A M-HEALTH PLATFORM FOR SUPPORTING CLINICAL DATA INTEGRATION AND SERVICE DELIVERY: AN EXAMPLE FROM AUGMENTATIVE AND ALTERNATIVE COMMUNICATION INTERVENTION

by

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Submitted to the Graduate Faculty of

School of Health and Rehabilitation Sciences in partial fulfillment

of the requirements for the degree of

Doctor of Philosophy

University of Pittsburgh

2016

UNIVERSITY OF PITTSBURGH

SCHOOL OF HEALTH AND REHABILITATION SCIENCES

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Erh-Hsuan Wang, PhD

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Improving the quality of healthcare while simultaneously reducing its overall costs remains a challenge. One of the recommended approaches for achieving this goal is to build high quality data collection and reporting systems to facilitate evidence-based practice (EBP), which emphasizes the importance of using the solid evidence available to make optimal clinical decisions. Along with the rapid adoption of mobile technologies in health care, many clinicians also use smartphones and tablets to collect and integrate clinical data.

Verbal communication is an essential skill for human beings and a major factor that influences the overall quality of life. People with communication disabilities (PwCD) may benefit from Augmentative and Alternative Communication (AAC) intervention. However, existing AAC technologies are not currently able to provide efficient real-time and clinically relevant performance measures to speech language pathologists.

This work combines mobile and web technologies with AAC intervention to create an integrated platform with a better data analytics approach to support data collection, integration, and reporting, as well as to streamline the workflow of AAC clinical service delivery. To achieve these research goals, three studies were conducted: 1) Exploration; 2) Design & Implementation; and 3) Evaluation. The first study identified the clinical needs and IT requirements of the platform. The second study implemented this platform, including a mobile AAC app, a web-

based portal, and data analysis procedures. The last study evaluated the integrated platform and compared the platform to other existing data collection and reporting approaches.

The usability and feasibility studies of the mobile AAC app were conducted with able-bodied individuals, health professionals, and PwCD. All participants agreed that the app establishes an alternative treatment protocol for communication rehabilitation, which incorporates AAC intervention with self-learning and real-time monitoring. Overall, the study results confirm that the integrated platform provides the ability to collect comprehensive clinical evidence, automatically analyze collected data in real time, and generate clinically relevant performance measures through an easily accessible web portal. The evaluation concluded that the integrated platform offers a better clinical data analytics approach for AAC clinical service delivery.

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PREFACE

I could not have achieved this moment without the inspiration, encouragement, and support of many people. I would like to express my gratitude to everyone who has supported me throughout this journey

First, I would like to thank my advisor Dr. Leming Zhou for his dedicated assistance and guidance, as well as members of the dissertation committee: Dr. Bambang Parmanto, Dr. Valerie Watzlaf, Dr. Katya Hill, and Dr. Jingtao Wang for their invaluable advice and patience. Their expertise, insight, and support throughout this dissertation have inspired me to achieve my best in conducting this research.

I would also like to thank my colleagues in the Health Information Management – students, faculty and staff. They have supported me and stood by my side every step of the way, and made this process so much easier. In addition, special thanks to the AAC Lab, ICANTM Talk Clinic, and AAC Institute for their devotion to this project.

Finally, and most importantly, I would like to take this opportunity to express my love and appreciation to my family and friends for their love, understanding, and encouragement. To my parents, there are no words to express how much your endless love and support have meant to me. I could not have completed this dissertation without them.

1.0 INTRODUCTION

1.1 THE PROBLEM AND MOTIVATION

A report released in 2013 by the Institute of Medicine (IOM) highlighted the significant demand for improving healthcare quality and reducing its cost in the U.S. One of the recommended approaches is to create high-quality data collection and reporting systems, since such systems can provide real-time access to patient data, translate the collected data into medical evidence, and as a result, facilitate evidence-based practice (EBP), which emphasizes the importance of using the best evidence available to make optimal clinical decisions (Ferguson, 2012; Smith, Saunders, Stuckhardt, & McGinnis, 2013). For that purpose, clinicians are required to collect, analyze, report and review their patients' performance data before they adjust treatment.

Verbal communication is an essential skill unique to human beings and a major influence on the overall quality of life; however, over 3.7 million people in the U.S. have a profound communication disability in the U.S. (Beukelman & Mirenda, 2005; Brault, 2012; DeNavas-Walt, Proctor, & Smith, 2010). Augmentative and Alternative Communication (AAC) intervention, including assistive technology and strategies, has been proven to be effective in enabling people with communication disabilities (PwCD) to express themselves, increase social interaction, and maintain independent communication across their lifespans (Katya Hill, Baker, & Romich, 2007). For clinical service delivery, EBP requires speech language pathologists

(SLPs) to collect and review clients' performance data, and to use the best evidence available to make clinical decisions (Katya Hill et al., 2007). Some traditional AAC devices can be used to collect user activity data and generate log files; however, the reports cannot be generated in the same treatment session without extensive manual work, and the log files cannot be retrieved remotely (Katharine Hill, 2001). In recent years, a few mobile AAC applications (apps) have become available to support automatic outcome report generation in real time. Unfortunately, those reports provide limited information for monitoring clinical outcomes. Therefore, the lack of efficient data collection and reporting in AAC intervention profoundly affects the process of clinical service delivery. The goal of this work was to develop an integrated system that can efficiently provide clients' performance reports to SLPs to improve the workflow of clinical service delivery.

In the area of communication science and disorders, this work is motivated by the emphasis of EBP. Sackett, Richardson, Rosenberg, and Haynes (2000) defined evidence-based medicine as the integration of best research evidence with clinical expertise and patient values (Sackett, Richardson, Rosenberg, & Haynes, 2000). In the field of AAC, it is necessary to collect, evaluate, and integrate the best evidence available for decision-making, including personal evidence, internal evidence, and external evidence (Dollaghan, 2007). Dollaghan (2007) has recommended that collecting internal evidence is one of the essential steps of the EBP process, in which evidence can be obtained through quantitative analysis of language samples (Dollaghan, 2007; Katya Hill et al., 2007).

This work is also motivated by the success of mobile technology and web portal platforms in the field of healthcare technology. Mobile technologies have been widely adopted throughout healthcare service delivery in recent years by targeting healthcare professionals and

patients, as well as healthy people (Fiordelli, Diviani, & Schulz, 2013). The portability and accessibility of mobile devices present an obvious opportunity for supporting a better quality of care in the health field. Available literature suggests that the use of mobile devices may serve a wide variety of purposes, such as disease diagnosis and assessment (Kumar, Wang, Pokabla, & Noecker, 2012; Takao, Murayama, Ishibashi, Karagiozov, & Abe, 2012), disease management and monitoring (Logan et al., 2007; Mattila et al., 2008), disease prevention (Cole-Lewis & Kershaw, 2010; Whittaker, Merry, Dorey, & Maddison, 2012), health education or promotion (Gerber, Stolley, Thompson, Sharp, & Fitzgibbon, 2009; Jordan, Ray, Johnson, & Evans, 2011), and data collection and reporting (Tomlinson et al., 2009; Yu, de Courten, Pan, Galea, & Pryor, 2009). These studies have suggested there are tremendous potential benefits in using mobile devices to provide more efficient, accessible, lower cost, and better quality of healthcare services. The advantages of mobile apps for real-time data collection and retrieval are very useful for healthcare professionals in patient monitoring (Ventola, 2014). A web portal may serve as a web-based resource that provides healthcare professionals with convenient access to comprehensive information about their patients' clinical performance.

1.2 SIGNIFICANCE

It is a challenging task to simultaneously improve the quality of healthcare and reduce its overall costs. One of the recommended approaches for achieving this goal is to build high-quality data collection and reporting systems to facilitate EBP. The adoption of mobile technologies in healthcare services has provided new ways of capturing user activity data and providing real-time outcomes. Patient-generated data can be used to monitor patient outcomes, improve

treatment strategies, and translate information into medical evidence by providing real-time access to knowledge. Integrating mobile devices and a web-based portal could serve as a platform to provide AAC service delivery the potential to allow SLPs, PwCD, and researchers to get a better view of future care improvement. The aim of this work is to integrate AAC service delivery with mobile health (mHealth) by extending traditional clinical intervention with a mobile AAC app and a web-based clinician portal to streamline the workflow of service delivery.

1.3 SPECIFIC AIMS AND HYPOTHESES

The aim of this work was to integrate AAC service delivery with mHealth by extending the traditional clinical intervention with both a mobile AAC app and a web-based clinician portal to streamline the workflow of service delivery. This research is divided into three studies: 1) Exploration; 2) Design and Implementation; and 3) Evaluation. The following specific aims were identified to achieve the overall goal of this work.

Study 1: Exploration. The clinical needs and IT requirements of the platform to support services were identified by (1) reviewing the literature to determine design criteria; (2) conducting a technical assessment on current AAC technologies; (3) conducting an interview with SLPs to explore their perspectives on service delivery; and (4) conducting a survey to understand SLP's clinical needs on performance measures. These research findings were applied to design a system architecture for AAC clinical service delivery that integrates all the

components, including people (SLPs and PwCD), technology (mobile app and web portal), and strategy (AAC intervention).

Aim 1.1: To identify the requirements of the integrated mHealth platform.

Aim 1.2: To design a system architecture for AAC clinical service delivery.

Aim 1.3: To verify the design of the architecture against the identified requirements.

Hypothesis 1: The designed architecture can capture the identified requirements.

Study 2: Design & Implementation. The mobile AAC app was designed and implemented to collect and process user-generated data in real time. This mobile app was developed according to the design principles of the system architecture. Along with typical clinical web portal design principles, the analyzed results from the survey were used to design and develop the web-based clinician portal.

Aim 2: To implement an integrated platform with a mobile AAC app and a web-based clinician portal.

Hypothesis 2: The integrated platform is properly implemented, according to the designed architecture and verified requirements.

Study 3: Evaluation. A usability study was conducted to discover problems in the implemented mobile app. After the identified problems were fixed, a feasibility study was conducted to evaluate the viability of the mobile app for potential users. The integrated platform was compared with the existing approaches on defined characteristics. A usability study was conducted to evaluate if the proposed approach provides a better workflow for data collection and reporting for clinical intervention.

Aim 3: To evaluate the effectiveness, efficiency, user satisfaction of the integrated system.

Hypothesis 3: The proposed method can better support AAC clinical service delivery compared to the existing approaches.

1.4 DISSERTATION OUTLINE

The remainder of this dissertation consists of five chapters:

2.0 LITERATURE REVIEW provides a review of the literature, situating this study in using mHealth in AAC service delivery to support evidence-based practice, and providing background about the three key components: mobile health, communication disabilities, and evidence-based practice.

3.0 EXPLORATION identifies the clinical needs and technical requirements of the integrated platform based on the results from clinician interviews, technical assessments, and literature findings. A system architecture is designed in order to provide design guidelines for the integrated platform.

4.0 DESIGN AND IMPLEMENTATION describes interface design and system development of the tablet-based AAC app and the web-based clinician portal.

5.0 EVALUATION provides the evaluation methods and results of the user studies, including the usability and feasibility studies of the mobile AAC app, as well as the usability study of the integrated platform. It is divided into several sections: the purpose of the study, the experimental design, and the study results.

6.0 CONCLUSION AND DISCUSSION concludes the dissertation by presenting overall results and study implications, identifying limitations, and suggesting future research directions.

Figure 1 provides a visual overview of the background, problem, objective, and research methodology of the three studies.

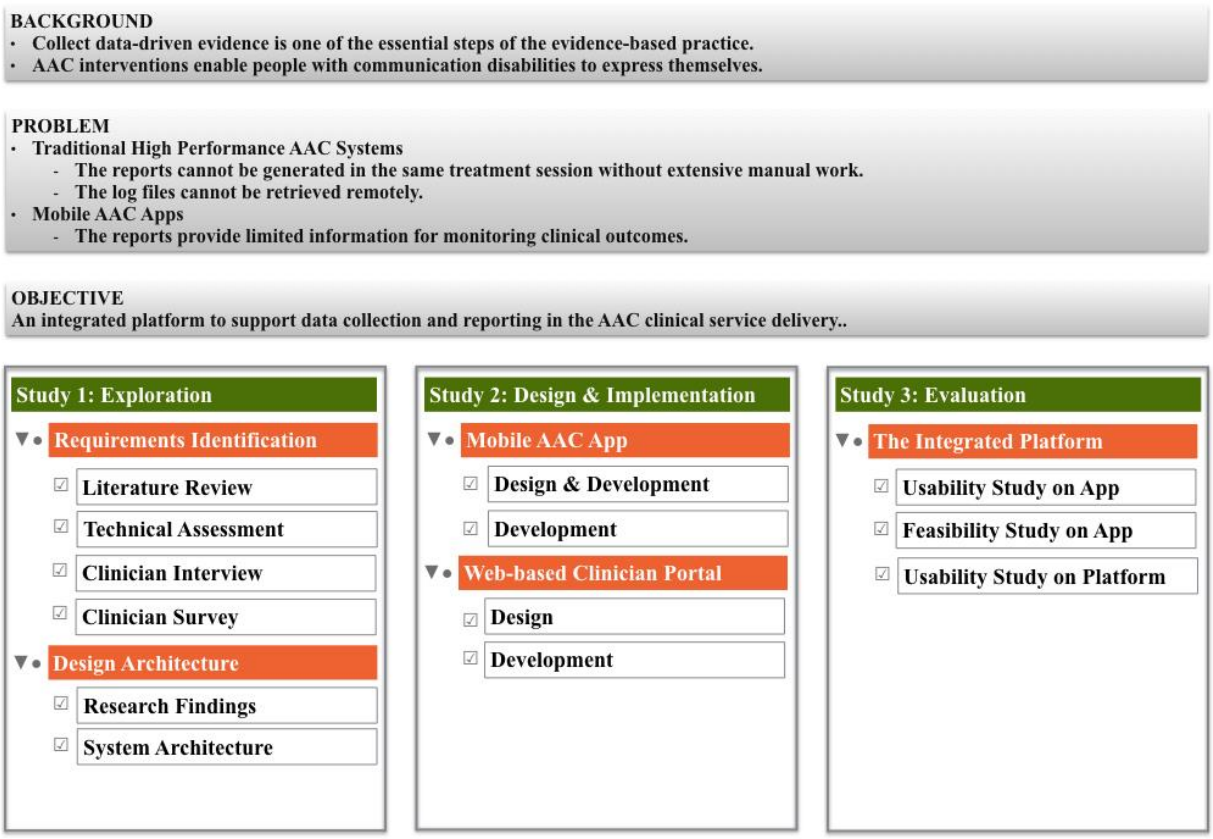


Figure 1. Overview of the Dissertation Work

2.0 LITERATURE REVIEW

2.1 HEALTHCARE AND TECHNOLOGY

In the effort to improve the quality of care and to reduce overall healthcare costs, health technologies are emerging as a key driver in the transformation of healthcare. The Health Information Technology for Economic and Clinical Health (HITECH) Act was signed into law in 2009 to improve health care quality, safety, and efficiency through the promotion of health information technology (HealthIT.gov, n.d.).

2.1.1 Telemedicine and telehealth

Telemedicine was introduced 40 years ago to support extended care to patients in remote areas (American Telemedicine Association, n.d.-a). Along with improvements in technology and medicine, many different healthcare fields have integrated the use of telemedicine. The American Telemedicine Association (ATA) defines telemedicine as the use of medical information exchanged from one site to another via electronic communications to improve a patient's clinical health status. Telemedicine includes a growing variety of apps and services that use two-way video, email, smartphones, wireless tools and other forms of telecommunication technology (American Telemedicine Association, n.d.-b, n.d.-c). It refers to the actual delivery of remote clinical services using technology. The term "telehealth" is closely associated with

telemedicine, which was introduced to present a broader scope of remote care that does not always involve clinical services, such as medical education and nursing call centers (American Telemedicine Association, n.d.-c; Fatehi & Wootton, 2012). U.S. Department of Health and Human Services (HHS) defined telehealth as the use of technology to deliver health care, health information or health education at a distance (U.S. Department of Health and Human Services, n.d.). Health care services provided by telemedicine include: (1) primary care and specialist referral services; (2) remote patient monitoring; (3) consumer medical and health information; and (4) medical education (American Telemedicine Association, n.d.-b).

Intervention services can also be delivered via telemedicine. One of the advantages of in-home visits for children with disabilities is to provide services in natural environments. However, in rural areas, families may need to undertake a substantial amount of travel and time to reach medical services. Kelso, Fiecbtl, Olson, and Rule's (2009) study evaluated the feasibility of using videoconferencing to provide intervention services through the Internet without travel. Different from distance education that usually uses simultaneous visual and voice contact, this study examined the benefits and limitations of a two-way interactive service model that targeted children with disabilities aged between 0 to 3 years. In the study, the researchers used desktop videoconferencing (a computer with a web camera) to deliver early intervention services to participated families. This early intervention educated parents in how to meet the special needs of their children with disabilities. The overall experiences from the participants showed that early intervention via desktop videoconferencing is usable and satisfactory, although additional troubleshooting resources are expected to be provided in the future (Kelso, Fiecbtl, Olsen, & Rule, 2009).

Telehealth has been widely used in medical education. Continuing medical education (CME) programs provide healthcare professionals with resources to meet their professional needs; however, travel time and costs may become an issue. In the early years, telehealth medicine programs were limited due to the high costs and technical limitations. In Callas, Ricci, and Caputo's (2000) study, remote attendees were asked to complete an evaluation form after a remotely attended CME program. Questions regarding their perspectives on telehealth were also included. The results showed that 77% of the respondents would not have attended if the program had not been available via telehealth. In addition, 73% of the respondents concluded that the telehealth program is just as effective as attending a program in person (Callas, Ricci, & Caputo, 2000).

2.1.2 Mobile health (mHealth)

The key difference of mHealth is the "mobility aspect" from health-related information technology solutions, as discussed previously. Mobile communication devices, in conjunction with Internet and social media platforms, present opportunities to enhance disease prevention and management by extending health interventions beyond the reach of traditional care – an approach that is referred to as mHealth (Estrin & Sim, 2010). The mobile phone market is constantly evolving, and the majority of people now own mobile devices of some type. The use of smartphones is rapidly expanding in the healthcare fields, since the ubiquity of smartphones makes them an ideal tool for enhancing the quality of health care. We have seen increasing adoptions of smartphone-based apps by both healthcare professionals and the general public in recent years, and these apps are used for medical reference, medical education, patient

monitoring, point-of-care, personal care, and fitness. mHealth is part of a key trend in the delivery of health care.

mHealth is referred to as the use of mobile communication devices, such as mobile phones and tablets. In healthcare services delivery, mHealth is aimed to improve the quality or effectiveness of health care, including health outcomes, services, and research (HIMSS, 2012; Torgan, 2009; World Health Organization, 2011). With the growing mobile market worldwide, the idea of improving quality care services through the utilization of smartphones or tablets marks a revolution to the healthcare system.

2.1.3 The characteristics of mHealth

Similar to telemedicine and telehealth, mHealth offers the following benefits (Eysenbach, 2001; Free et al., 2010; Mosa, Yoo, & Sheets, 2012; Tachakra, Wang, Istepanian, & Song, 2003):

- Supporting greater patient access to the health care services: Mobile devices provide patients with higher accessibility to healthcare services.
- Improving health information sharing with real-time, location-based data: Real-time data is beneficial for both patients and healthcare providers, as it provides information on the most recent health status of patients. Moreover, patient location information is critical, especially in emergencies.
- Providing ongoing patient-physician communication: Patient-physician communication can take place more frequently be improved via mobile devices, instead of at a one-time visit at a hospital.
- Lowering costs: Higher accessibility, better quality, less transportation, and shorter waiting times are all necessary components of lowering health care costs.

