before and after treatment revealed that there was an improvement in all of the QAB subtests: level of consciousness, connected speech, word comprehension, sentence comprehension, picture naming, repetition, reading aloud, and motor speech. This suggests that the development of this speech therapy game and the preliminary findings from the pilot study may indeed be an effective neurorehabilitation instrument for therapy of aphasia patients.

Keywords—Mobile Game Application, Neurorehabilitation, Speech Therapy, Video Game Rehabilitation, Aphasia, Stroke

I. INTRODUCTION

Aphasia is medically defined as an acquired impairment of language processing and production, usually a result of a left-hemispheric stroke. Other possible causes are infections, head trauma and brain tumor and neurodegenerative diseases [1]. According to a national survey on aphasia awareness, a third of strokes result in aphasia [2]. As a consequence of losing language modalities, aphasic patients are associated with multimodal neurophysiologic disorder manifested by difficulties in reading, writing, and even mathematics [3]. Given that language is a medium of communication that is pivotal to daily living, aphasia is found to cause frustration and feelings of loneliness, isolation, and alienation due to fear or rejection [4-6], of being inadequate, and a burden on relatives and friends [7]. Furthermore, since our ability to communicate and express our ideas and feelings are such a fundamental function, language impairment as well as the difficulty in interpreting responses from the environment caused by multimodal disorder may result in considerable activity limitation [8] and a challenge to all relationships [9]. Moreover, self-confidence and self-image may be negatively affected as well [5, 10] due to trimmed possibilities of imparting personality, relatedness, and competence through communication. Lastly, prior hobbies may be gruesome to pursue as a result of substantial participation restriction [4-7], and it may be likewise difficult to find new, meaningful

activities to engage with [6, 11, 12]. The unfathomable level of negative psychosocial consequences and its potent impact on one's life, as discussed and described above, was the main reason and inspiration for conceiving this study.

Fortunately, aphasia is one of the effects of stroke that can be treated by speech therapy - which is typically used as a language skills rehabilitation treatment - and can even be improved by a self-delivered therapy treatment via an app to supplement communication experiences as demonstrated by a recent study [13]. Undeniably, the computer game-based rehabilitation has revolutionized the home-based healthcare for various medical conditions, diseases, and disorders such as multiple sclerosis [14], stroke [15], Parkinson's disease [16], cerebral palsy [17], cardiovascular disease [18], and muscle training [19] just to name a few. In a study conducted by Jonsdottir *et al.* [14], the feasibility of using a serious games-based rehabilitation as the chief adjunct to traditional healthcare for persons with multiple sclerosis (MS) was investigated, and it was revealed that there were clinically significant improvements in arm function in the serious games group than the traditional group. Garcia *et al.* [15], on the other hand, employed a virtual reality (VR) application to determine its effects on balance and mobility of subjects with stroke though it was found out that there was no significant difference between conventional physiotherapy sessions and virtual reality games. Another VR-based therapy was tested by Loureiro *et al.* [16], this time with Parkinson's disease, to

examine if it is a useful instrument to improve the balance in PD patients. The test result was very promising as it showed statistically significant developments in the patients’ balance. As proven by these computer game-based treatments, the use of gaming technology for patient rehabilitation has boundless prospects for a wide variety of medical conditions.

In particular, video games that are enrolled in the field of neurorehabilitation have been proven to improve the process of motor learning and recovery from traumatic brain injury, incidents of stroke, and other neuromuscular impairment by increasing user motivation during training. As a contribution to the body of knowledge, video gaming neurorehabilitation, and therapeutic game industry in general, this paper introduced a novel method of patient rehabilitation through a speech therapy game application dedicated for aphasic people. The study specifically aimed to design and develop a computer-based aphasia therapy that will allow patients to exercise independently at home and speech therapists will be able to assign tasks to patients and track their results online. In the next chapter, the game development was discussed along with game research route, game usability evaluation, aphasia assessment test reference, characteristics, gameplay, and additional gaming features. Moreover, findings from the investigation on the feasibility and practicability of using Theraphasia (Mobile Speech Therapy Game) as an adjunct to traditional neuromuscular rehabilitation both in a natural clinical practice environment and at the comfort of patients’ homes through an eight-session mobile game-based speech therapy, 10-15 minutes per day, once a week, for 8 consecutive weeks was also reported in detailed.

from quick aphasia battery (QAB) – a reliable and multidimensional assessment of language function [20] as the main assessment tool that features a series of subtests such as level of consciousness, connected speech, word comprehension, sentence comprehension, picture naming, repetition, reading aloud, and motor speech. While there are several reliable and valid aphasia tests such as Ege Aphasia Test, Gülhane Aphasia Test-2 (GAT-2), Western Aphasia Battery (WAB) and a lot more, QAB was used instead as the assessment reference as it can yield a multidimensional profiles of individual patients in a shorter period of time [20]. Moreover, the game includes several exercises and tasks hints in form of pictures, video and/or audio recordings grouped into seven categories, as can be seen on table 1, that complement the QAB subtests since the QAB assessment will be used before and after the treatment (with an exclusion of “level of consciousness” since it does not contribute to any of the summary measures). Moreover, the QAB was also used to evaluate the results of the therapy sessions as it has already a rubric available. As thoroughly introduced in the previous section, the main functionality of the game was drawn principally from a valid Aphasia assessment tool: QAB. A deeper view of this project, however, will reveal that this is just a small part of the game research route. In fact, the game research route includes need analysis, game design, game development, and game usability testing. As shown on Figure 1, the game research route has an iterative nature which religiously ensures that the improvement of the game will always be applied. With this, it became possible to return to previous life cycle stages to modify what needs to be modified which consequently optimize the game.

TABLE I. THERAPHASIA GAME CATEGORIES AND ITS EQUIVALENT TO QUICK APHASIA BATTERY SUBTESTS

Game Category	QAB Subtest Equivalent	Task Description
Talking Therapy	Connected Speech	Converse with a chatbot using one or more pre-determined conversation topics.
Word Therapy	Word Comprehension	Map word forms onto referents by identifying objects containing semantic or phonological foils.
Sentence Therapy	Sentence Comprehension	Answering pre-defined questions using the thumbs up/thumbs down button graphical user interface.
Picture Therapy	Picture Naming	Recognize the given set of pictures through confrontation naming and identify or speak the right word.
Repeat Therapy	Repetition	Repeat pre-defined words recording consecutively using built-in speech recognition.
Reading Therapy	Reading Aloud	Map orthographic word forms to phonological word forms through stored associations.
Speech Therapy	Motor Speech	Speak words (automatic recording) consecutively with alternating motion and sequential motion rate.

II. THERAPHASIA: A MOBILE SPEECH THERAPY GAME

Theraphasia is an interactive therapeutic game focusing on the neuroplasticity of language networks of aphasic patients after damage to language regions of the brain. It is a mobile game-based rehabilitation that was drawn principally