- Increasing patient safety: With supported medical apps, there is a reduced possibility of medical errors occurring.
- Reducing health disparities: People in rural areas could get an equivalent quality of care services, despite distance barriers.
- Empowering patients' self-care management: Patients could achieve a higher degree of control over their personal health.

2.1.4 Application of mHealth

There is growing research evidence that mHealth allows healthcare professionals to monitor patient conditions, while simultaneously enabling individuals to monitor their own health. Blake (2008) conducted a systematic review of the contribution of mobile technology to healthcare management in chronic diseases. The review concluded that there are significant benefits to using mobile devices in healthcare systems and that they will become increasingly important in the healthcare field (Blake, 2008). Chronic disease management apps help patients with chronic conditions, such as diabetes and Parkinson's disease, to regularly track their vital signs, monitor medical symptoms, adhere to care regimens, and change life behaviors (Goyal et al., 2016; Pan, Dhall, Lieberman, & Petitti, 2015). An alert system was implemented in the study of Hardinge et al (2015), in which an alert signal was sent to a patient when a particular medical treatment was initiated. The alert was determined by patient-generated clinical data (Hardinge et al., 2015). Moreover, in order to support continuous self-management for patients with chronic diseases, Park, Cho, and Kim (2016) developed a mHealth app to ensure the interoperability of various personal health devices and electronic medical record systems (Park, Cho, & Kim, 2016).

To shift self-monitoring to coordinate better across the continuum of care, Kock et al. (2015) implemented a mobile app to provide information about the patient's individual aftercare plan and appointment management. The app was designed to support long-term follow-up for childhood cancer survivors (Kock et al., 2015). Another mHealth app developed by Layton et al. (2014) also focuses on follow-up care, which monitors medication compliance in patients with cardiac disease around the time of their discharge (Layton et al., 2014). Furthermore, mobile technologies enable better two-way communication between clinicians and patients. A virtual consultation can be provided on a timely basis, with supporting evidence collected through episodes of self-monitoring (Hartman et al., 2014; Parmanto, Pramana, Yu, Fairman, & Dicianno, 2015; Torbjornsen et al., 2014).

Several articles discussed self-monitoring for people with mental disorders. For example, Beiwinkel et al. (2016) indicated that relapse prevention in bipolar disorder can be improved by a mobile monitoring app, which tracks a patient's daily mood, physical activity, and social communication (Beiwinkel et al., 2016). Some other studies also suggested that the mHealth apps have the capacity to improve health outcomes for people with mental disorders through self-monitoring and teletherapy (Juengst et al., 2015; Owen et al., 2015; Pramana, Parmanto, Kendall, & Silk, 2014; Tregarthen, Lock, & Darcy, 2015; Watanabe et al., 2015). Weight control is another example of the mHealth applicability to self-monitoring. Burke et al. (2012) conducted a 24-month randomized control trial of overweight adults in which participants were assigned into three different groups (paper-based, mobile-based, and mobile-based with social intervention). Findings from this study suggested that both the use of mobile-based tools and feedback messages enhanced self-monitoring adherence and improved weight loss outcomes (Burke et al., 2012). Another study conducted by Patrick et al. (2014) also concluded that using

mobile and social technologies could promote healthy weight-related behaviors (Patrick et al., 2014).

Mobile technology, wearable technology, wireless sensors, and advances in analytic techniques have enabled individuals, healthcare professionals and researchers to collect a large amount of data that could help them make better decisions to improve health. Gay and Leijdekkers (2015) demonstrated a mobile app, which is used to aggregate health and fitness data from several sources and integrate that data into one place. The result of the study showed that the app with a data-analytics approach offers better and more personalized care for individuals (Gay & Leijdekkers, 2015). Another study used a wearable sensor to track the patient's trunk posture. The data collected through the sensor could support healthcare professionals in the functional assessment of trunk endurance (Banos et al., 2015). Moreover, collecting field data periodically or even collecting comprehensive information on specific events could help researchers to predict health issues that could arise in the future (Eskenazi et al., 2014; Raja, Tridane, Gaffar, Lindquist, & Pribadi, 2014).

2.1.5 mHealth apps

An app review was conducted to have a better understanding of the existing mHealth apps on the market. This analysis was based on information from the Apple App Store and Google Play in October 2014. A total of 400 apps were reviewed, including the top 50 Free/Paid iOS Health & Fitness apps, the top 50 Free/Paid iOS Medical apps, the top 50 Top Free/Paid Android Health & Fitness apps, and the top 50 Android Medical apps. By reviewing the detailed descriptions of each app, these apps were grouped into seven categories, based on functional similarity: fitness

and diet, health activity, health monitor, personal health record, prenatal and neonatal care, medical reference, and sleep aid. Table 1 lists the main features of each apps' category.

Table 1. The mHealth App Categories

Categories	**Features**
Fitness & Diet	• Fitness – activity tracker, exercise guide, visual trainer, pedometer • Diet – food tracker, calorie counter, recipes, carb control • GPS tracker – running, cycling • Weight loss – physical activity & food tracker, goal setting • Interval timer – workout timer for interval training • Hypnotherapy
Health / Medical Activity	• Online consultation – discuss symptoms with a live doctor • Appointment scheduling • Medical images sharing (among healthcare professionals) • Note-taking – clinical notes • Meditation • Yoga • Quit smoking • Brainwave entertainment

Table 1 (continued)

Health Tracker / Monitor	• Health tracker/monitor – diabetes log, cancer screening, blood pressure, heart rate, heartbeat, temperature • Period tracker • Medication - pill monitor, medication reminder • Disease surveillance
Personal Health Record	• Personal health/medical information • Family health/medial information • Insurance information
Prenatal & Neonatal Care	• Pregnancy test • Pregnancy tracker, guide • Baby tracker, development information • Contraction timer • Baby heartbeat recorder
Health / Medical Reference	• Medical reference – emergency, diagnoses, paramedic protocol, anatomy, lab value, medical literature, dictionary • Health reference – clinical resources, disease and conditions, treatment information • Medication reference – drug reference, pill identifier, drug price comparison • Exam Preparation - quizzes, review guides • Calculator – medical equations, conversions, dosage

Table 1 (continued)

Sleep Aid	• Sleep cycle alarm clock • White noise, nature sounds • Sleep tracker • Snoring management • Meditation • Yoga • Hypnotherapy
Others	• Online ordering – contact lenses • Blood donation – donor information • Marijuana information • Dream interpreter • Aromatherapy • Thermometer • Improve hearing

Figure 2 shows that 30% of the mHealth apps fall under the health and fitness category; 26% are health and medical references; 16% focus on health trackers/monitors; and 10% of the apps are about prenatal and neonatal care. The rest of the categories (sleep aids, health activity, and personal health records) represent less than 10% of the market share.

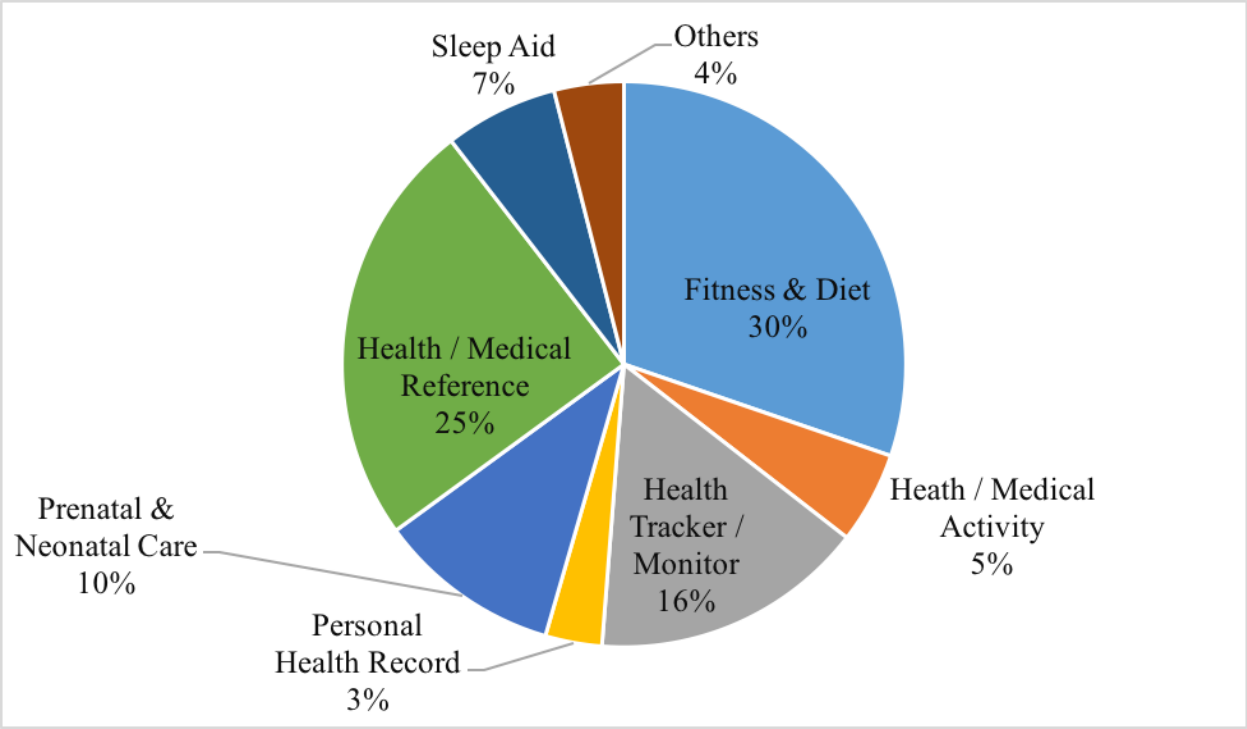


Figure 2. The Percentages of mHealth App Categories

2.2 COMMUNICATION DISABILITIES

2.2.1 Communication disabilities

Communication is vital to living. It is important to people of all ages to share information, their feelings, and their thoughts with others. Most people use their natural speech to communicate with others. However, for people with communication disabilities, communication problems may affect their ability to speak or communicate spontaneously. According to American with Disabilities in 2010, there are over 3.7 million people in the United States with profound communication disabilities (Beukelman & Mirenda, 2005; Brault, 2012; DeNavas-Walt et al., 2010). The American Speech-Language-Hearing Association (ASHA) provided the following

definition of a communication disorder (American Speech-Language-Hearing Association, 1993):

> *A **Communication disorder** is an impairment in the ability to receive, send, process, and comprehend concepts or verbal, nonverbal and graphic symbol systems. A communication disorder may be evident in the processes of hearing, language, and/or speech. A communication disorder may range in severity from mild to profound. It may be developmental or acquired. Individuals may demonstrate one or any combination of communication disorders. A communication disorder may result in a primary or it may be secondary to other disabilities.*

2.2.2 Assistive technology for people with communication disabilities

Communication is what makes us uniquely human. The National Joint Committee for the Communication Needs of Persons with Severe Disabilities developed a Communication Bill of Rights in 1992, which illustrated that all people with a disability have the right to communicate to the fullest extent possible (Brady et al., 2016). Healthy People 2020 also emphasized that people with disabilities need to receive well-timed interventions, interact with their environment without barriers, and participate in everyday life activities (HealthyPeople.gov, 2014). Therefore, an effective communication aid should give users the ability to express themselves as naturally as possible. Assistive technology or assistive devices can refer to devices that help people with communication disabilities to express themselves, which may increase social interaction and feelings of self-worth.

2.2.3 Augmentative and alternative communication

According to ASHA, “People with severe speech or language problems rely on AAC to supplement existing speech or replace speech that is not functional (American Speech-Language-Hearing Association, n.d.).” Augmentative and Alternative Communication refers to any communication approach that supplements or replace natural speech and/or writing that may be impaired (Katya Hill et al., 2007). It includes devices, various types of content used to express needs and thoughts, and clinical strategies to enhance or replace natural speaking abilities. AAC can be considered an approach of communication, as well as a tool to develop language skills. AAC strategies can range from no-technology (using a pencil and a paper for manual signs) to high-technology (electronic devices with vocal output). The AAC technique has been proven to enable people with communication disabilities to express themselves, increase social interaction, and maintain independent communication across the lifespan (Katya Hill et al., 2007). The development of AAC technologies has also paralleled changes and innovations in computing technologies.

In the early 1980s, dedicated AAC devices began to incorporate microprocessor technology. Some AAC manufactures offered communication software, coupled with physical access options, for use on personal computers (Brandenburg & Vanderheiden, 1987). Also, speech generating devices (SGDs) began to serve not only as a platform for interpersonal communication, but also as a way to perform other functions, such as word-processing, data entry, and gaining access to new learning experiences. Even though access strategies have increased over time, there are still significant physical, cognitive, and linguistic barriers to communication for many individuals who could benefit from AAC (Shane, Blackstone, Vanderheiden, Williams, & DeRuyter, 2012).

Mobile technologies are relatively more portable and affordable than traditional AAC devices. Therefore, mobile apps can provide powerful new tools for people with communication disabilities to facilitate their communication needs. The advantages of mHealth have been recognized to make communication more accessible and cost-effective for people with communication disabilities (Rehabilitation Engineering Research Center on Communication Enhancement (AAC-RERC), n.d.). Intuitive design strategies used to create the apps that employ symbols and sounds can provide an alternative way to communicate and offer a learning tool to build vocabulary and enhance word knowledge. On the other hand, such apps allow clinicians and researchers to have unprecedented accessibility to data collection (Gosnell, 2011). In the past few years, there has been an explosion of mobile apps available to support communication (Alliano, Herriger, Koutsoftas, & Bartolotta, 2012; Gosnell, 2011; Hershberger, 2011). Mobile AAC has offered a number of potential benefits for people with communication disabilities, including increased awareness and social acceptance, greater consumer empowerment, increased adoption rate, greater functionality and interconnectivity, and research advancement (McNaughton & Light, 2013). Like traditional AAC devices, these mobile devices often have touch screens, plenty of processing power and speech output capabilities. While there may be trade-offs such as durability and accessibility, price and convenience often make these products an attractive alternative to traditional AAC devices (Hershberger, 2011).

2.3 EVIDENCE-BASED PRACTICE

Evidence-based practice (EBP) is the integration of best research evidence with clinical expertise and patient values (Sackett et al., 2000). It emphasizes the importance of using the most solid

evidence available to make optimal clinical decisions. However, in the field of communication disorders, making a decision on the basis of an expert opinion is inherently limited (American Speech-Language-Hearing Association, 2004). As a result, E^3BP was suggested as a way to factor in all three types of evidence. Dollaghan (2007) defined E^3BP as the conscientious, explicit, and judicious integration of 1) best available external evidence from systematic research; 2) the best available evidence internal to clinical practice; and 3) the best available evidence concerning the preferences of a fully informed patient. Figure 2 represents the synergy that occurs among these evidence categories when savvy clinicians apply E^3BP (Dollaghan, 2007; Katya Hill et al., 2007).

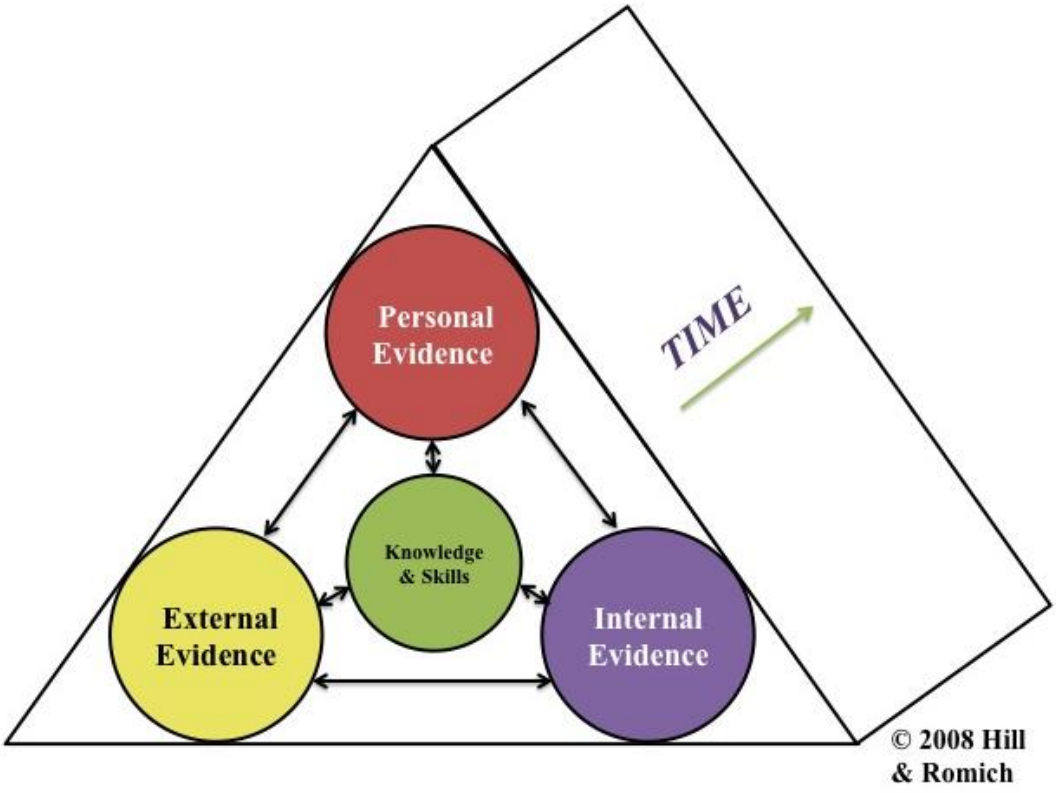


Figure 3. Evidence-based Practice Integrates Personal, Internal, and External Evidence

Internal evidence to clinical practice with a particular patient is an important complement to external evidence from systematic research; although high-quality external evidence can

reveal valuable information about average patterns of performance across groups of patients, its applicability to an individual patient is unknown (Bohart, 2005). Internal evidence is collected through quantitative analysis of language samples, which results in performance data on how someone uses AAC assistive technology and strategies (Katya Hill et al., 2007).

3.0 EXPLORATION

3.1 IDENTIFICATION OF PROBLEMS AND NEEDS

3.1.1 Literature findings

The Healthy People 2020 initiative emphasized that people with disabilities need to receive well-timed interventions, interact with their environment without barriers, and participate in everyday life activities (HealthyPeople.gov, 2014). These should also be the goals for PwCD.

Currently, AAC technologies used by PwCD are mainly traditional SGDs and mobile AAC apps (Alliano et al., 2012). Based on SLPs' clinical experiences and observations, feedback from the targeted end users (PwCD), as well as a comprehensive review of the literature, the currently available AAC technologies present a number of limitations for both PwCD and SLPs to receive and provide effective AAC services and to achieve desired communication outcomes. The details of three major limitations follow.

First, existing mobile AAC apps may not support PwCD reaching the desired communication quality in everyday life, since some specific features limit PwCD performance. The primary features of an AAC system are based on how language is represented and generated (Katya Hill et al., 2007). Although there are many mobile AAC apps on the market, a majority of these AAC apps have failed to support PwCD with a systematic approach to generate utterances,

which include vocabulary selection and organization. For example, using pre-stored sentences may be convenient for PwCD to use the app at first; however, their continued use does not lead to long-term benefits, such as language development or the spontaneous novel utterance generation (Donald, 1988; Katya Hill, 2010). A previous study on one AAC mobile app showed that AAC users' real-time communication did not include significant use of the pre-stored sentences available in the system (Balandin & Iacono, 1999). Mainly relying on pre-stored sentences can limit the potential for PwCD to generate their own words and sentences to express their unique ideas and needs. Ultimately, these AAC apps limit the linguistic and communication competence that an individual can demonstrate.