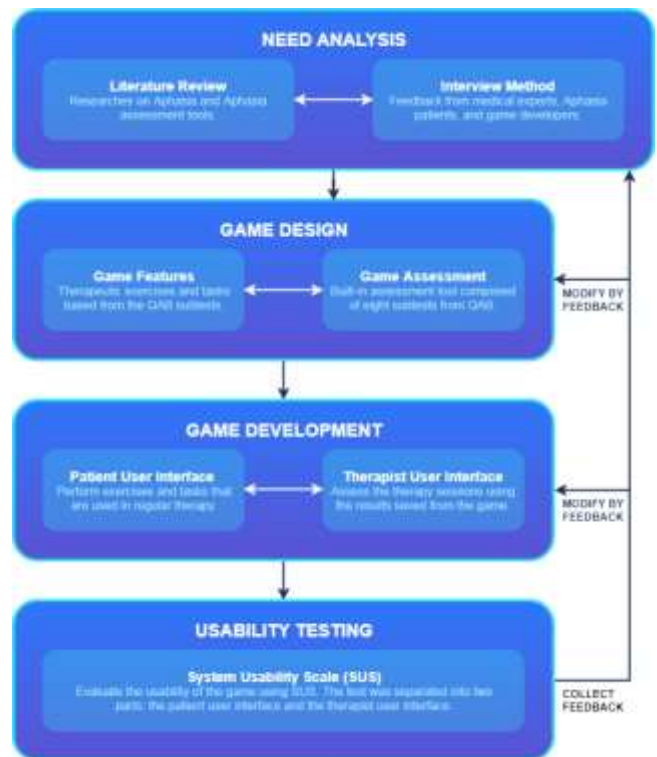


Figure 1. Theraphasia Game Research Route.

A. Need Analysis

The research idea started with informal interviews with therapists, game developers, researchers, and key patient population to explore the feasibility a computer game-based therapy in general and particularly for Aphasia when possible. All the stakeholder groups were then informed regarding the planned neurorehabilitation game for people with Aphasia and asked for possible development features. Consequently, the concept of off-the-shelf video games as rehabilitation tools was supported and encouraged. Finally, a second confirmation was conducted through literature review of rehabilitation games for several disorders and conditions. The anecdotal evidence suggest that people are open with games specifically designed for rehabilitation.

B. Game Design

One way to establish assurance that a rehabilitation game will indeed rehabilitate the patients is to make sure that the game features are based from scientifically and medically proven concepts. As can be seen on Table 1, the therapeutic exercises and tasks of Theraphasia have a corresponding equivalent to a validated assessment tool purposely designed for Aphasia; thereby, ensuring that the neurorehabilitation game has a strong scientific and medical foundation. For the assessment of game therapy sessions, the computations and formulas were based from the rationale and Excel Macro provided by Wilson *et al.* [20] in the QAB tool.

C. Game Development

Addressing the traditional setup of neurorehabilitation to harness what has been effective in the field requires the division of two main groups: the speech therapists and aphasic patients, thereby, the creation of separate user interfaces. The patient interface will allow the patients to perform exercises and tasks that are commonly used in traditional therapy sessions while the therapist interface will allow the professionals to assess the therapy sessions to monitor progress. For this pilot study, the contents are fixed and there was no backend interface available. However, it will be part of the recommendation to develop a backend interface that will allow therapists to customize the tasks and questions for their patients according to their specific needs. Nonetheless, a web server was established in order to make sure that both interfaces, patient and therapist, can work side-by-side remotely (Computer-Assisted Treatment).

D. Usability Testing

Performing game usability testing reduces the risk of building the wrong game in terms of structure and contents; thereby saving money, time and other resources. Summative tests were performed for patient and therapist interfaces using interview method for the first few iterations of the game research route and SUS (System Usability Scale) – a ten-item questionnaire with five response options ranging from strongly agree to strongly disagree – for the final usability evaluation. With a limited number of respondents,

SUS is the best choice as it has become a standard in evaluating products on small sample sizes [21]. Success rate and time per task were likewise deliberately calculated and recorded for supplementary insights to further measure and validate the applicability and feasibility of Theraphasia.

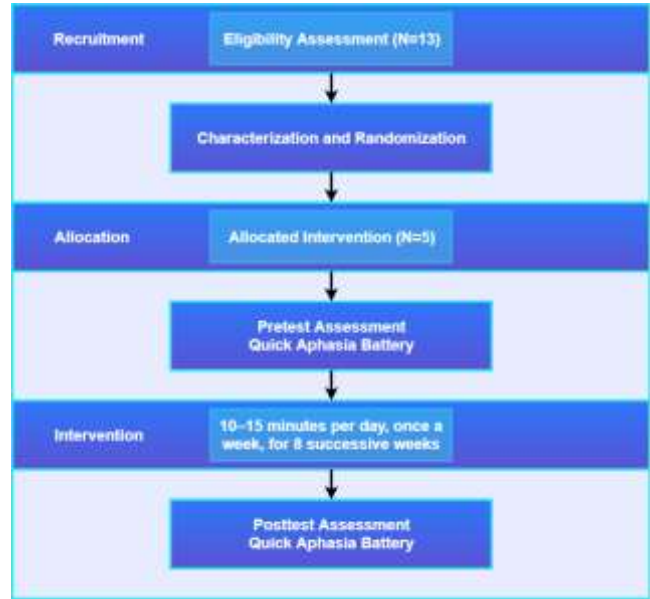


Figure 2. Research Study Design for Theraphasia

III. METHODOLOGY

A. Study Design

After the study was approved by the Institution’s Research Ethics, a pilot single-blind randomized clinical trial was carried out with aphasic patients through the help of one of the hospitals in Valenzuela City. Five patients (3 males, mean age 61.5 ± 9.2 years and 2 females, mean age 55.2 ± 12.2 years) with aphasia (mean duration 53.9 ± 32.1 months), out of thirteen potential participants, were among the recruited participants who passed the inclusion criteria and agreed to be part of the research study. To qualify for inclusion in this study, patients had to meet 3 criteria: (1) nonfluent aphasia classification, (2) single left hemisphere stroke and (3) at least one year after stroke which were based from the inclusion criteria of Fridriksson *et al.* [22] of treating visual speech perception in aphasia. As part of the recruitment procedures, the patients were asked to sign a Free and Clarified Consent Term to participate in the experimental procedure. In the form, the patients have freely given their consent for their clinical information to be reported in this paper. The patients fully understand that their names and initials will not be published in any part of this paper and due efforts will be strictly implemented to conceal their identity, thereby, the use of pseudonyms and nicknames as patient identifiers (if necessary). The study design can be seen on Figure 3 where the sequence of research tasks such as recruitment, allocation, and intervention as well as its corresponding activities are properly layout.