Second, the currently available AAC technologies cannot support traditionally recommended face-to-face treatment approach at a low cost. The intensity of treatment is a key component of successful communication rehabilitation across different communication disorders such as aphasia (8 intervention hours/ week), and autism (38 intervention hours/week) (Bhogal, Teasell, & Speechley, 2003; Sallows & Graupner, 2005). However, typical insurance plans may cover only 60 hours across all types of rehabilitation services over a single year. A tremendous gap exists between professional recommendations for therapy and insurance companies' limits for coverage.

Third, the patient performance report from SGDs is either not conveniently available or does not provide patient-friendly information. Progress monitoring is one important factor in self-regulated task engagement (Bhogal et al., 2003). The feedback provided to PwCD throughout the learning process can be critical to PwCD's task engagement (Butler & Winne, 1995). An evidence-based practice also requires clinicians to collect and evaluate PwCD's performance data so that they can make optimal clinical decisions. Some traditional SGDs can

store PwCD's activity data as Language Activity Monitoring (LAM) log files (Katharine Hill, 2001). A basic LAM log file includes the timestamp of each language event, the content of the event, and the representation method of the event. To measure communication performance, the LAM log file needs to be downloaded from the SGDs, and then a specifically designed computer program (Performance Report Tool, or PeRT) needs to be used to extract the desired data from the LAM log file (Katharine Hill, 2001). Because of this manual and multi-step process, clinicians typically generate a performance report after the treatment session, which is later provided to the PwCD. In other words, the PwCD can never obtain real-time feedback about their performance when they use traditional SGDs (Katya Hill, 2004). A few mobile AAC apps provide outcome reports to their users (Speak For Yourself AAC, n.d.). However, the reliability and validity of such outcome data are highly questionable, because their calculation methods may not be well tested or may be based on existing, inadequate standards.

To summarize comprehensive review (Table 2), the currently available AAC technologies have clear limitations in supporting PwCD's communication needs and improving their communication skills. The recommended communication rehabilitation regimen is difficult to follow under the current health care system. Without sufficient therapy sessions, PwCD may not learn how to use the SGDs or mobile AAC apps effectively, nor will they be able to improve their communication skills and reach their full language potential. Currently existing AAC systems do not concurrently support automatic data collection and reporting processes with meaningful clinical information. In addition, the lack of high intensity treatment sessions with experienced SLPs and a lack of quality control on system design profoundly affect the life experience of an individual with a severe spoken - language communication disability.

Table 2. Summary of Comprehensive Review

Type of AAC	**Limitations**
Dedicated AAC Devices	• A big gap in treatment • No automatic analysis • No real-time reporting • Prohibited funding policies and procedures • Stigma • High abandonment rates
Mobile AAC Apps	• Insufficient language elements • Limited clinical support or technical guidance, warranties • Reported data is not quantified or available for analysis • Evidence on user performance not available • Lack of research-based design • High abandonment rates

3.1.2 Technical review

Based on the research findings and research goals, key characteristics were identified throughout the entire data collection and reporting process. Five key characteristics of the integrated system include: comprehensive, automatic, real-time, clinically relevant, and easily accessible.

Comprehensive: Collect a comprehensive internal evidence.

Automatic: Automatically analyze collected data.

Real-time: Analyze collected data in real-time.

Clinically relevant: Generate clinically relevant performance measurements.

Easily accessible: Provide easily accessible clinical information.

Figure 4 illustrates the process of data collection and reporting in AAC clinical service delivery on an mHealth platform. Starting from data input on mobile devices, the mobile app directly collects comprehensive internal evidence from users. During the process of analysis, the collected user data is analyzed automatically in real-time on the server, and clinically relevant performance measurements can be generated. In the last step, an easily accessible performance report is provided on a web-based portal for clinicians, where the report is designed to support clinical evaluation and decision-making.

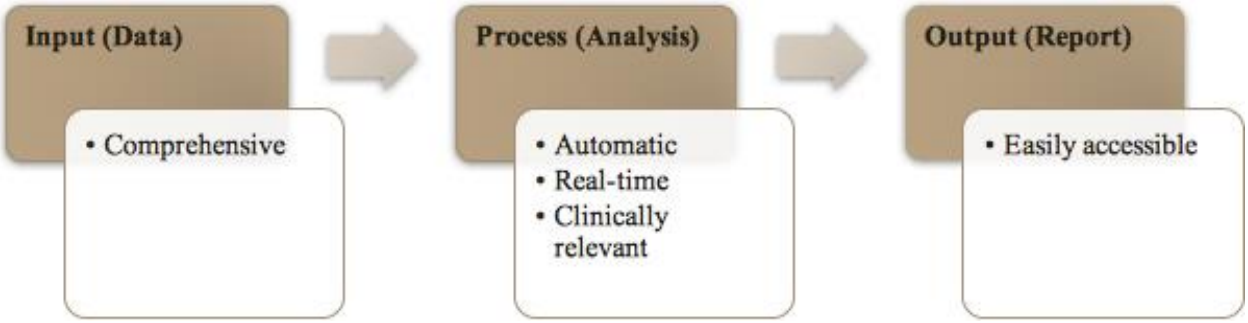


Figure 4. Key Characteristics of the Integrated System

With the identified five key characteristics, the capabilities of existing AAC technologies were examined for the purpose of gap analysis. AAC technologies include low-tech (paper and pencil) and high-tech (dedicated devices, computers, and mobile devices) approaches. In this work, only high-tech devices are discussed because of their abilities for data collection and reporting. Two data collection and reporting approaches were identified and examined: one approach is used on the dedicated AAC devices, and another is used on the mobile AAC apps.

Approach #1: Dedicated AAC Device

One of the most sophisticated approaches was developed in Hill's work (Hill, 2000). This approach was specifically designed to use in dedicated devices. The language sample is automatically recorded, including the content and time of language events generated during the use of the AAC devices. The sample data consists of two required fields and one optional field. Two required fields present a timestamp and the content of each language event. The optional field presents a three-letter mnemonic indicating how the language event was generated. Figure 5 shows an example of the collected language sample, including the language content, the language timestamp, and the generation method. The language sample is stored as a text file (LAM file) in the device. SLPs can retrieve the data log through a USB flash drive.

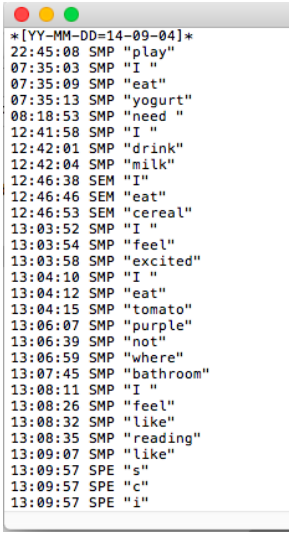


Figure 5. An Example of a Collected Language Sample

After the data log is obtained by SLPs, the file can be processed through the computer software (PeRT). In order to create a performance report, two steps are included in this process. Figure 6 provides a screenshot of the main page of the PeRT interface. In the first step, SLPs manually segment utterances (left panel of Figure 6). Once all language events are segmented

into utterances (top right of Figure 6), a performance report can be automatically generated. Figure 7 illustrates the process of this approach.

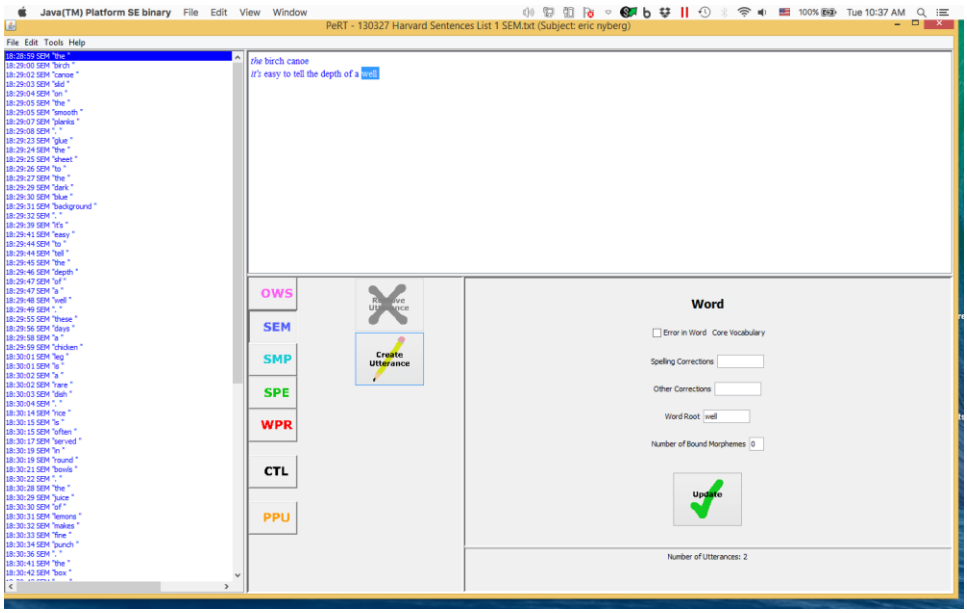


Figure 6. Screenshot of the Computer Software (PeRT)

Figure 7. The Process of Data Collection and Reporting – Dedicated AAC Device

Approach #2: Mobile AAC App

The second data collection and reporting approach was implemented in a mobile AAC App, which is called Speak For Yourself (Speak For Yourself AAC, n.d.). The app is able to collect user data and automatically generate performance reports in real-time. As shown in Figure 8, the app provides SLPs a brief summary of user performance, as well as the full word and utterance list. The timestamp of each event is also included in the report. SLPs can either

review the result directly in the app or ask their clients (or caregivers) to email the report through the app. Figure 9 illustrates the process of this approach.

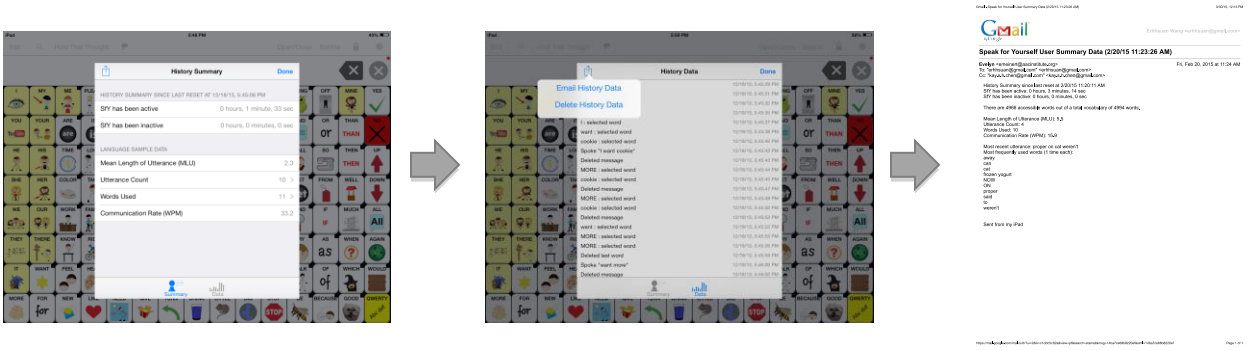


Figure 8. Screenshots of the Mobile App (Speak For Yourself)

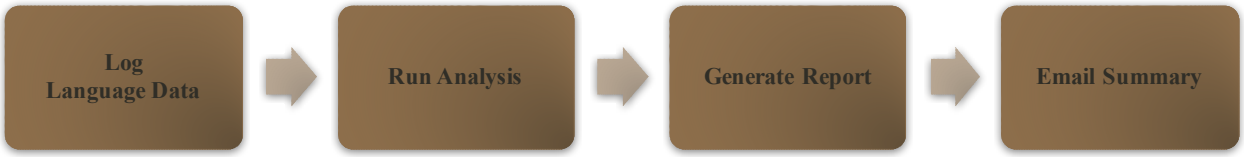


Figure 9. The Process of Data Collection and Reporting – Mobile AAC App

The result shows that the dedicated AAC devices can collect a comprehensive internal evidence and can generate a clinically relevant performance report. However, there are limitations in real-time automatic analysis, as well as the accessibility of information. When using the mobile AAC app, although data can be collected and automatically analyzed in real-time, the quality of the information provided is still a concern. Therefore, these two types of high-tech AAC technologies are not fully able to include these five characteristics in their data collection and reporting approaches. Table 3 provides a checklist for two existing data collection and reporting approaches in terms of their capabilities in the five key characteristics.

Table 3. Gap Analysis on Data Collection and Reporting Approaches

Key Characteristics	**Dedicated AAC Devices**	**Mobile AAC Apps**
Comprehensive	Some	No
Automatic	No	Yes
Real-time	No	Yes
Clinically relevant	Yes	No
Easily accessible	No	No

3.1.3 Clinician interview

3.1.3.1 Purpose of the study

The purpose of the clinician interview was to understand the perspective of SLPs on patient-generated performance data on AAC devices. For that purpose, we interviewed five SLPs in the greater Pittsburgh area with open-ended questions. The participants were recruited through professional referrals. Each interview took roughly one hour, and each interview was audio recorded for further data analysis. The questions were designed to cover several topics in order to help us to identify the clinical needs of the proposed platform. The topics include: (1) the existing approaches of data collection; (2) the perspective on mobile AAC apps and a web-based clinician portal; (3) what type of information could be beneficial to SLPs; and (4) if a web-based clinical portal is a potential solution to improve the current workflow. The open-ended questions asked are listed in the next section.

3.1.3.2 Interview questions

1. Background questions
    - How many years of work experiences do you have as a SLP?
    - Are you working as a full-time SLP? Or part-time?
    - What is your current work setting?
    - What is your caseload per week?
    - What are the age groups of your clients?
    - How many SLPs are in your clinic?
    - Have you provided AAC intervention to your clients?
    - What is the overall process of the AAC service delivery (from intake to AAC intervention)? Are there any exceptions?
2. The existing approaches of data collection
    - Do you collect data (e.g. language samples) during the AAC intervention? If yes, please briefly describe your data collection method.
    - What is your main purpose for data collection? (e.g. treatment adjustment, evaluation, reimbursement)
    - Are you able to monitor clients' everyday activities on AAC devices/apps in real time? If yes, please describe your approach.
    - Are you satisfied with your current data collection approach? Why or why not? Please describe.
    - What are the problems/limitations of the current data approach? Are there any changes that you expect to see?

3. Perspective on a mobile AAC app

    - Have you used any mobile AAC apps before? Do you like those apps? Why or why not?
    - What are the advantages and disadvantages of mobile AAC apps?
    - What are the benefits and drawbacks of using a mobile AAC app with data collection features?

4. Perspective on a web-based clinician portal

If a web-based clinician portal has already been developed to provide you with convenient access to comprehensive information about your clients' data, please answer the questions below:

- With all different types of outcome measurements, please describe your preferences.
    - Which outcome measurements do you want to see?
    - Are there any specific outcome measurements you use for your reports (e.g. evaluation report, reimbursement)?
    - Which type of presentation method would you prefer to use for your collected data and outcome measures? (e.g. charts, curves, tables, numbers)
- Do you think the following proposed features of the clinician portal are beneficial? Why or why not?
    - Able to monitor clients' performance anytime through the Internet
    - Provide a brief summary (with charts and curves) for SLPs to quickly review clients' performance
    - Provide outcome details (tables, numbers) for SLPs to conduct further analysis

- Are there any other features that you would expect to see?
- Do you believe such a web portal (specifically designed for SLPs) will support AAC service delivery?
- Will the clinician portal enhance the current data collection and reporting process?
- Will the clinician portal improve both the quality and efficiency of health service delivery?
- What are the benefits and drawbacks in using such a clinician portal?

3.1.3.3 Interview results

A total of five certified SLPs were recruited to participate in this interview study. Participants' work experiences ranged between 4 to 12 years. Four of the five participants were experienced SLPs (with 5+ years of work experience). Participants' current work settings included private clinics (outpatient, home visit) and schools, and all participants had experiences with AAC intervention. Participants' perspectives on patient-generated performance data on AAC devices are addressed below:

Existing Approaches of Data Collection

The existing approaches for data collection include behavior observation (taking notes), video/audio recording, and LAM reports. Behavior observation is the method that most participants used on a daily basis. Reimbursement and treatment adjustment are two main purposes for which SLPs would collect clients' performance data. All participants agreed that they are not satisfied with the current data collection approach, since it takes extra time to do so manually. Moreover, participants are not easily able to monitor clients' everyday activities in real time. In order to improve the current data collection approach, the participants expect to

have a new approach that is able to automatically collect real time data and provide quality information.

Perspective on a Mobile AAC App

Four of the five participants had experiences using mobile AAC apps. They all agreed that mobile AAC apps have the potential to help people with communication disabilities. However, the quality of the apps is one of their biggest concerns, because most mobile AAC apps on the market were not designed by healthcare professionals. Moreover, mobile devices may have limited use for people with motor impairments.

Perspective on a Web-based Clinician Portal

All participants believed that a clinician portal could support AAC service delivery, enhance the current data collection and reporting process, and ultimately improve both the quality and efficiency of health service delivery. They all agreed that the proposed features on the clinician portal could be beneficial, including remote monitoring and a dashboard overview, as well as detailed outcome information. They suggested including the ability to select the time period of the data and various options for exporting data.

Type of Information

Four of the five participants indicated that the usage time of the AAC is important to track. Other outcome measurements include communication rate, mean length of utterance, error rate, and among others. Three participants expressed a need to distinguish the logs by different users, such as clients vs. family members.

Table 4 summarized SLPs' perspectives regarding the proposed data collection approach, mobile AAC app, and web-based clinician portal.

Table 4. Summary of Clinician Interview Results

Topic	**SLPs' Perspectives**
Data Collection	• Current approaches: behavioral observation (taking notes), audio/video recording, and LAM. • Main purposes: reimbursement, treatment adjustment. • All participants are not satisfied with the existing approaches.
Mobile AAC Apps	• 80% of participants had experience using AAC apps. • All participants agreed that mobile AAC apps could help patients. • The quality of the app is the biggest concern.
Web-based Portal	• All participants agreed that a web portal could be beneficial. • 80% of participants indicated that it is important to track total usage time. • Portal users should be able to select data from a specific time period. • Portal users should be able to distinguish the data logs generated by different users.

3.1.4 Clinician survey

3.1.4.1 Purpose of the study

The purpose of this research study was to understand the types of information that SLPs feel are important to clinical intervention and outcome measurement. For that purpose, an online survey was conducted with SLPs via the Qualtrics Survey System in the United States. The survey was

revised from the AAC Sampling Procedures and Performance Monitoring Questionnaire (Katharine Hill, 2001). The survey questions include SLPs' perspectives on traditional language sampling methods, as well as an innovative automated data analysis procedure. Some questions were updated because of advancement in technology. All updates to survey questions are shown in Table 5. See Appendix A for the full survey questionnaire. All potential participants were approached by: (1) AAC Institute Newsletter, and (2) 2015 Clinical AAC Research Conference, since most of the members and attendees from the above communities and conference are SLPs. The results of this survey were used to design and development on the web-based clinician portal.

Table 5. Updates on AAC Sampling Procedures and Performance Monitoring Questionnaire

Hill's (2001) Questionnaire	**New Questionnaire**	**Reasons for Update**
Q4: Select types of dedicated AAC devices that are presently used?	Q4: List types of dedicated AAC devices that are presently used. Q5: List types of mobile AAC apps that are presently used.	• Allow clinicians to list all the devices/apps they use, instead of selecting from the given options • Added a new question regarding the use of mobile AAC apps
Q5 (b): Use videotape to collect language samples.	Q6 (c): Use video recording to collect language samples.	• Videotape is seldom used • Video recording is becoming more common in today's practice

Table 5 (continued)

Q7: Indicate the use of the various methods to collect AAC performance data.	Q7: Indicate the use of the automatic methods to collect language samples.	• Most of the traditional data collection methods listed are no longer used • To follow up with Q6, the question was updated to ask about automatic data collection methods
Q12 – Q17: Indicate the selection of word-based and utterance-based summary measures.	Q13 – Q18: Indicate the selection of utterance-based, word-based, and app-based summary measures.	• Several utterance-based and word-based summary measures were added according to the design of data analytic strategies in this work • App-based summary measures were added to include app-specific data analysis
(The second question set) SLPs' perspectives on the data logging feature on the AAC device.	Q20: SLPs' perspectives on the data logging feature on the mobile AAC app.	• To understand SLPs' perspectives on the mobile AAC app in order to meet the research goal of this work

3.1.4.2 Survey results

A total of 26 responses were collected from this survey study. The length of time that each participant has provided AAC clinical services ranged from 1 year through 34 years with an average of 12 years of experience. Figure 10 shows the years of AAC experience of the survey participants. Table 6 lists clinical experiences of survey participants.

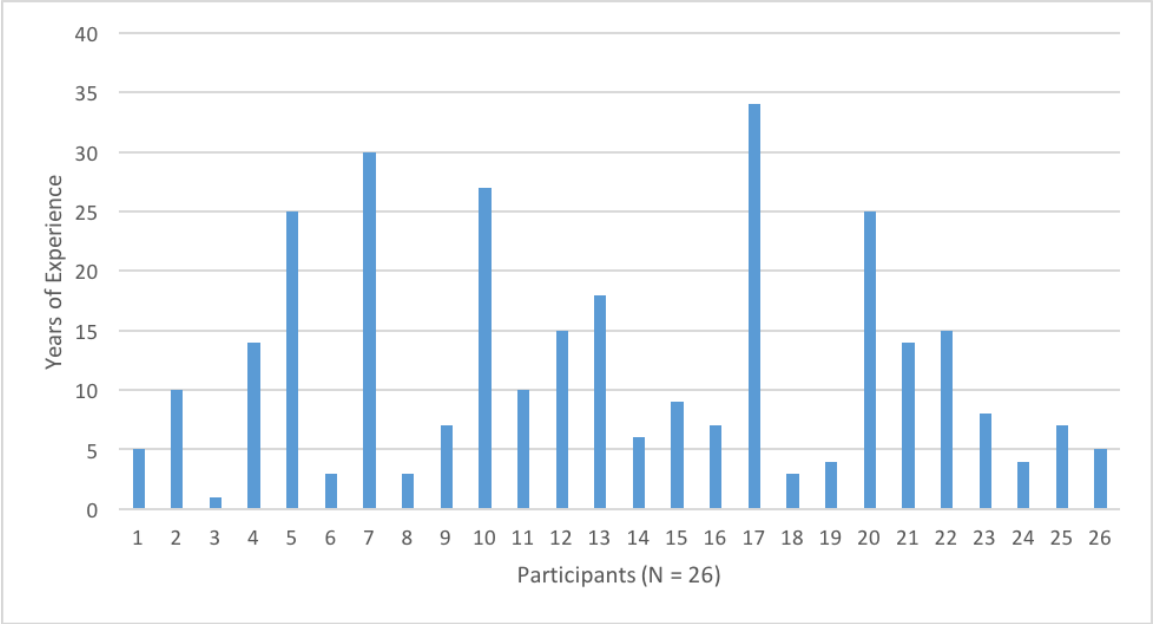


Figure 10. Years of AAC Experience of Survey Participants

Table 6. Clinical Experiences of Survey Participants

Age Groups of Clients	**N**	**%**
Infant/toddler	10	38%
Preschool	17	65%
Elementary school	20	77%
Middle/high school	21	81%
Adults	12	46%
Geriatric	3	12%

Table 6 (continued)

Types of Employment	N	%
Self-employed	4	15%
Public school	10	38%
Rehabilitation facility	4	15%
Hospital/Clinic	7	27%
Private agency	3	12%
College/University	7	27%
Manufacturer	2	8%
Other	4	15%

The first section of the survey deals with questions on SLPs' perspectives on language sampling methods. Language sampling methods include personal observations and charting, audio/video recording, and automatic data logging.

Method of Collecting Language Samples

The questions in this set were measured on a 4-point Likert scale of agree, agree somewhat, disagree somewhat, and disagree. The result combined the 4-point scale into 2 categories: agree and agree somewhat, disagree and disagree somewhat. Table 7 and Figure 11 show different methods of collecting language samples, including handwritten, from audio recordings, and from video recordings. A total of 68% of the participants collect handwritten language samples. Consequently, 32% do not collect handwritten data. Second, only 16% of participants collect audio recording language samples. Therefore, 84% of the participants do not

collect audio record data. Finally, 56% of the participants collect video recording language samples, whereas 44% of participants do not collect video recording data.

Table 7. Language Sampling Methods: Data Collecting

	Disagree	Disagree Somewhat	Agree Somewhat	Agree
I always collect handwritten language samples.	8%	24%	32%	36%
I always audio record language samples.	52%	32%	16%	0%
I always video record language samples.	24%	20%	40%	16%

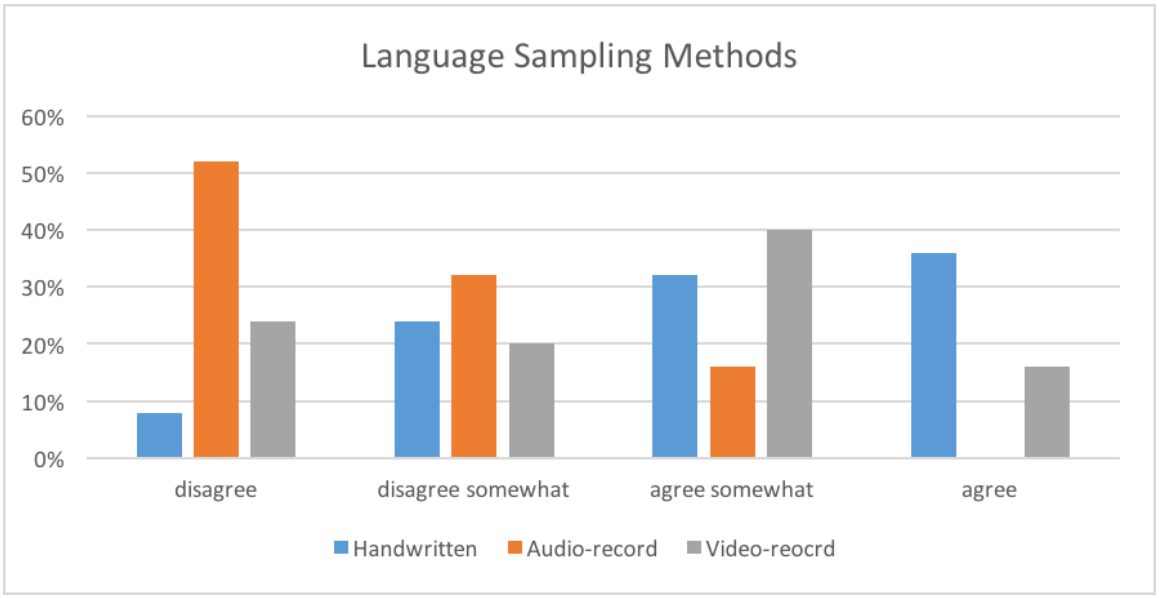


Figure 11. Language Sampling Methods: Data Collection

Table 8 and Figure 12 show different types of AAC technologies for data collection, including dedicated AAC devices and mobile AAC apps. Fifty-four percent of the participants collect language samples from dedicated AAC devices, while 46% do not collect data from these

dedicated devices. Forty-four percent of the participants collect language samples from mobile AAC apps, while 56% do not collect data from mobile apps.

Table 8. Language Sampling Methods: Types of Devices

	Disagree	Disagree Somewhat	Agree Somewhat	Agree
I always collect language samples generated by dedicated AAC devices	27%	19%	27%	27%
I always collect language samples generated by mobile AAC Apps.	40%	16%	24%	20%

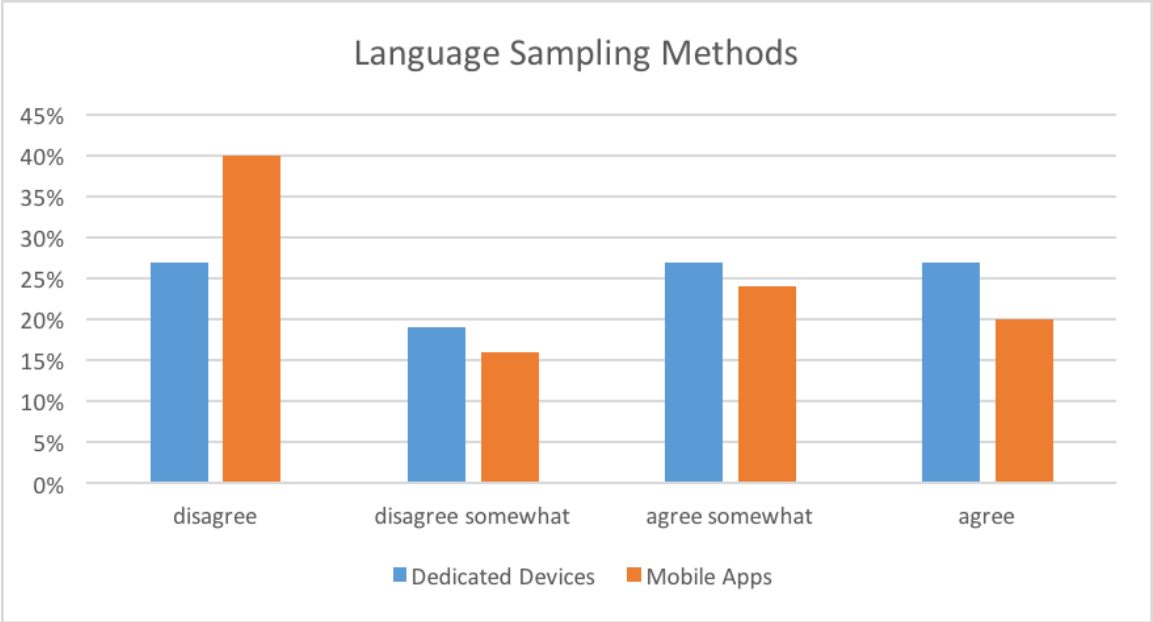


Figure 12. Language Sampling Methods: Types of Devices

Frequency of Language Sample Collection

Figure 13 shows the percent of responses for the question "How often do you collect language samples for an AAC user on your caseload?" Twenty-three percent of the participants indicated that they collect language samples once a week. Fifteen percent of the participants

indicated that language samples were collected twice a month. Other responses regarding frequency include both initial and monthly assessments, at each session, at IEB review or re-evaluation, and only when necessary or asked.

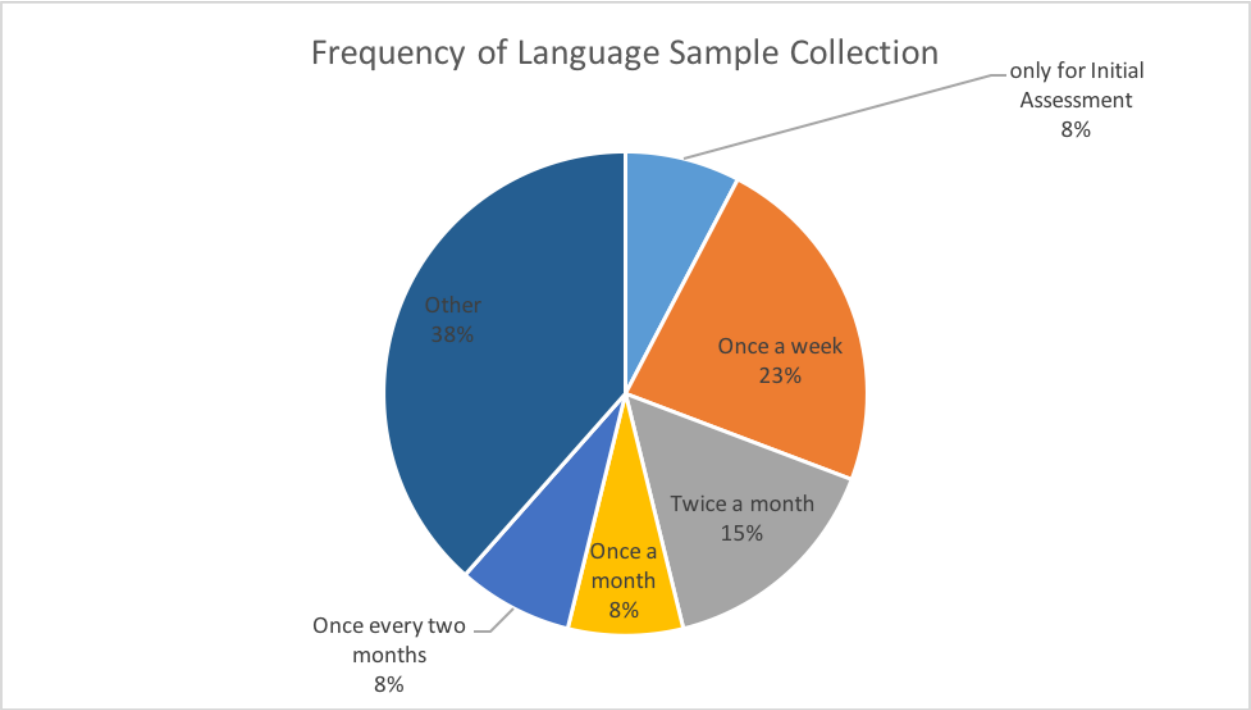


Figure 13. Frequency of Language Sample Collection

Techniques of Evaluating Language Samples

Table 9 and Figure 14 show different techniques for evaluating language samples, including a paper-based or computer-based standard approach, and a paper-based or computer-based self-designed approach. This question was measured on a 3-point frequency scale of never, sometimes, and always. Sixty-eight percent of the participants used paper-based standard analysis systems, while 54% of the participants used computer-based standard analysis system. For the self-designed analysis systems, 92% of the participants used paper-based systems; however, only 43% of the participants used computer-based systems.

Table 9. Techniques for Evaluating Language Samples

	Never	Sometimes	Always	N/A (n)
Standard analysis system: Paper-based	32%	52%	16%	1
Standard analysis systems: Computer-based	46%	42%	12%	0
Self-designed analysis systems: Paper-based	8%	42%	50%	2
Self-designed analysis systems: Computer-based	57%	30%	13%	3

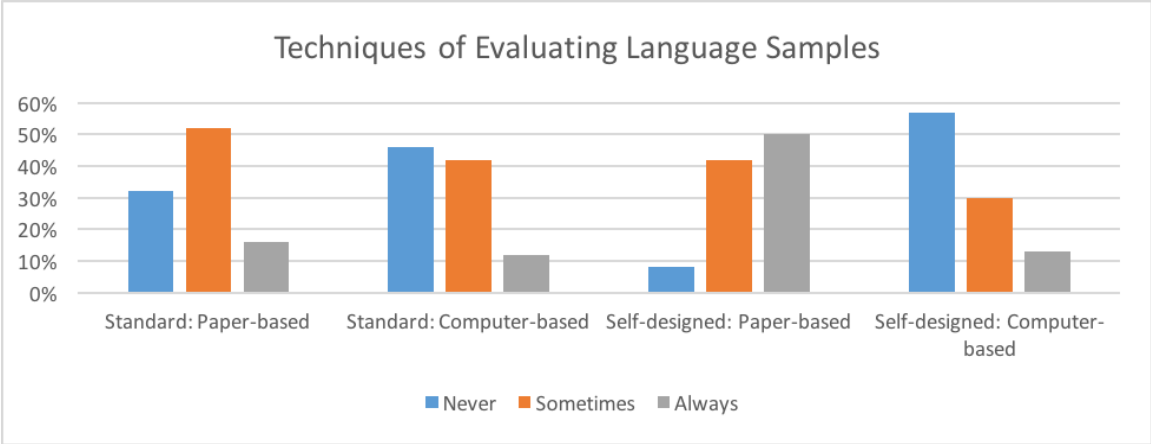


Figure 14. Techniques for Evaluating Language Samples

The second part of the survey deals with questions on an innovative data analysis approach that is designed to facilitate data collection and reporting. Automated data-logging records language and non-language events that occur during AAC device/app use. Because of the timestamps, the captured data provides information that is not normally available to clinicians using traditional language sampling procedures. Consequently, automated log files can contribute additional data that was not previously documented to support evidence-based practice. The participants were asked to select the summary measures that they felt were

important. The summary measures in this section were divided into 3 lists: utterance-based, word-based, and app-based. Tables 10-12 show SLPs' perspectives on the different types of summary measures. Each table shows the percentage of each summary measure from the highest to the lowest. These results were used to implement the web-based portal.

Table 10. SLPs' Perspectives on Utterance-based Summary Measures

Utterance-based Summary Measures	**Percentage**
Utterances structure	81.82%
Total utterances	77.27%
Average communication rate in words	77.27%
Mean length of utterances in words	72.73%
Method of generating utterances (SNUG)	59/09%
List of generating utterances	59.09%
Peak communication rate in words	45.45%
Percentage of complete utterances	40.91%
Mean length of utterances in morphemes	36.36%
Mean length of utterances in keystrokes	36.36%
Average communication rate in keystrokes	36.36%
Peak communication rate in keystrokes	22.73%

Table 11. SLPs' Perspectives on Word-based Summary Measures

Word-based Summary Measures	**Percentage**
Percentage of core vocabulary	90.00%
Total number of words	85.00%
Total number of different words	70.00%
Method of generating words	55.00%
List of generating words	50.00%
Errors per selected word	45.00%
Selection rate	40.00%
Different word roots	35.00%
Communication rate by language representation method	35.00%
List of customized words	35.00%
List of spelled words	35.00%
Rate index	30.00%
Sentence part of generating words	25.00%
Errors per spelled and predicted word	25.00%
Deletions per error	25.00%

Table 12. SLPs' Perspectives on App-based Summary Measures

App-based Summary Measures	Percentage
Usage frequency of the app	90.91%
User language performance at home	90.91%
Usage frequency of different activities (AAC, training, etc.)	72.73%
Usage progress in embedded training materials	54.55%
User progress in embedded training materials	50.00%

The last set of questions asks for SLPs' perspectives on the usefulness of collected data on decision-making support, as well as their overall perspective on data collection and reporting. These questions were measured on a 4-point Likert scale of agree, agree somewhat, disagree somewhat, and disagree. Table 13 shows SLPs' opinions on the usefulness of performance data. Ninety-five percent of the participants agreed that analyzed performance data would provide more effective therapy and 66% of the participants agreed that it would provide faster progress in the intervention process. Second, 95% of the participants agreed the analyzed data would benefit people who reply on AAC, 90% agreed that it would better clarify needs, and 81% agreed that it would lead to more effective communication. Furthermore, 90% of the participants agreed that the performance data provides more effective data to justify the selection of an AAC system, while 90% agreed on supporting the funding process. Sixty-two percent of the participants agreed that an add-on device for data collection is easy and practical.