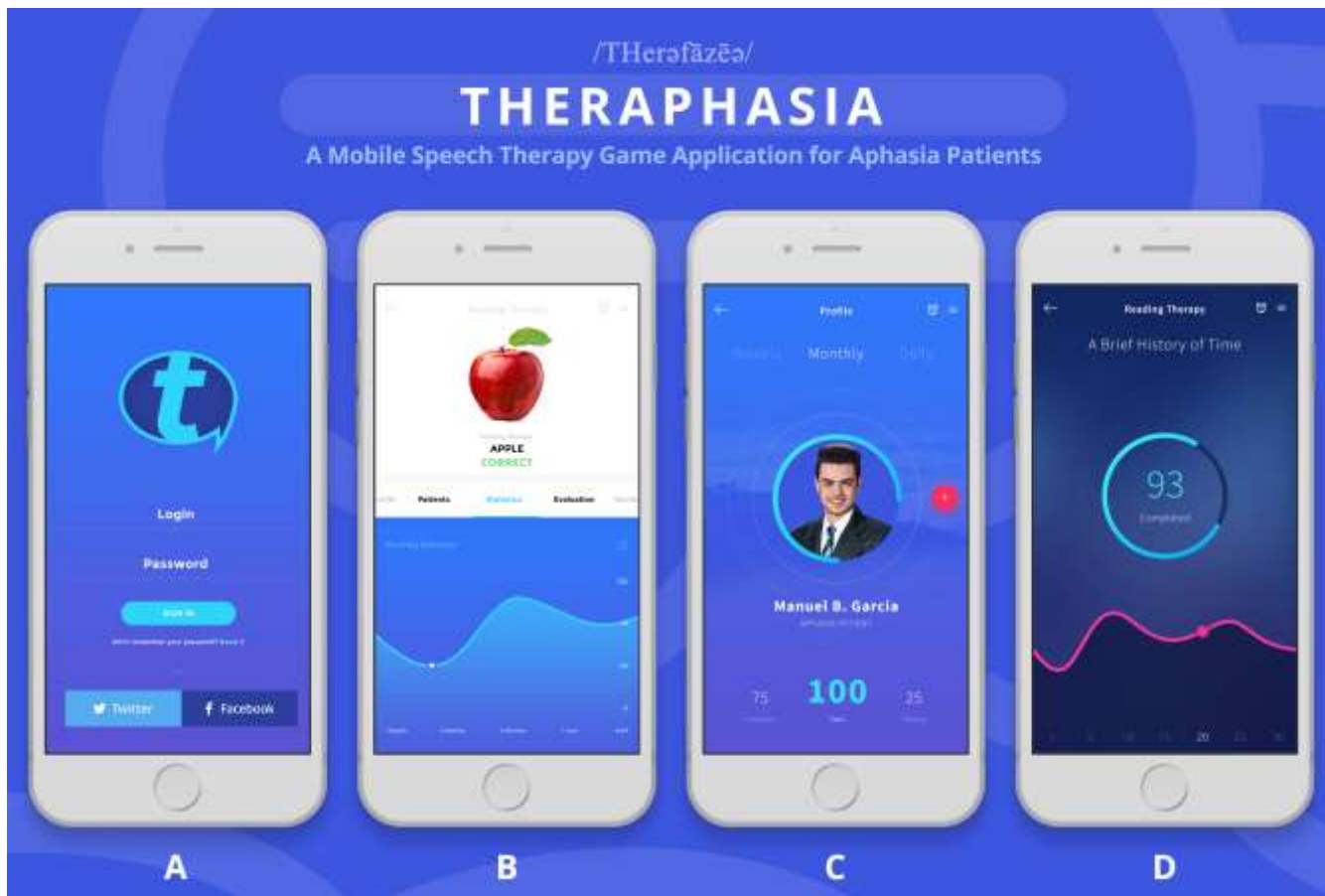


Figure 3. Visual presentation of Theraphasia speech therapy game application mockup design (as shown on a mobile user interface): (A) login system for therapists and patients with social network authentication (Facebook and Twitter); (B) naming therapy with graphical representation of the evaluation and data visualization; (C) patient profile with progress tracker; and (D) reading therapy that records the speech of patients (audio file)

B. Evaluation of Aphasia

Assessment was conducted through the employment of Quick Aphasia Battery (QAB) test as the sole evaluation tool built-in in the game application which was performed before and after the eight-session game-based therapy. The validity and reliability study of QAB was initiated and performed by Wilson *et al.* [20] which was purposely administered with Western Aphasia Battery (WAB) simultaneously to assess concurrent validity of two different Aphasia examination instruments. As previously discussed, QAB consists of eight subtests whereas each subtest has a different number of subsections that contains between 5 and 12 items, each of which is scored on a 5-point scale running from 0 to 4, thereby the transformation of raw scores as a proportion of the cut-off score in order to compare the subtests across time-points. As a result, each aphasic patient fairly received a proportional clinically-relevant final QAB ratings. Part of the expectation after patient' evaluation is that the inbuilt QAB-based assessment feature would be recognized as a helpful and essential module of the mobile game application not only to remove the paper-based assessment but also to automatically calculate each subtest scores and the overall QAB rating, and present findings to therapists in an instant.

C. Intervention Program

In total, eight-session mobile game-based therapy (10–15 minutes per day, once a week, for 8 successive weeks) was applied to the aphasic patients in which they performed all of the tasks scheduled for the session with the help of either their speech therapists or family, or both, who served as the coinvestigators. The tasks per session were all based from the QAB test [20] which includes a conversation using pre-defined open ended questions (connected speech), answering pre-defined questions using the thumbs up/thumbs down button (sentence comprehension), mapping word forms onto their referents by identifying objects containing semantic or phonological foils (word comprehension), repetition of pre-defined words using speech recognition (repetition), picture recognition through confrontation naming (picture naming), mapping of orthographic word forms to phonological word forms (reading aloud), and speaking words consecutively with alternating motion and sequential motion rate (motor speech) which were all performed after patients' traditional speech therapy. The task results were automatically saved to the database which can be accessed by their therapists for further analysis which is an additional layer for making sure that there will be improvements in the patients.