Table 13. The Usefulness of Performance Data

	Disagree	Disagree somewhat	Agree somewhat	Agree	N/A (N)
Would provide for more effective therapy.	5%	0%	43%	52%	5
Would benefit people who rely on AAC.	5%	0%	67%	29%	5
Would provide faster progress in the intervention process.	5%	29%	33%	33%	5
Would provide better clarity of needs for people who rely on AAC.	5%	5%	57%	33%	5
Would lead to more effective communication.	5%	14%	43%	38%	5
Would provide more effective data to justify the selection of an AAC system.	5%	5%	24%	67%	5
Would provide more effective data to support the funding process.	5%	5%	33%	57%	5
The use of an add-on device is easy and practical.	10%	29%	38%	24%	5

Table 14 shows SLPs' overall perspective on data collection and reporting. Seventy-two percent of the participants agreed that the use of built-in data logging feature of an AAC app is easy and practical, and 90% percent of the participants would be more likely to use this built-in feature. Ninety percent of the participants agreed that the availability of automated performance monitoring tools will allow for more frequent collection of language samples, and 95% agreed that using such a tool can improve the analysis process. Consequently, 95% of the participants agreed that these tools have to be easy and user-friendly in order to integrate the tool into the intervention program. Moreover, 95% of the participants would collect performance data if the performance monitoring tools were able to make the process easy and efficient, while 90% would use analyzed performance data more often if the tools were available as an entire packet of materials. In terms of education and training for data collection and reporting, 90% of the participants agreed that adequate training is needed, and 95% accepted distance training as a viable option. Ninety-five percent of the participants agreed that pre-service training is needed to support the widespread application of performance monitoring.

Table 14. The Overview Perspective on Data Collection and Reporting

	Disagree	Disagree somewhat	Agree somewhat	Agree	N/A (n)
The use of data logging as a built-in feature of an AAC app is easy and practical.	10%	19%	48%	24%	5
I would be more likely to use data logging as a built-in feature to an AAC app.	5%	5%	38%	52%	5
I would not be likely to supplement my data collection with video or audio recording.	19%	29%	38%	14%	5
The availability of automated performance monitoring tools will allow for more frequent collection of language samples.	5%	0%	43%	52%	5
More efficient performance monitoring tools are needed to improve the analysis process.	0%	5%	29%	67%	5
Performance monitoring tools are needed to be easy and user-friendly for me to integrate them into my intervention program.	0%	5%	29%	67%	5

Table 14 (continued)

I would collect more performance data on my clients if I had automated tools that make the process easy and efficient.	5%	0%	19%	76%	5
I would use analyzed performance data more often if the performance monitoring tools were available as an entire packet of materials.	0%	10%	38%	52%	5
Adequate education and training is needed before I would use performance monitoring tools.	0%	10%	43%	48%	5
Distance learning would be an acceptable approach to receive training on performance monitoring.	0%	5%	48%	48%	5
Pre-service training is needed to support the widespread application of performance monitoring.	0%	5%	48%	48%	5

3.2 SYSTEM ARCHITECTURE

The limitations of the currently available AAC systems were identified in previous sections. The proposed integrated system aims to (1) follow research-based design principles to develop a mobile-based AAC app; (2) develop a web-based clinician portal, based on SLPs' clinical requirements; (3) provide real-time clinically relevant outcome measurements with no manual inputs; and (4) apply the advantage of mHealth to support EBP and streamline the workflow in AAC clinical service. Therefore, an integrated platform for AAC clinical service delivery was designed as a potential solution for SLPs to support data collection and reporting in AAC intervention. The integration of communication, treatment, and monitoring system is expected to maximize communication potential, facilitate spoken-language skills, enhance life participation, and ultimately improve the quality of service delivery.

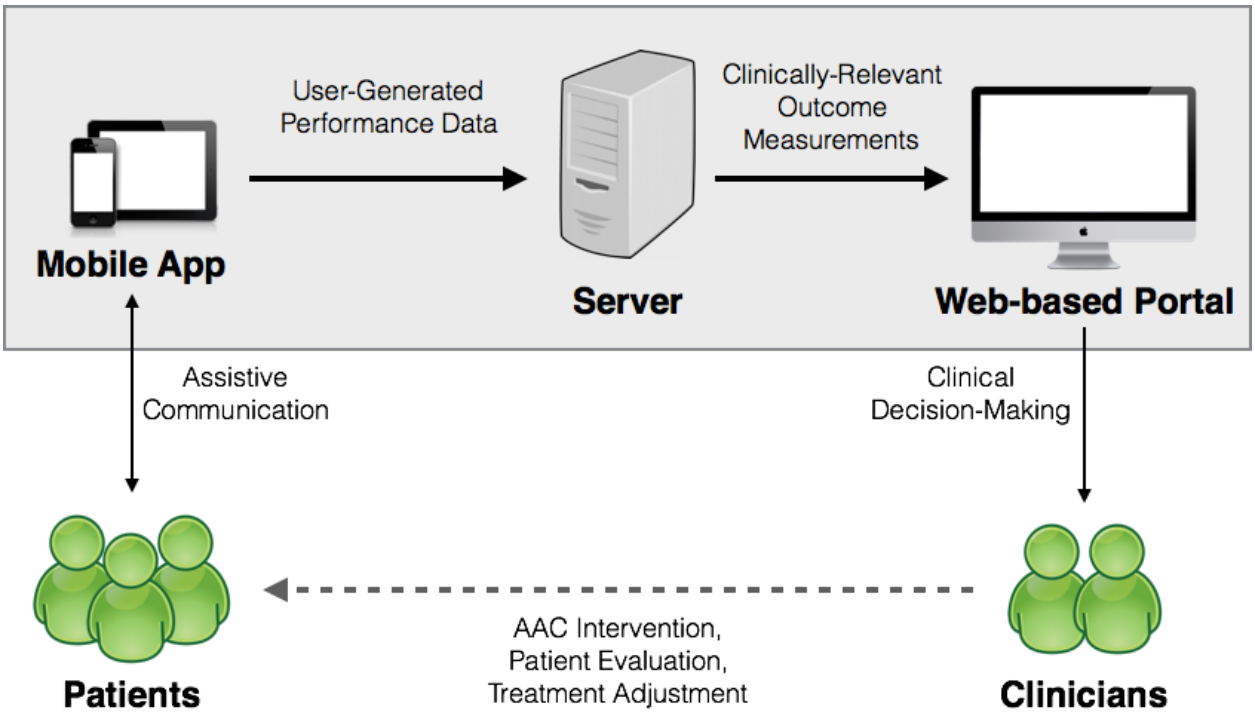


Figure 15. System Architecture

The proposed system architecture (Figure 15) was developed to ensure that the implementation of the integrated platform meets both IT and clinical requirements. The system architecture was examined with the five key characteristics identified in the earlier work to make sure the architecture contains all the components and also meets the requirements of data analysis procedures (Table 15). With this tablet-based app, PwCD are able to generate spontaneous utterances with anyone in their community. Beyond daily communication, caregivers can also assist PwCD to practice embedded training modules in the app. Furthermore, easy-to-read visual reports allow caregivers to monitor the progress and understand the performance of PwCD. On the backend side, all user activity logs are sent to a server. Comprehensive internal evidence is available by collecting all user-generated activities and language data. The data on the server is then analyzed and a detailed evaluation report can be generated automatically. SLPs can login to the web portal and evaluate communication performance of their patients anytime and anywhere. This can help them determine the effectiveness of their AAC intervention as well as adjust their treatment plans if necessary.

Table 15. Checklist of the System Architecture

	Requirements	**System Architecture**
☑	Comprehensive	Collect all user-generated activities and language data
☑	Automatic	Log all user data automatically
☑	Real-Time	Analyze collected data in real-time
☑	Clinically Relevant	Generate clinically-relevant performance measures
☑	Easily Accessible	Access performance report via a web-based portal

4.0 DESIGN AND IMPLEMENTATION

4.1 MOBILE AAC APP

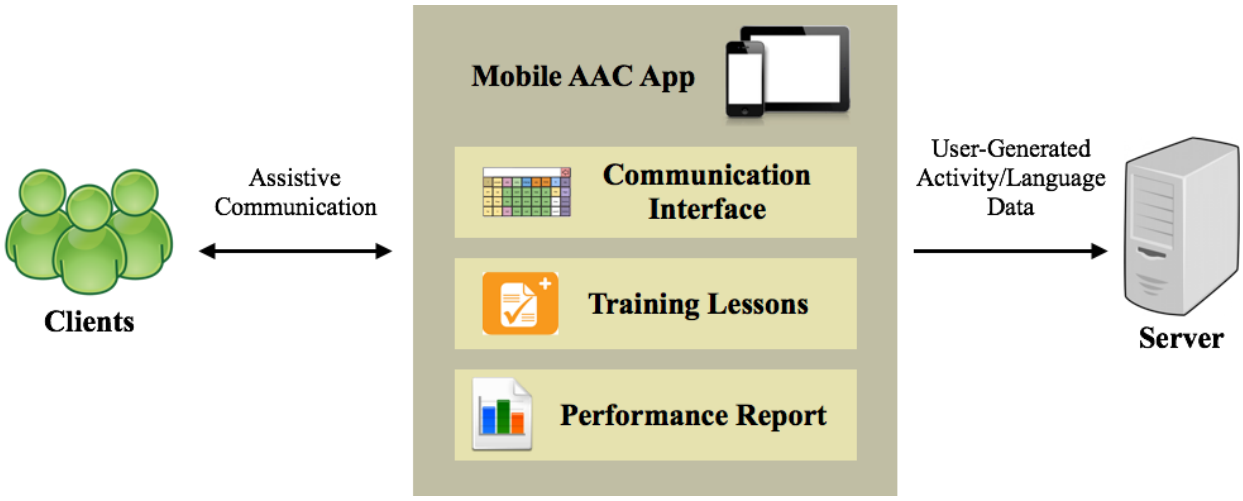


Figure 16. Mobile AAC App Architecture

As described in the system architecture, Figure 16 illustrates the key components of the integrated AAC system. This tablet-based AAC app was designed to incorporate the communication interface, training, and reporting capabilities. The communication interface provides both the communication program and clinical treatment exercises for PwCD. PwCD can use the mobile app to communicate with other people, and would also attend training under the guidance of SLPs. The embedded training materials are designed to extend the treatment time, which provides PwCD an opportunity to continue practicing at home. All user activities are

logged and stored on a secure server. Outcome reports and performance measures are generated automatically and are accessible to the individual, caregivers and SLPs. Moreover, the conveniently available outcome reports help SLPs to determine the progress of clinical intervention as well as to make any necessary adjustment to the treatment plan for each of their patients.

As described earlier, the purpose of creating this mobile app is to find a reasonable solution to the existing problems associated with AAC clinical service delivery to PwCD. This tablet-based communication app, EuTalk, was developed on the Android platform (Chen & Wang, 2013; Wang, Chen, Zhou, & Hill, 2013). The app was written in the JAVA programming language. The VoiceText™ Embedded SDK for Android platform was used to provide the text-to-speech (TTS) feature. A SQLite database in the app and a MySQL database on a Linux server were created for data collection, data management, outcome analysis, and report generation purposes.

4.1.1 Data collection

The main goal of this work is to support data collection and reporting. Therefore, it is vital to identify strategies that support this goal during the design phase: for instance, what types of data are collected, how collected data are stored, and how outcome measurements use the collected data.

Data collection and information delivery is one important feature of the app. This app was designed to collect user activity data and to automatically analyze the data in real time. The app has a SQLite database to store setup, logging information, and a dictionary. A MySQL database is created on a secured server, which is used to aggregate user activity information,

perform data analysis, and generate performance reports. Each mobile device (tablet) collects data generated by PwCD, and then stores the data in both the SQLite database and the remote MySQL database server.

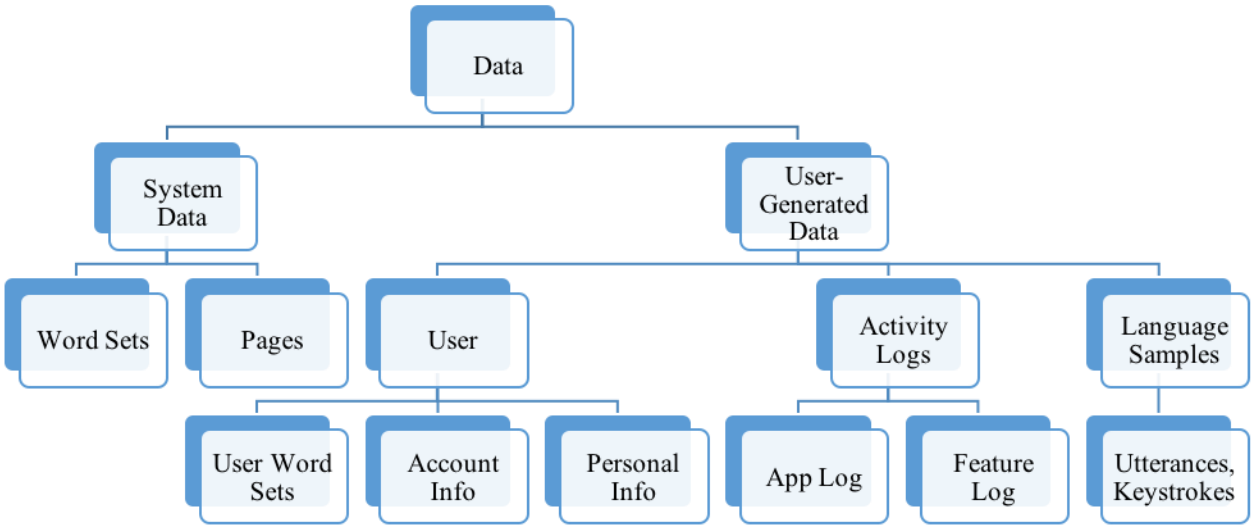


Figure 17. Data Collection

Figure 17 illustrates the data hierarchy in this work. Two types of data are stored in the database: system data and user-generated data. Table 16 provides an overview of both system and user-generated data. System data are pre-stored in the system, which consist of both word and page information; each word is well defined with both system and language details. These data support the automatic analysis in the next step; also, they provide flexibility that can be used to expand system vocabularies in the future.

Table 16. An Overview of the Stored and Collected Data

Type of Data	**Description**
User Information	Demographic information and clinical background (type of disorder, onset date).
System (default) Word Sets	Each word was assigned with a 5-digit ID: the first digit identifies the utterance generation approach and language of the word. It also includes the definition of each word, such as location, page navigation, icon, word type, TTS, language, etc.
User Word Sets	Customized word sets will be generated for each user for customization purposes. For example, add/delete or hide/show a word.
Activity Log	Log in/out timestamps, timestamps for different features.
Language Samples	Utterance logs, timestamp for each keystroke in communication board, training (mode) flag, etc.
Others	Logs of training modules and other features.

User-generated data are collected while users use the app, which consist of user information, activity log, and language samples. EuTalk records all user activities and logs all data elements based on Hill's (2004) research (Katya Hill, 2004). All user activities and language data elements are logged, and user click-thru and navigation within the app are also tracked. In other words, a user's every event from logging to logging out of the app is logged. All timestamps are stored as one analysis variable. A special design of "training flag" is implemented for data analysis, so that clinicians' activities (if present) can be excluded in order

to get a more accurate evaluation. Both user-oriented and clinician-oriented reports can be generated in real time by using both system data and user-generated data. Figure 18 shows an example of how language samples are collected through the process of utterance generation.

Figure 18. An Example of Backend Data Logging

4.1.2 Communication interface

The communication user interface provides the primary language components with graphic symbols used to represent vocabulary to support the spontaneous generation of sentences. The vocabulary was selected from word frequency studies that identified high frequency core vocabulary in daily conversation (Katya Hill, 2004). The core/high frequency words are highly flexible so that they can replace low frequency or fringe words in different circumstance. For example, the vocabulary is organized in a semantic syntactic 8 x 4 grid display (Beukelman &

Mirenda, 2005). The location of vocabulary is based on Chen's study (Chen & Hill, in preparation). An 8 x 4 grid (Figure 19) is configured as an optimal size considering the tablet size and symbol size. Each cell consists of a word and a symbol taken from the Pixon™ Project Kit (PRC). Five functional buttons on the right side are designed to provide more language elements and ensure the most flexible use of the app. The Talk Bar on the top allows users to view the utterances they generate, and enable the device to create speech. Symbol keys (core vocabulary cells) are color-coded based on the sentence parts.

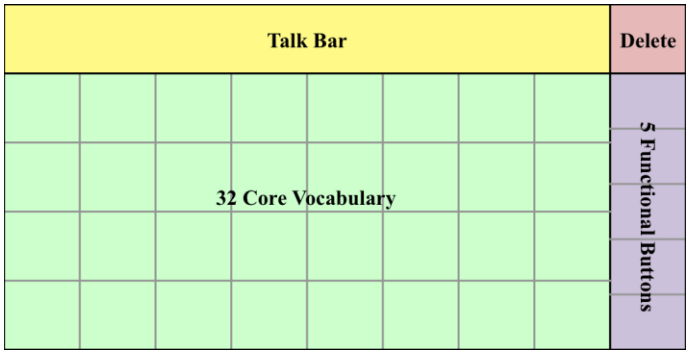


Figure 19. Interface Design of the Home Page

The utterance generation approach implemented in the current design is called a 1-hit approach. The home page (Figure 20) contains the most essential vocabulary for sentence construction. The TTS function is available to each word that needs a pronunciation attached. The utterance generation uses a straightforward approach. Users can construct utterances simply by pressing the word they need. In this design, different tenses of pronouns (Figure 21) are provided in a sub-layer under the home page. Other than the pronouns, the rest of the words on the home page are linked to a connected page (Figure 22) with related vocabularies. For example, under the word "drink," users can find different kinds of drinks, such as coffee or juice. There are a total of 24 pages (including the home page), 21 connected pages, 1 alphabet page,

and 1 number and punctuation page. These pages consist of 305 words and 29 special words (different tenses of pronouns). Figure 23 shows the overall flow of utterance generation.