IV. RESULTS AND DISCUSSIONS

All patients (three males, mean age 61.5 ± 9.2 years and two females, mean age 55.2 ± 12.2 years) with aphasia completed their protocol (10–15 minutes per day, once a week, for 8 successive weeks) from pretest assessment using the QAB questionnaire to posttest assessment using the QAB rubric and no hostile events or negative outcomes were encountered during the treatment period. The rehabilitation intervention aimed to cover the lack of repeatability and objective measurability in following the improvements of patients when there is a human involvement. To make sure that the game achieves its goals, feedbacks during the preliminary test using interview method were considered. During this first iteration, the initial game prototype was already developed containing both the patient and therapist interface and was assessed using System Usability Scale (SUS) with objective data such as success rate and time on task for additional insights. Lastly, a comparison of before and after treatment using QAB were conducted by using the built-in feature of Theraphasia as an intervention tool.

A. Feedback of the preliminary test during need analysis

As part of the game research route, a summative test in a form of interview was conducted to gather the feedback of both patients and therapists. During the interview session, several enhancements and suggestions for the improvement of the game were given and were grouped into themes:

- **Device (mobile phone):** A larger screen size like a tablet or desktop computer will be more appropriate since patients with aphasia are normally old.
- **Gameplay goals:** Provide a tutorial that is available in Filipino language before starting the game to ensure that the patients understand the purpose.
- **Scoring:** Aside from the given summary results, an individual scoreboard for each game category will help the patients track their progress.
- **Graphics:** Make the typography bigger and clear, and use a simple background to avoid distraction. If possible, provide a setting menu to adjust the font size and option to change background themes.
- **Audio:** Avoid loud, disrupting background music during the gameplay and enhance the sound effects related to the therapy tasks for each game category.
- **Narrative:** Requested by therapists, a background story in a form of cut scenes showing the life of aphasic people may establish self-relatedness, and decrease the feeling of loneliness and isolation.
- **Level Design:** Change each level background as the patient progress on the difficulty of the tasks.

The aforementioned suggestions for each of the themes were considered, and then integrated into the game design document for further improvement of the mobile speech therapy game. It is expected that these improvements will result to an increase on the user evaluation scores. Following this preliminary test, the final game design was then created.

B. SUS Evaluation for Therapist and Patient Interface

For the final usability evaluation, SUS was used for both therapist and patient interface. Each user performed a task corresponding to their role in the game and the success rate and time on task were both recorded as additional insights on how the users perceive the level of difficulty of the game. The first few game stages per each category comes with an instructional support as a guide. The difficulty was increased by switching to a tricky vocabulary and language, and by reducing the amount of support during gameplay.

TABLE II. SUS SCORES FROM PATIENTS AND THERAPIST

Subject	SUS Score	Success Rate	Time on Task
Patient 1	97.50	93.25	4.43s
Patient 2	97.50	89.50	4.17s
Patient 3	100	98.75	2.25s
Patient 4	97.50	93.25	4.25s
Patient 5	97.50	89.50	4.19s
Therapist 1	77.50	83.50	3.50s
Therapist 2	80	83.50	3.38s

Both patients and treating therapists attested high SUS scores ($\bar{x}_{Patient} = 98$; $\bar{x}_{Therapist} = 78.75$) to the final user interface. An important contributor to the success of the system usability evaluation is the integration of the feedback given during the summative test stage. Noteworthy, both the patients and therapists appreciated the opportunity of having a customization menu for the game. Change in typography, gameplay, and level design brought a significant amount of motivation too in the success of the evaluation. Participants were more confident in manipulating the game because of these improvements thereby the creation of impact in the success rate ($\bar{x}_{Patient} = 92.85$; $\bar{x}_{Therapist} = 83.50$) or the ability of playing the game in their own. However, there still has an improvement to make on the therapist interface particularly on the progress monitoring. The therapists were looking for printable reports of the progress of their patients. And while it was mentioned that the contents will be fixed and there will be no backend interface available for this pilot study, the therapists also eagerly recommended having one available on the web. Lastly, the speed of completing the therapeutic tasks was also recorded ($\bar{x}_{Patient} = 3.86s$; $\bar{x}_{Therapist} = 3.44s$) in order to gain insights on how difficult or easy the gameplay is especially with the game tasks equivalent to QAB. Overall, the final game for the pilot study was efficient in terms of its usability, success rate, and time on task. This was the needed confirmation before the game implementation. After this, the game was mounted as an intervention tool as adjunct to traditional neuromuscular rehabilitation every session in clinical practice environment.

TABLE III. SCORES OF QUICK APHASIA BATTERY (QAB) BEFORE AND AFTER SPEECH GAME THERAPY

QAB Subtests (Game Category)	Pre-treatment [mean ± SD, median (min-max)]	Post-treatment [mean ± SD, median (min-max)]	P*
Connected Speech (Talking Therapy)	1.3 ± 1.6, 0 (0-4)	2.4 ± 1.8, 2 (0-4)	0.0001
Word Comprehension (Word Therapy)	7.2 ± 4, 8 (0-13)	10.7 ± 2.6, 11 (0-13)	0.0000
Sentence Comprehension (Sentence Therapy)	4.7 ± 4.7, 3 (0-14)	7.7 ± 5.1, 8 (0-14)	0.0000
Picture Naming (Picture Therapy)	2.1 ± 2.9, 0 (0-10)	4.6 ± 3.9, 5 (0-10)	0.0000
Repetition (Repeat Therapy)	1.7 ± 1.8, 1 (0-5)	3.1 ± 1.9, 4 (0-5)	0.0000
Reading Aloud (Reading Therapy)	6.5 ± 4.2, 6 (0-14)	10.7 ± 3.5, 12 (0-14)	0.0000
Motor Speech (Speech Therapy)	5.7 ± 6.4, 4 (0-22)	10.2 ± 7.3, 8 (0-22)	0.0000
QAB Total Score	29.2 ± 22, 26 (1-76)	49.4 ± 23, 51 (5-80)	0.0000



Figure 4. Game Score Monitoring and Evaluation Using Therapist Interface

C. Before and After Speech Game Therapy

Apart from the usability evaluation to the game, efficacy was also assessed. First, the patients performed the QAB test before the treatment procedure. After this, eight sessions of mobile game-based therapy (10–15 minutes per day, once a week, for eight consecutive weeks) playing various game categories equivalent to the QAB subtest was performed by the aphasic patients with the help of either their speech therapists and/or relatives. Lastly, the patients performed the QAB test again after the speech therapy sessions. It is pertinent to note that some of the questions and tasks from the QAB subtests were modified a little bit in order to make sure the applicability with the qualified patients. Based on a

clinician’s perspective, tailoring the treatment program to better fit individual patients could produce better outcome.

The connected speech, word comprehension, sentence comprehension, picture-naming, repetition, repetition and reading aloud (P = 0.000; except connected speech with P= 0.0001) scores and total scores (P = 0.000) were significantly improved after treatment compared with before treatment (Table 3). Though the level of consciousness subtest was not part of the report as previously disclaimed, it played an important role in determining whether it is in fact feasible to evaluate language function and the status of the patient [20]. These present findings suggest that incorporating the “play” component, in the form of video game, in the rehabilitation of aphasia can improve speech

production. Although this study could not entirely claim the success of the aphasia treatment as it did not address the neural mechanisms which supports such recovery, it is possible that incorporating the speech therapy game during treatment sessions modulated the frontal speech network that encouraged improved speech production as established by previous evidence [23]. Besides, patients who experience computer-based therapy exercises in addition to traditional therapy sessions have exhibited greater improvements than patients without computer-based rehabilitation intervention according to Stachowiak [24] and Lopes *et al.* [25]. Though, games should be remembered as a complement to traditional therapy sessions and not as a substitute to the practice.