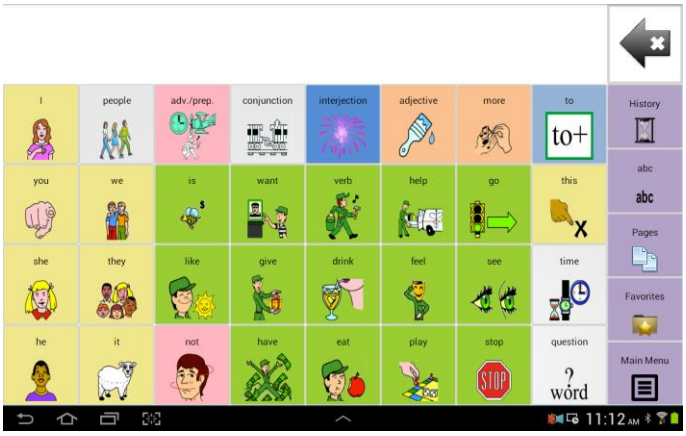


Figure 20. Home Page of the Communication Interface

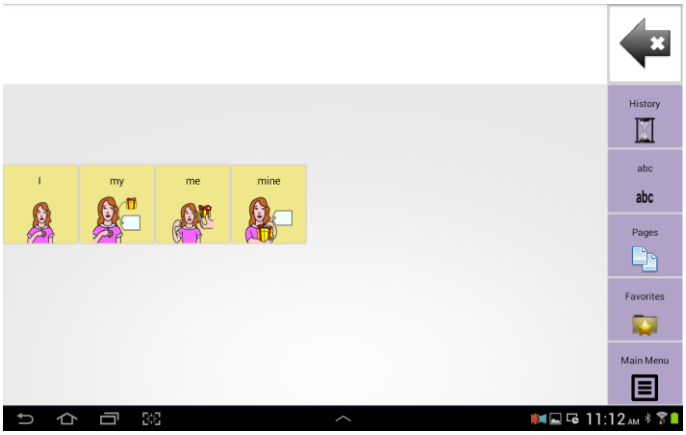
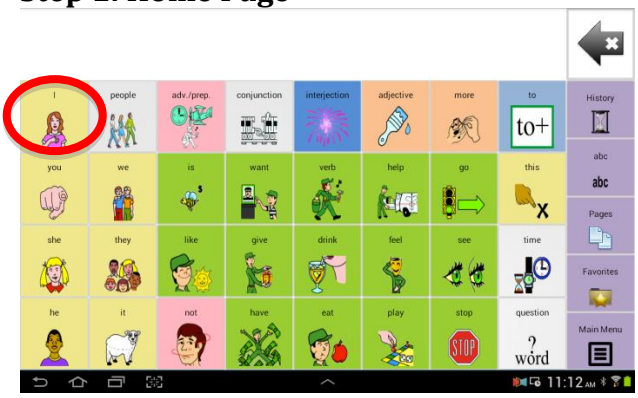


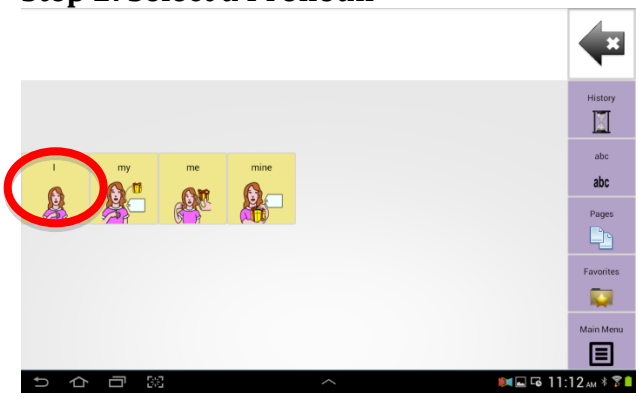
Figure 21. Home Page of the Selected Pronoun

Figure 22. Connected Page of the Communication Interface (1-hit)

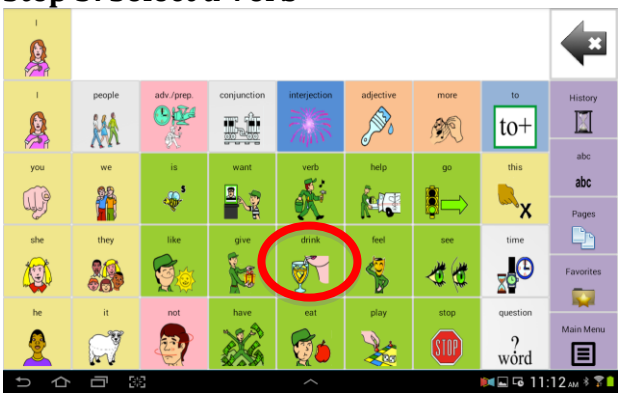
Step 1: Home Page



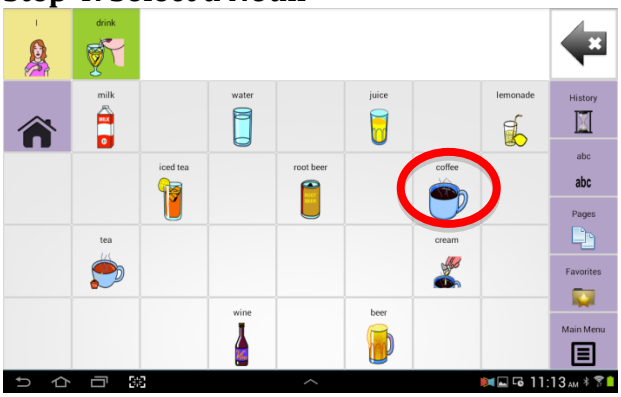
Step 2: Select a Pronoun



Step 3: Select a Verb



Step 4: Select a Noun



Step 5: Check the Sentence

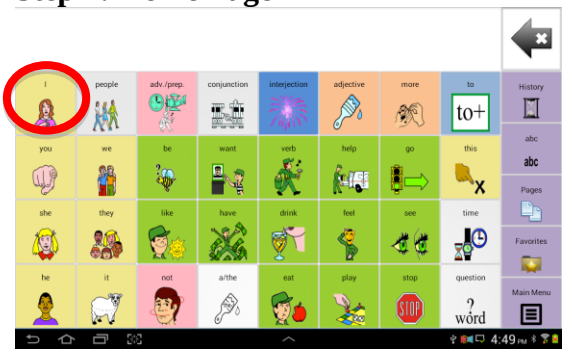
Step 6: Text-to-Speech

Figure 23. Flow of Utterance Generation: 1 hit

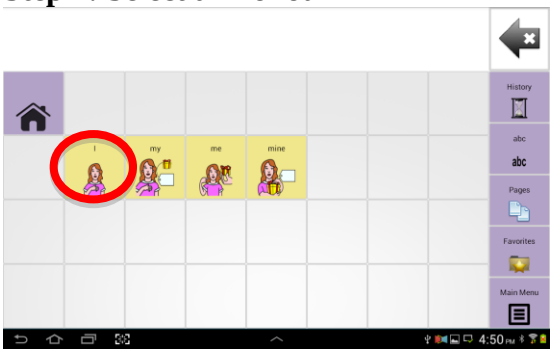
The second utterance generation approach is called the 2-hit approach. In contrast to the 1-hit approach, each word on the home page has a folder-like design. Each word directs to a connected page that contains all related vocabularies. For example, under the word “drink,” users can find not only different kinds of food but also the verb “drink” (see Figure 24). There are a total of 37 pages, including the home page, 34 connected pages, 1 alphabet page, and 1 number and punctuation page. These pages have a total of 359 words. Figure 25 shows the flows of utterance generation in the 2-hit approach.

Figure 24. Connected Page of the Communication Interface: 2-hit

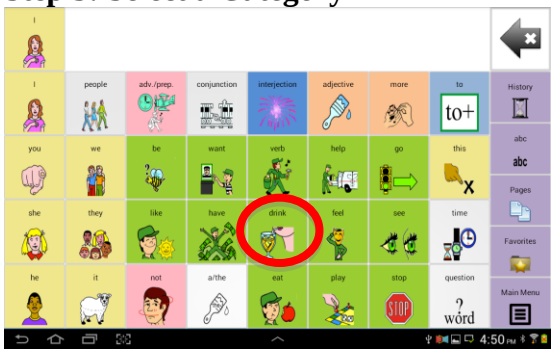
Step 1: Home Page



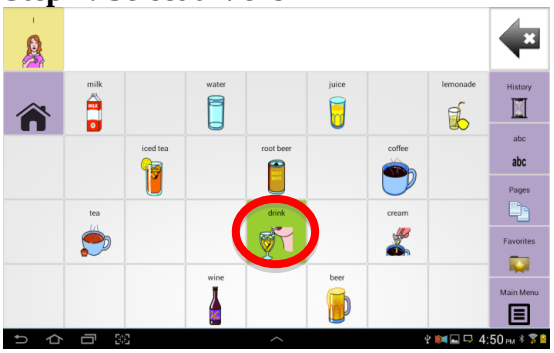
Step 2: Select a Pronoun



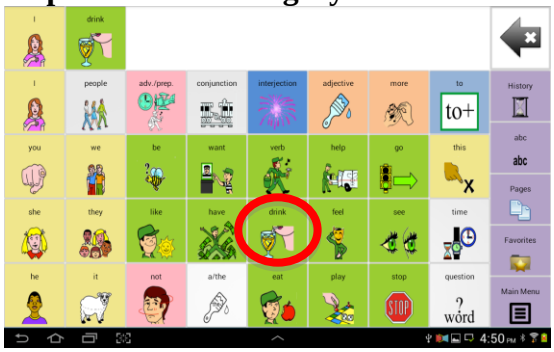
Step 3: Select a Category



Step 4: Select a Verb

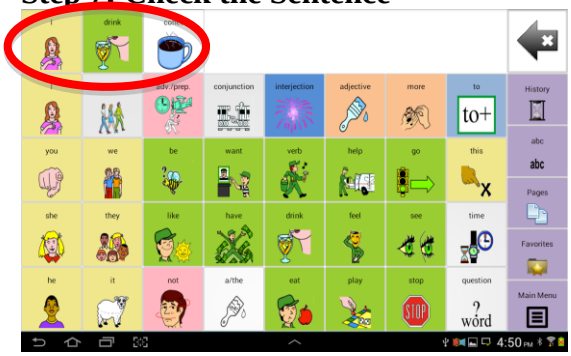


Step 5: Select a Category



Step 6: Select a Noun

Step 7: Check the Sentence



Step 8: Text-to-Speech

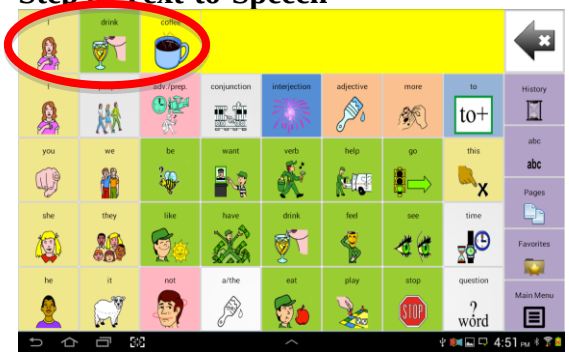


Figure 25. Flow of Utterance Generation: 2 hit

4.1.3 Training modules

The app was designed to provide highly accessible training lessons to expand regular training so that PwCD can improve their communication skills in any location and at any time, which in turn can prevent financial or geographical difficulties. The embedded training is divided into two parts: games and practices.

According to various studies, applying gamification to a non-game application can improve overall user experience and user engagement (Deterding, Sicart, Nacke, O'Hara, & Dixon, 2011). The gamification feature seeks to boost users' motivation to continue practicing. The purpose of the training game (Figure 26) is to help PwCD to become familiar with the main page of the communication interface and to provide opportunities to improve communication effectiveness. The idea is similar to existing typing games for computer keyboard training. Four word sets are provided with different combinations of main-page vocabulary. Moreover, different levels of difficulty (size of word set and time span of word appearance) are implemented to help PwCD to remember the locations of the main page vocabulary.

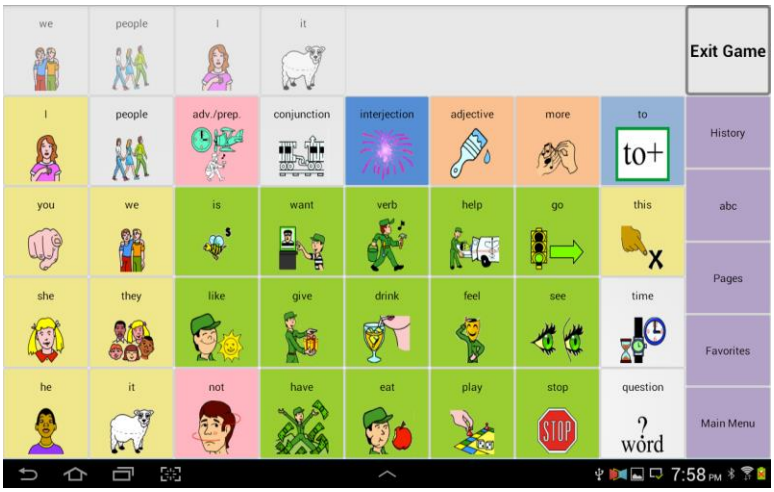


Figure 26. Game in Training Modules

As mentioned earlier, providing a sufficient intensity of treatment and sufficient practice is a key factor to ensure that the PwCD will improve/recover their language and communication skills. In order to use an AAC app effectively, PwCD need to be familiar with the content of the app. The practice method in the app (Figure 27) covers words that are used in daily conversations on the communication interface. The practice includes tasks at different difficulty levels. PwCD can use the practice exercises to learn the locations of the high frequency words, and help them to use those words in their conversations as efficiently as possible. The app also provides audio cues (TTS), text, and symbols to facilitate the learning process (Mayer & Moreno, 2002).

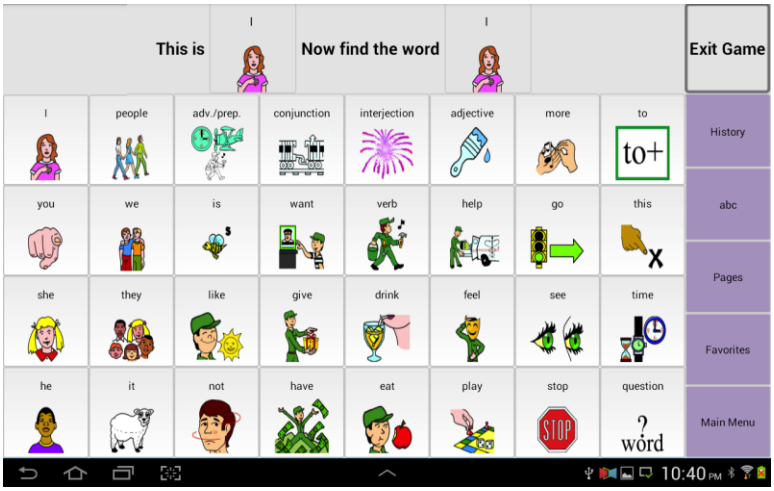


Figure 27. Practice in Training Modules

4.1.4 In-app performance report

Based on Hill's (2007) research, EuTalk records all user activities and logs all data elements that are needed by SLPs (Katya Hill et al., 2007). Each user's click-thru and navigation are also tracked in the app. The databases store users' every click event with a corresponding timestamp in the app from logging in to logging out.

A report or summary (Figure 28) can be generated in real time based on user-generated data. On the tablet, a visual report is generated for PwCD and their caregivers. Six measures of language performance are provided to PwCD and their caregivers. Records in games and practices are presented as line charts. PwCD can easily see their progress in the training lessons over a period of time. Besides the training results, four more communication measures are provided to each user, including communication rate (words per minute), number of unique words, word types, and average length of utterances (Katharine Hill, 2001). Line charts are used for both communication rate and average length of utterances since they can show the trend (improvement) in both measures. The number of unique words is presented in a bar chart to show comparisons over a given time period. A pie chart is used for word types to illustrate numerical proportion for each word type.

Figure 28. Performance Report

4.1.5 User customization

The default setting of the app supports basic communication needs. In order to increase the flexibility of the app, customization features were designed to meet users' personal needs. All connected pages (pages with words linked to the ones in the home page) in the communication

board can be customized. PwCD or their caregivers can add or remove words according to their personal preferences. SLPs can hide any words on the communication interface to customize the training that they assign to their patients. In the TTS engine, both male and female voices are supported, so that PwCD or their caregivers can select their preferred voice. “Favorites” is a feature that helps users to store up to 20 sentences that they use often or those that are needed in emergencies. For instance, PwCD can store sentences such as their home address, name and contact information of their caregivers, or frequently requested medical information and health care providers. Users or their caregivers can type in sentences using a soft keyboard provided in the app. They can also conveniently update these sentences when necessary.

4.2 WEB-BASED CLINICIAN PORTAL

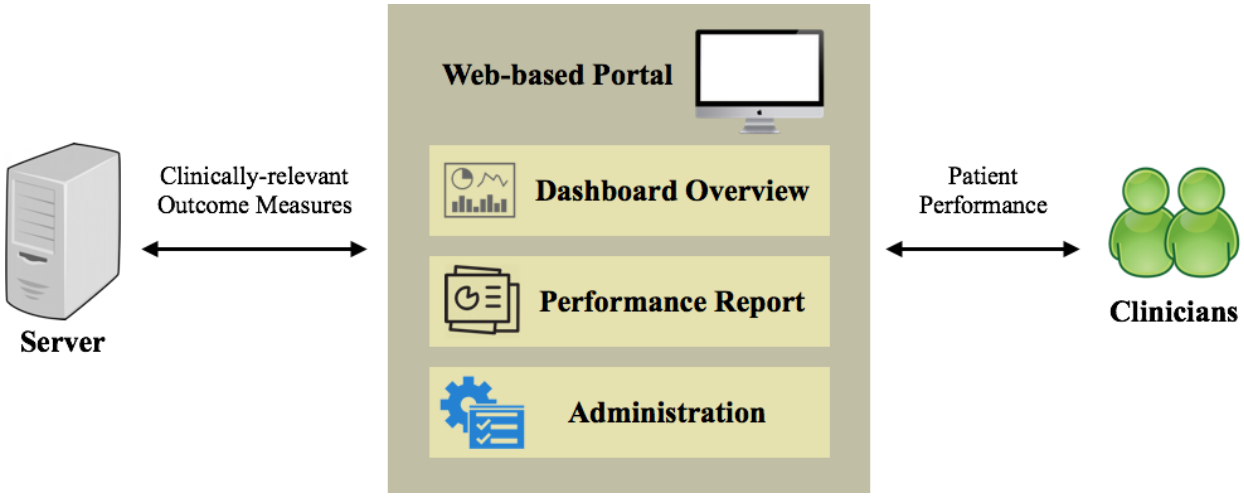


Figure 29. Web-based Clinician Portal Architecture

As described in the system architecture, Figure 29 illustrates the key components of the web-based clinician portal. The web portal was developed to provide a detailed communication

performance evaluation for SLPs. This is different from the app report, which provides a basic overview of users' communication performance. After logging into their online account, detailed user activity information is available for clinicians to review. The dashboard design provides clinicians an easy-to-read interface to examine clients' progress reports. In addition to the graphical charts, clinicians will be able to access LAM data and tables of numerical data for further evaluation. With this provided information, clinicians can get a better picture of their clients' communication routines and overall progress.

Moreover, the complete data collection provides clinicians and researchers with the best available evidence to improve clinical decision-making and further support care improvement in the community. In addition to reviewing clients' performance, clinicians can adjust their treatment materials and personalize app settings for each client. Since age, type of disorders, onset date, and more information is collected when users create their accounts (though it is optional for users to fill in all the information), statistics on users activity and outcome performance among different groups of users can be analyzed. The results can help researchers to boost the clinical development of better treatment and care.

4.2.1 User performance overview

According to the results from the clinician survey, the top selected summary measures (70% and higher) are included in the performance overview to provide SLPs with a summary report of their client's language performance. These selected summary measures (Table 17) include three app-based, three word-based, and four utterance-based summary measures. Table 18 explains how each summary measure is automatically analyzed in EuTalk.

Table 17. Top Selected Summary Measures

Selected Summary Measures	**Percentage**
Usage frequency of the app	90.91%
User language performance at home*	90.91%
Percentage of core vocabulary	90.00%
Total number of words	85.00%
Utterance structure	81.82%
Total utterances	77.27%
Average communication rate in words	77.27%
Mean length of utterances in words	72.73%
Usage frequency of different activities (AAC, training, etc.)	72.73%
Total number of different words	70.00%

* User language performance at home is not included in the overview; instead, the analysis of the user's home performance is supported in all performance report's summary measures.

Table 18. Analysis of Selected Summary Measures

Summary Measure	**Analysis**
App usage frequency and usage frequency of different activities	The app usage frequency calculates the total time (from Log In to Log Off) that the user spent in EuTalk during the given time period. The usage frequency of different activities divides the total usage time into different activities (e.g. communication interface or training modules). The timestamp of every activity is logged when the user starts or leaves the activity.