Success notwithstanding, the use of playing Theraphasia does not reduce, in any way, the role and importance of clinician-based aphasia treatment. This is the reason why the game was designed with the therapists in mind. Functional neuroimaging analysis may be needed in order to determine whether there is plasticity in regions in the damaged area [26] especially that the adaptive brain plasticity operates differently in each patient [27], and on lesion site and size [28]. Also worth mentioning, therapists' and participants' feedback alike regarding the video game-based treatment was overwhelmingly positive. One patient even narrated a story when her grandkids bonded and played with her, and taught her how to use the gadget. Additionally, the practical [29, 30] and emotional [30, 31] support of family members (who were assigned as co-investigators in this study) may have also deeply contributed to the positive outcome of the intervention sessions. Future researchers may consider adding a user access and interface for family members since family-oriented interventions on Aphasia patients can result to improved family relationships [32] and an increased acceptance of the altered life situation [33] as aphasia is burdensome for the family members [34]. Nevertheless, one possible reason that can be attributed to the participants' response is the feeling of greater control over their own treatment as opposed to a treatment dictated by a clinician. Moreover, therapists' positive response may be attributed to the ease of treatment delivery and the engagement brought by the game. In closing, the proposed speech therapy game principally drawn from QAB has successfully performed its mission to be a rehabilitation tool for aphasia.

V. CONCLUSION

In this pilot investigation, the preliminary research merits a confirmation that the speech and language therapy applied to aphasic patients using a mobile game-based rehabilitation as an intervention was an effective therapeutic tool towards the treatment of Aphasia in a natural and community-based clinical practice. Findings revealed a statistically significant improvement in aphasia patients' before and after treatment as drawn from the QAB assessment tool covering the level of consciousness, sentence comprehension, picture naming, connected speech, repetition, word comprehension, reading aloud, and motor speech which could serve as a basis for

future research in larger trials since the study is limited by the small sample size. The result is consistent with various studies [35-41] that supports the use of computer-assisted aphasia therapy as a rehabilitation device. Apart from the sample size, there are other limitations that should also be reported. First, there was no non-treated control group for concurrent therapy because of hospital regulations and procedures stating that all stroke patients at the hospital should receive proper treatment. Additionally, the amount of gaming time was self-selected by each aphasia patient as recommended by their therapists though it ranged from 10 to 15 minutes per session. Gaming time and the absence of post-intervention testing are factors that must be controlled in future research. Finally, there were no other evaluators to further validate the outcome measures of the therapies.

For future works, several features grounded from medical studies are part of the consideration although these features deviate from the objective of the application: speech therapy game. Still, there are workaround on how to integrate these features within the game. First, a social networking feature where patients can connect to other patients, perhaps play together, as connecting to other patients with comparable experiences is part of recognized needs of aphasic patients [31]. Online counseling is also a feature to envision where people (patients, family, and therapists) can freely express their feelings whenever they feel open and ready so as to find an expression for frustration and anxiety as verified by old-fashioned counseling [33, 42]. Future studies could also consider testing single and/or specific combination of game categories as drawn from QAB to measure and assess which are the most contributor to intervention efficacy. Altogether, this proof-of-concept study thereby supports the feasibility and provides initial evidence for the appropriateness and applicability of the deployment and implementation of a game-based neurorehabilitation technology in language and speech therapy sessions of aphasic patients. By embedding therapeutic activities in video games, Aphasiologists, speech therapists, and aphasia patients have passionately welcomed the additional supplementary therapy treatment modality in the mainstream speech rehabilitation programs. Game tasks drawn from QAB also led to potentiating therapeutic gains. Lastly, the present review of the implementation of game-based rehabilitation underscored a major contribution to the medical field, and to a greater success of Aphasia treatment.

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