Table 18 (continued)

Total number of words / different words and core vocabulary percentage	Total number of words is calculated by summing up words from all generated utterances*. The total number of different words only summarizes the number of different words used. The core vocabulary analysis uses the list of target words that are defined by SLPs as the core vocabularies. The core vocabulary percentage calculates the portion of the total words that were defined as core vocabularies.
Utterance structure	Utterance structure is an indication of relative use of the sentence parts used in the generated utterances (e.g. pronoun, verb, adjective). The sentence part of each word is pre-defined in the system data.
Total utterances	The total number of utterances that are generated in the given time period.
Average communication rate in words	The communication rate uses the total number of words divided by utterance time** in each utterance. The average communication rate calculates the average rate of all generated utterances in the given time period.
Mean length of utterances in words	Mean length of utterances in words calculates the average number of words in all generated utterances.

* Utterance: When the user presses the Talk Bar, all words in the Talk Bar are defined as one complete utterance.

** Utterance time = utterance end time – utterance start time. The utterance start time is defined as the timestamp of the first selected vocabulary in the Talk Bar; the utterance end time is defined as the timestamp when the user presses the Talk Bar to generate speech of the full utterance.

These summary measures are provided under the first tab in a dashboard format (Figure 30). The purpose of this dashboard overview is to provide SLPs with a quick review of PwCD's performance. SLPs can review the result in different periods of timeframes. Three options are provided in this design that include the last 30, 60, or 90 days. The app usage frequency, total words, total utterances, communication rate, and mean length of utterances are presented with a weekly analysis in the line charts. The line chart is used to visualize the trend of language performance over intervals of time. The usage frequency of different activities is shown in the pie chart in order to illustrate the numerical proportion of each activity. The top five utterance structures are listed in a table, with both the sentence structure and the number of each structure is being used. Moreover, the percentage of complete utterances and the percentage of target vocabularies are included.

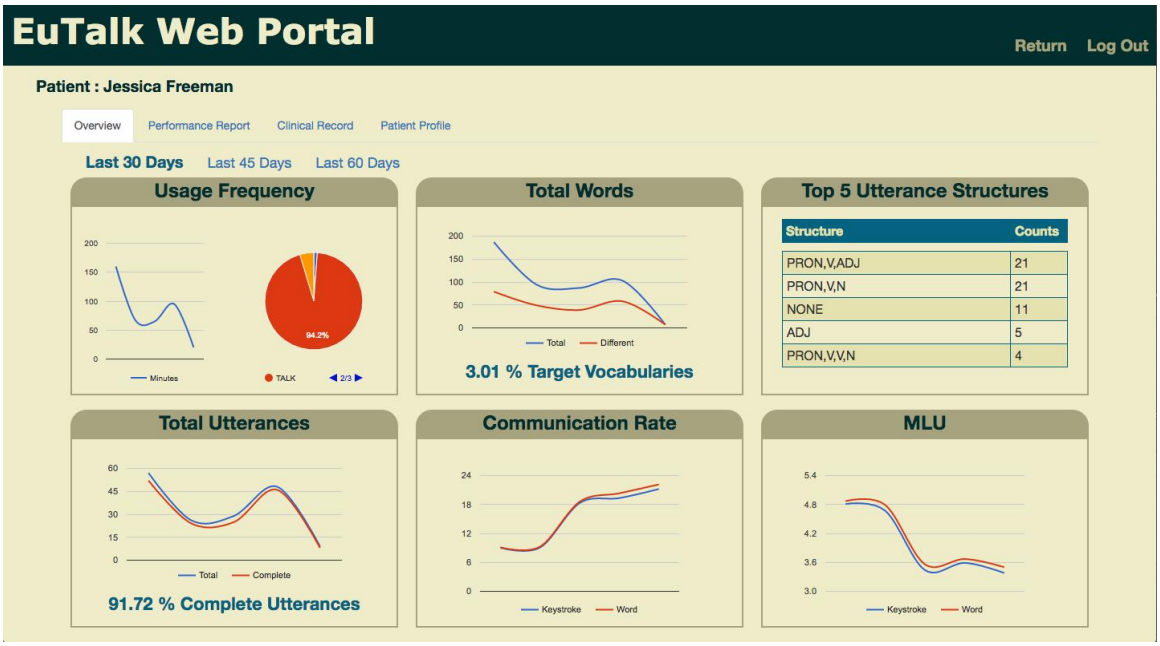


Figure 30. Web Portal: Dashboard Overview

4.2.2 User performance report

In contrast to the dashboard overview, the user performance report provides detailed analysis along with daily results – though the daily results do have the detailed analysis on different summary measures. Three types of summary measures are provided in the second tab (Figure 31), including outcome measurement, summary measures, and language samples. This report gives SLPs the ability to select the specific information they are interested in. The purpose of the performance report is to give SLPs the comprehensive information for clinical evaluation and treatment adjustment. Furthermore, in the clinician survey, most of the participants (90.91%) agreed that it is important to track clients' performance while they are at home. Therefore, a checkbox under each section is provided, which gives SLPs the option to review clients' home performance. When the checkbox is selected, the data collected through the therapy session are automatically excluded from the analysis.

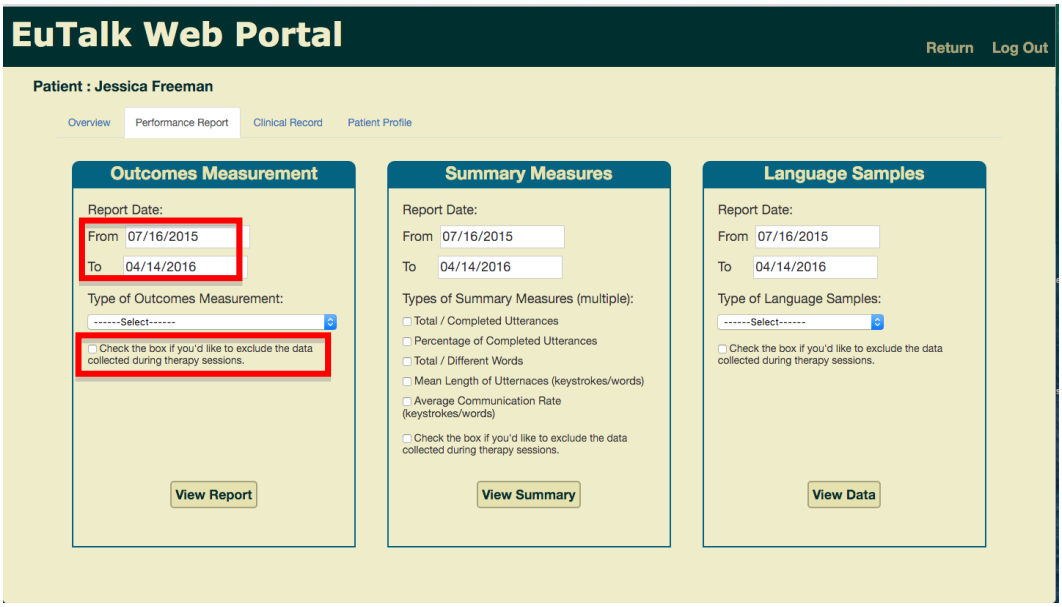
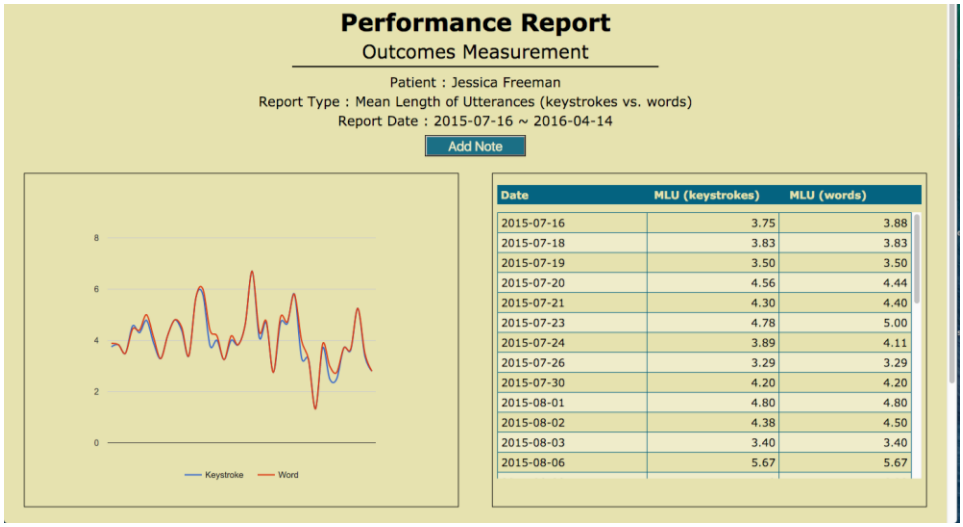


Figure 31. Web Portal: Performance Report

Figure 32 through 35 show examples of performance report with different types of information. The outcomes measurement shows daily average/total for each measure over the selected time period. The summary measures provide an average/total of each measure over the selected time period. The language samples generate different types of lists, which provide SLPs with detailed information on clients' language performance.



Date	MLU (keystrokes)	MLU (words)
2015-07-16	3.75	3.88
2015-07-18	3.83	3.83
2015-07-19	3.50	3.50
2015-07-20	4.56	4.44
2015-07-21	4.30	4.40
2015-07-23	4.78	5.00
2015-07-24	3.89	4.11
2015-07-26	3.29	3.29
2015-07-30	4.20	4.20
2015-08-01	4.80	4.80
2015-08-02	4.38	4.50
2015-08-03	3.40	3.40
2015-08-06	5.67	5.67

Figure 32. Performance Report: Outcomes Measurement

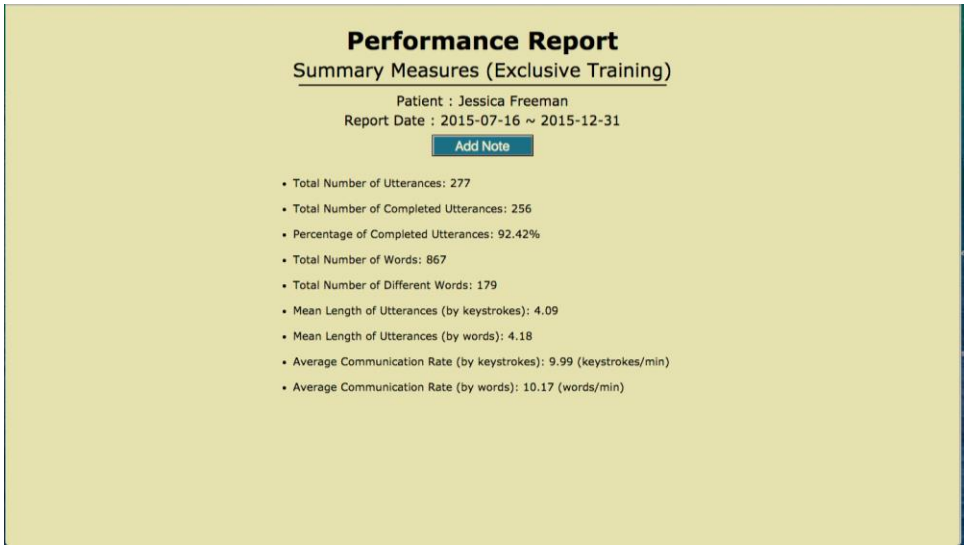
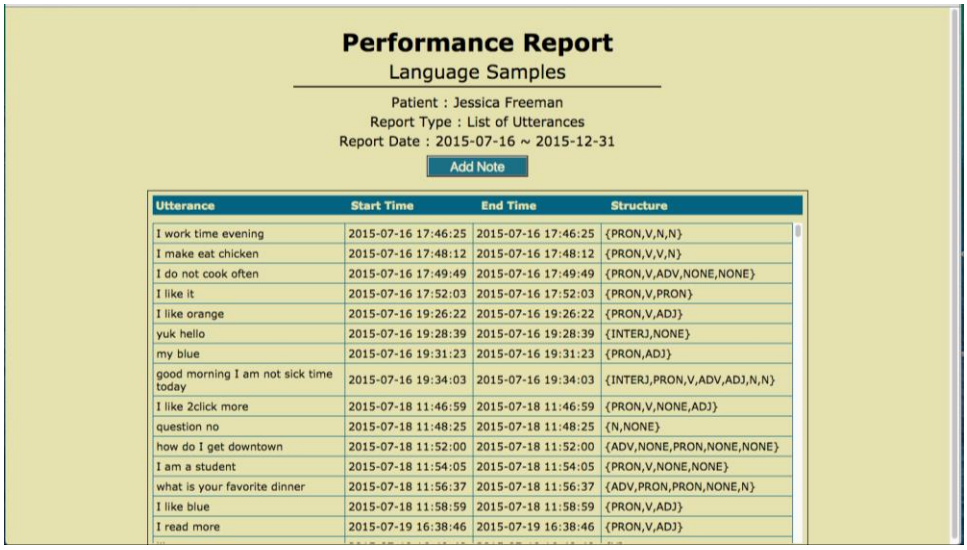


Figure 33. Performance Report: Summary Measures



Performance Report

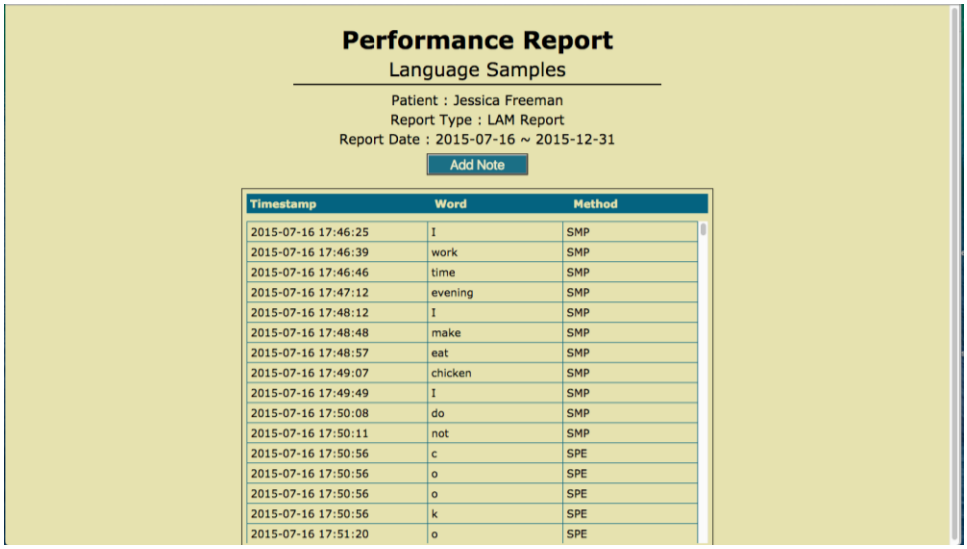
Language Samples

Patient : Jessica Freeman
Report Type : List of Utterances
Report Date : 2015-07-16 ~ 2015-12-31

Add Note

Utterance	Start Time	End Time	Structure
I work time evening	2015-07-16 17:46:25	2015-07-16 17:46:25	{PRON,V,N,N}
I make eat chicken	2015-07-16 17:48:12	2015-07-16 17:48:12	{PRON,V,V,N}
I do not cook often	2015-07-16 17:49:49	2015-07-16 17:49:49	{PRON,V,ADV,NONE,NONE}
I like it	2015-07-16 17:52:03	2015-07-16 17:52:03	{PRON,V,PRON}
I like orange	2015-07-16 19:26:22	2015-07-16 19:26:22	{PRON,V,ADJ}
yuk hello	2015-07-16 19:28:39	2015-07-16 19:28:39	{INTERJ,NONE}
my blue	2015-07-16 19:31:23	2015-07-16 19:31:23	{PRON,ADJ}
good morning I am not sick time today	2015-07-16 19:34:03	2015-07-16 19:34:03	{INTERJ,PRON,V,ADV,ADJ,N,N}
I like 2click more	2015-07-18 11:46:59	2015-07-18 11:46:59	{PRON,V,NONE,ADJ}
question no	2015-07-18 11:48:25	2015-07-18 11:48:25	{N,NONE}
how do I get downtown	2015-07-18 11:52:00	2015-07-18 11:52:00	{ADV,NONE,PRON,NONE,NONE}
I am a student	2015-07-18 11:54:05	2015-07-18 11:54:05	{PRON,V,NONE,NONE}
what is your favorite dinner	2015-07-18 11:56:37	2015-07-18 11:56:37	{ADV,PRON,PRON,NONE,N}
I like blue	2015-07-18 11:58:59	2015-07-18 11:58:59	{PRON,V,ADJ}
I read more	2015-07-19 16:38:46	2015-07-19 16:38:46	{PRON,V,ADJ}

Figure 34. Performance Report: Language Samples – List of Utterances



Performance Report

Language Samples

Patient : Jessica Freeman
Report Type : LAM Report
Report Date : 2015-07-16 ~ 2015-12-31

Add Note

Timestamp	Word	Method
2015-07-16 17:46:25	I	SMP
2015-07-16 17:46:39	work	SMP
2015-07-16 17:46:46	time	SMP
2015-07-16 17:47:12	evening	SMP
2015-07-16 17:48:12	I	SMP
2015-07-16 17:48:48	make	SMP
2015-07-16 17:48:57	eat	SMP
2015-07-16 17:49:07	chicken	SMP
2015-07-16 17:49:49	I	SMP
2015-07-16 17:50:08	do	SMP
2015-07-16 17:50:11	not	SMP
2015-07-16 17:50:56	c	SPE
2015-07-16 17:50:56	o	SPE
2015-07-16 17:50:56	o	SPE
2015-07-16 17:50:56	k	SPE
2015-07-16 17:51:20	o	SPE

Figure 35. Performance Report: Language Samples – LAM Report

4.2.3 User profile management

Other than the user performance overview and user performance report, which provide clients' language performance for SLPs to help them with decision-making and treatment adjustment,

several other features were implemented to better support the automatic analysis and service delivery. These features include (Table 36):

Patient Appointments: SLPs can use the appointment (scheduling) feature to track clients' appointment dates. Moreover, SLPs can save report for every therapy session.

Manage Raw Data: This feature gives SLPs the ability to manually remove certain utterances from the analysis. The complete utterance is defined automatically in the system, which may not always provide fully correct result; therefore, this feature allows SLPs to manually adjust language data in order to generate a more accurate analysis.

Set Target Vocabularies: The list of target vocabularies is used to calculate the percentage of core vocabularies. SLPs can set target vocabularies for the clients and update the list along with the therapy sessions.

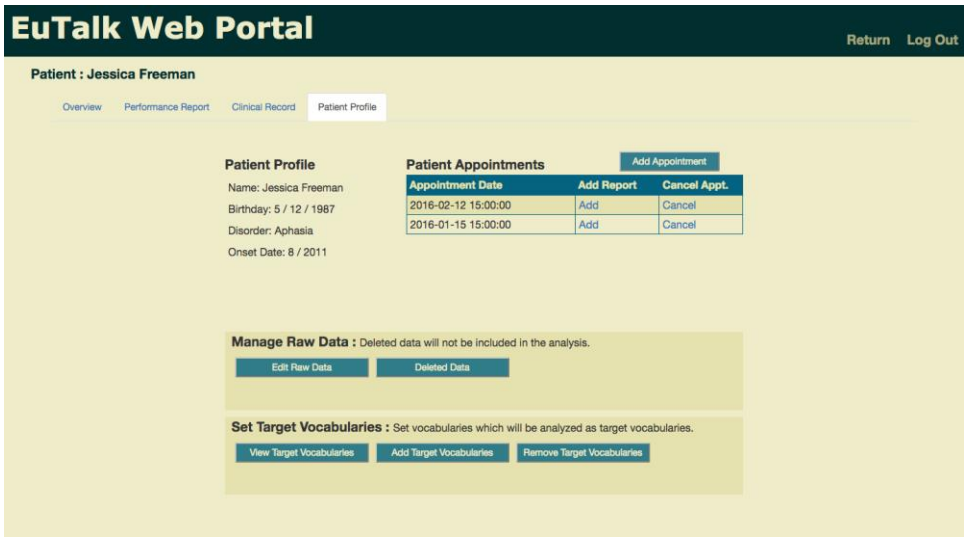


Figure 36. Web Portal: Patient Profile

4.3 SUMMARY

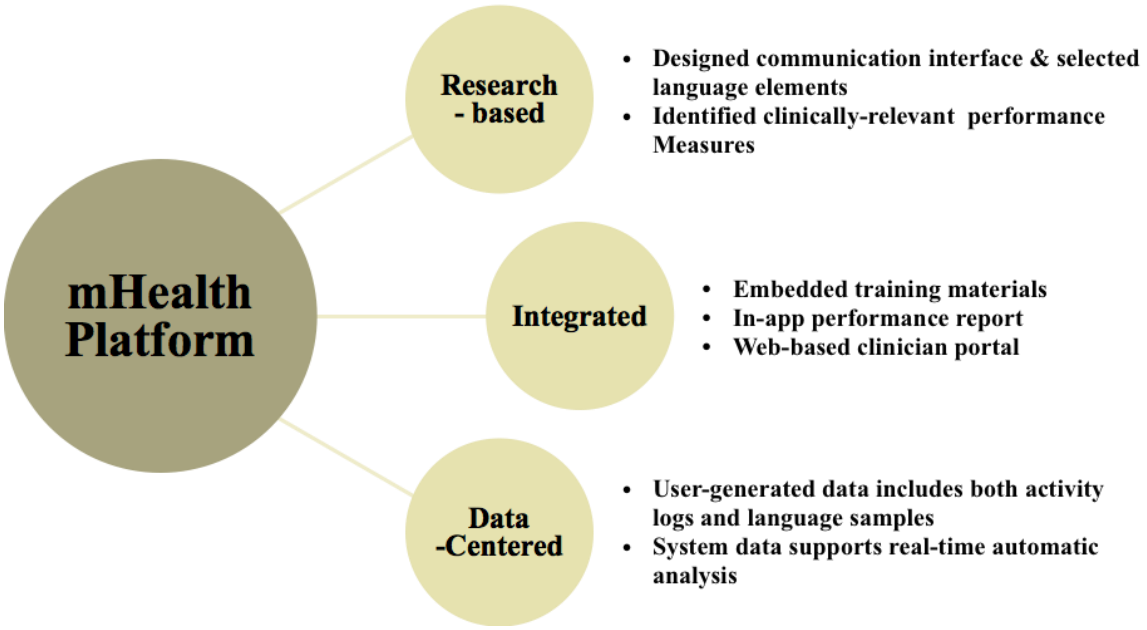


Figure 37. Implementation of the mHealth Platform

The mHealth platform (Figure 37) was implemented with a mobile AAC app (EuTalk) and a web-based clinician portal. The design specifications of the platform followed the findings from the literature review, clinician interview, clinician survey, and the designed system architecture from the previous study. The platform integrates a communication interface, embedded training materials, and in-app performance reports, then further connects the app with a web-based portal to support AAC service delivery. Moreover, to meet the research goal of this work, all user-generated data and user activities are collected. The system data are well defined to support automatic language analysis.

The core vocabularies used in the communication interface are able to cover daily conversations in different circumstances. The alphabet page also provides PwCD with another option to spell out certain words when they are not otherwise available in the provided

vocabulary. Moreover, the customization feature gives PwCD and SLPs the flexibility to change the settings to meet their personal needs or adjust treatment materials conveniently within the app.

The embedded interactive training modules provide PwCD with an alternative way to obtain highly accessible practice exercises without barriers. This design provides PwCD with access to the treatment materials anywhere and at any time. The know-how training also helps PwCD to learn how to use the app efficiently, while the implementation of gamification makes learning interesting, and communication training focuses on language learning. The approach assists PwCD with gaining or recovering knowledge of language elements. Both know-how training and language training can help PwCD learn how to use the app as well as to improve their overall communication competence.

In order to meet the performance measurement requirements, from the very first time a new user account is created every single event from logging in to logging out is recorded in the database. Once user activities are collected, outcome analysis is automatically performed in real time. An easy-to-read visual outcome report is provided to PwCD and caregivers to visually track the progress and have an understanding of their performance. Clinicians can monitor PwCD's performance at any time through the web portal and can adjust the treatment lessons accordingly. In addition to supporting personal monitoring and clinical evaluation, researchers can use this feature for research purpose, since the app stores the detailed LAM log file of events.

5.0 SYSTEM EVALUATION

Three user studies were conducted to evaluate the design and development of the mHealth platform (Table 19). First, a usability study (Appendix B) was conducted with able-bodied participants to discover design and implementation problems in the mobile app from a user's angle. Secondly, after the problems identified in the able-bodied usability study were fixed, a feasibility study (Appendix C) was conducted on PwCD to determine if the targeted users could easily use this app. For the web portal, another user study (Appendix D) was conducted with health professionals to evaluate the usability of the system and to compare the designed platform to existing data collection and reporting approaches.

Table 19. User Studies for System Evaluation

System	**Evaluation**	**Purpose**	**Participant**
Mobile App	Phase 1: Usability study	Discover design problems and evaluate the usability of the app.	Able-bodied participants
	Phase 2: Feasibility study	Evaluate the usability of the app for real users.	People with communication disabilities
Web Portal	Phase 3: Usability study	Evaluate the usability of the portal. Compare our platform to existing data collection and reporting approaches.	Health professionals

5.1 USABILITY AND FEASIBILITY STUDIES ON MOBILE APP

5.1.1 Methods

5.1.1.1 Recruitment

Considering that the mobile AAC app was under the development process, able-bodied individuals were recruited for the first usability study. In order to prevent misleading results, potential participants were individuals whose native language is English and who have ages between 18 and 65. Additionally, eligible participants must have the ability to operate a tablet device and have no communication disabilities. Twenty adults who meet the inclusion and exclusion criteria were selected to participate from a pool of volunteers recruited via following procedures: (1) a recruitment flyer was posted in the greater Pittsburgh area; (2) word of mouth. Individuals who were interested in participating received a phone call from the principal investigator to verify their eligibility to participate in this study.

For the feasibility study, people with communication disabilities were recruited for the study. Potential participants were individuals whose native language is English and who have ages between 18 and 65. Additionally, eligible participants are required to have the ability to follow oral instructions and operate a tablet device. Potential participants were excluded if they were not able to understand the oral instructions from the principal investigator or were not able to operate a tablet device. Five adults with communication disabilities who met the inclusion and exclusion criteria were selected to participate from a pool of volunteers recruited via the following procedures: (1) clinician referral; (2) the CTSI Research Participant Registry. Individuals who were interested received an email from the principal investigator to confirm the event. All potential participants were asked to take Western Aphasia Battery (WAB) test and try

the Android "Mole Hammer - Whack a Mole" app to verify that they meet the inclusion/ exclusion criteria described above. This screening procedure was performed on the same day as the study date, before potential participants were accepted. The screening procedure took around 15 minutes and was conducted at the study site.

5.1.1.2 Procedures and tasks

The experiment consisted of a demographic survey, an introduction of the study, a demonstration of the app, a task section with six different activities, a self-exploration section, two post-task questionnaires, one usability questionnaire, and a post-session interview. The entire study took 1.5 - 2 hours to complete (Figure 38).

First, the participant was asked to complete a questionnaire on their demographic information including age, education level, mobile devices experiences, etc. Thereafter the participant was introduced to the mobile device, and was given a brief orientation and demonstration of the testing app running on the tablet.

In order to get the real experience of using the app, the participant was first asked to perform a number of tasks, including use communication board to make a conversation based on given scenarios, try the game and practice modes, read and interpret the report, and use the ICU and Favorites panels to communicate with the researcher. During the evaluation process, the participant was encouraged to think out loud. Upon completion of assigned tasks after each session, the participant was asked to complete a post-task questionnaire. The post-task questionnaire was designed to collect immediate feedback from the participants about the specific features of the app.

Second, the participant was given 20 minutes to explore the app, following guidelines provided by the researcher. In the meantime, the principal investigator monitored the

participant's real-time activities through the Internet. All activity data, such as communication board usage, training experiences, and others, were logged in the device and were synced to a secure server.

After the participant finished self-exploration, the participant was asked to complete a customized usability questionnaire to provide feedback on their overall perception of and satisfaction with the app. The principal investigator asked general and open questions about the app. The responses to the general questions were collected through the Qualtrics survey system. The principal investigator took notes for the responses to the open questions.

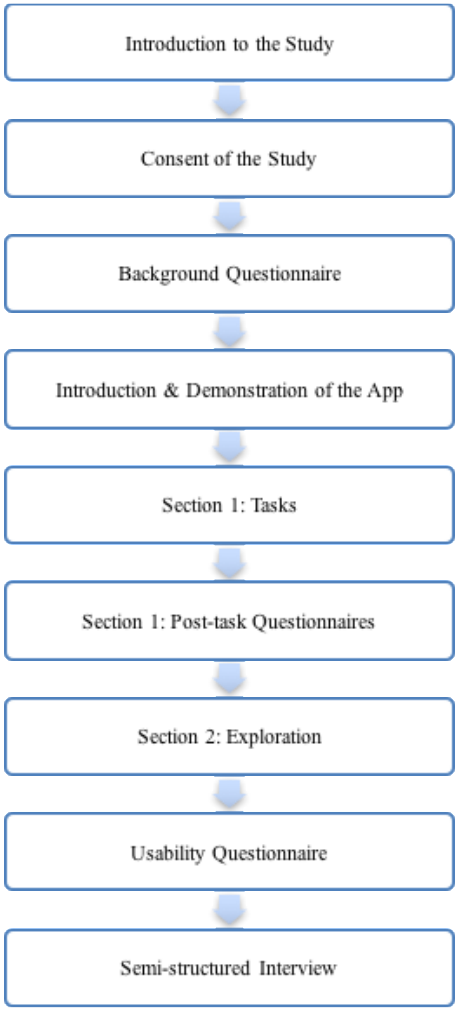


Figure 38. Study Flow Chart: Mobile App

Demographic Survey. Each participant completed a demographic survey, including information on participants' age, education level, mobile devices experiences, and other relevant information. The data collected from this survey are for statistical purposes.

Tasks Section. The tasks in this section were designed to discover usability errors.

- Task 1. Account Sign Up: The participants were asked to create a new user account, including creating a new user ID and password, entering demographic information, and answering clinical questions.
- Task 2. Game: The participants were asked to try the game two times in two different levels.
- Task 3. Practice: The participants were asked to try the practice mode two times with two different word sets.
- Task 4. 1-hit Talk: This task contains two subtasks. The participants were asked to answer seven conversation questions using communication board to express their feelings and basic needs in subtask 1. Then the participants were asked to engage in small talk with the study investigator in subtask 2. In this task, the communication board was set in the 1-hit design.
- Task 5. 2-hit Talk: This task contains the same subtasks as Task 4, but the communication board was set in the 2-hit design. Instead of the purpose mentioned in Task 4, this task was designed to evaluate user experiences between the 1-hit and 2-hit design.
- Task 6. Favorite, ICU, and Report: This task contains three different scenarios in order to provide participants hands-on experiences with the Favorite, ICU, and Report features. In scenario 1, the participants were asked to use the Talk and

Favorites features to create sentences to use in an emergency situation. In scenario 2, the participants were asked to use Talk and ICU to communicate with healthcare professionals in a hospital setting. In scenario 3, the participants were asked to review a possible report and discuss it with the study investigator. These scenarios were designed to evaluate and understand user perception on a possible report as caregivers and clinicians.

Post-task Questionnaires. Each participant filled out total two post-task questionnaires and provided written comments after the completion of assigned tasks. These two questionnaires were designed to collect immediate feedback from the participants.

Self-exploration Section. In this section, the participants were guided to explore the app alone with the suggested activities. This section was designed to provide participants more hands-on experiences with no limitations from pre-designed conversations and scenarios. In the meantime, the study investigator remotely monitored participants' real-time performance for further discussion in the semi-structured interview.

Usability Questionnaire & Semi-structured Interview. The participants were asked to provide feedback on their overall perception of and satisfaction with the app. Afterward, a semi-structured interview was conducted, based on participants' performance on and experience in the Task and Self-exploration sections as well as their feedback on the post-task questionnaires.

For the feasibility study, which was conducted on people with communication disabilities, the study procedures were adjusted to meet the participants' needs. To avoid misleading results, Task 6, the self-exploration section, and the semi-structured interview were removed from the usability study procedure. The questions in the usability questionnaire were also revised.

5.1.2 Results – usability study

5.1.2.1 Participants

A total of 20 participants were recruited to participate in this usability study. The participants were between the ages of 20 and 64 (M 31.35, SD 14.14). Forty-five percent of participants were male (n = 9); 55% were female (n = 11). Five of the twenty participants had knowledge of communication sciences and AAC, and the other fifteen participants were from various backgrounds. Tables 20 - 22 below list background characteristics, mobile devices experiences, and overall AAC literacy of summative study participants.

Table 20. Background Characteristics of Summative Study Participants

Highest Academic Degree Completed	**N**	**%**
High School	10	50%
Bachelor's	6	30%
Master's	4	20%

Age	**N**	**%**	**Mean**	**SD**
18 – 30	13	65%	22.92	3.40
31 – 45	4	20%	37.00	4.69
45 – 65	3	15%	60.33	3.21

Table 20 (continued)

Area of Study / Work	**N**	**%**
Communication Science and Disorders	5	25%
Information Science*	4	20%
Occupational Therapy	2	10%
Bioinformatics / Health Informatics	2	10%
Others**	7	35%

* Information science, intelligence systems, and information technology

** Education, environmental science, facilities management, healthcare, management, mathematics, and statistics

Table 21. Mobile Devices Experiences of Summative Study Participants

Time Spent on Mobile Devices	**N**	**%**
< 1 hour	2	10%
1 – 3 hours	13	65%
3 – 5 hours	2	10%
> 5 hours	3	15%

Mobile Devices Experiences	**N**	**%**
iOS only	2	10%
Android only	6	30%
Both iOS and Android	11	55%

* One participant only had experience with using an Amazon Kindle

Table 21 (continued)

Confidence Level for Mobile Devices	**N**	**%**
Neither Confident or Unconfident	4	20%
Confident	10	50%
Very Confident	6	30%

Daily Activities on Mobile Devices	**N**	**%**
Email	18	90%
Health and Fitness	6	30%
Games	8	40%
Searching on the Internet	17	85%
Shopping	6	30%
Social Networking	14	70%
Others*	8	40%

* Calendar/reminder, banking, listening to music, school/homework, maps, reading e-books, texting, phone calls

Table 22. AAC Literacy of Summative Study Participants

Familiar with Communication Disabilities	**N**	**%**
Yes	15	75%
No	5	25%

Table 22 (continued)

Familiar with AAC	N	%
Yes	8	40%
No	12	60%

5.1.2.2 Error detection

Both human and system errors were detected in the usability study. The human errors included problems with the interface design, which could lead to user frustration. The system errors included incorrect system data and errors in the stored procedures.

- Human Errors
    - In task 1, participants were asked to sign up with a new user account. Several participants were not able to fill in all the demographic questions on the first sign up page, since there were a few questions hidden under the soft keyboard. *This error was fixed by configuring the page as a scrollable page.*
    - In Talk, participants were easily confused by the "Talk Bar" and "Delete" buttons. Participants tended to click "Talk Bar" to delete the word and clicked "Delete" to return to the previous page. *This error can be fixed by providing overlay instructions to the first-time user in further development. Also, the word "Delete" was added to the button to avoid confusion.*
- System Errors
    - In Talk, the background color for "strawberry" in the 2-hit approach is not correct. *This error can be fixed by updating the database.*

- In History (under Talk), the first 10 utterances are shown instead of the most recent 10 utterances. *This error was fixed by fixing error codes.*
- In Game (under Training), there is one missing icon in Level 2. *This error was fixed by fixing error codes.*
- In the backend data collection, the data elements collected from Talk (i.e. page transition, delete) did not store correctly in the corresponding table. *This error was fixed by fixing error codes.*

5.1.2.3 Overall usability

The IBM Post Study System Usability Questionnaire (IBM PSSUQ) was adopted to measure participant's perception of the app's overall usability (Lewis, 1995). The statements were chosen from IBM PSSUQ, but were slightly modified (since others are not relevant to this particular study); we believed that the questions would be more relevant if we used the name of the feature/app in the question, instead of referring it as 'the system.' All 20 participants completed both the post-task and usability questionnaires. Participants responded to all statements on a 5-point Likert scale that ranged from 1 (strongly disagree) to 5 (strongly agree). In other words, higher numbers indicate a greater level of satisfaction with the app. Tables 23-25 show usability assessments from 3 post-task questionnaires. On average, all the usability factors were rated at 3.95 out of 5. Table 26 presents a full breakdown of the numbers for each question.

Table 23. The Usability Study's Post-Task Results: Using the Communication Board

Item	Mean	SD
1.1 I would find the Communication Board easy to use.	3.75	.64
1.2 I was able to complete the tasks and scenarios using the Communication Board.	3.90	.45
1.3 I liked using the interface of the Communication Board.	3.90	.64
1.4 I would find the Communication Board intuitive to use.	3.45	.83
1.5 I would find the page navigation easy to understand.	3.65	.75
1.6 I would find the function keys helpful using the Communication Board.	3.90	.55
1.8 I would find 1-hit Setting is sufficient to make daily conversation.	3.30	.98
1.9 I would find 2-hit Setting is sufficient to make daily conversation.	4.15	.67
1.10 I would find 1-hit Setting helpful to make more accurate sentences.	2.80	.83
1.11 I would find 2-hit Setting helpful to make more accurate sentences.	3.90	1.02
1.12 I would find the vocabulary provided is sufficient to make daily conversation.	4.10	.45
1.13 I would find the display of icons helpful making sentences.	2.60	1.10
1.9 I would find 2-hit Setting is sufficient to make daily conversation.	4.15	.67
1.10 I would find 1-hit Setting helpful to make more accurate sentences.	2.80	.83
1.11 I would find 2-hit Setting helpful to make more accurate sentences.	3.90	1.02
1.12 I would find the vocabulary provided is sufficient to make daily conversation.	4.10	.45
1.13 I would find the display of icons helpful making sentences.	2.60	1.10

Table 24. The Usability Study's Post-Task Results: Embedded Trainings

Item	Mean	SD
2.1 I would find the Game easy to use.	4.10	.72
2.2 I was able to complete the tasks using the Game.	4.10	.72
2.3 I liked using the interface of the Game.	4.10	.55
2.4 I would find the Game intuitive to use.	4.00	.79
2.5 I would find the Game helpful to use the Communication Board.	4.35	.67
2.6 I would find the Practice easy to use.	4.10	.64
2.7 I was able to complete the tasks using the Practice.	3.90	.64
2.8 I liked using the interface of the Practice.	3.90	.64
2.9 I would find the Practice intuitive to use.	3.74	.81
2.10 I would find the Practice helpful to use the Communication Board.	4.21	.79
2.11 I would find the achievement banner (result) motivational.	3.70	1.03

Table 25. The Usability Study's Post-Task Questionnaire Results: Reporting and Other Features

Item	Mean	SD
3.1 I was able to complete the scenario using the Report.	4.00	.65
3.2 I liked the interface of the Report.	4.10	.55
3.3 I would find the information provided in Report easy to understand.	4.25	.55
3.4 I would find the information provided in Report helpful.	3.90	.72
3.5 I would find the Report helpful to use the Communication Board.	4.30	.66
3.6 I was able to complete the scenario using Favorites.	3.90	.72

Table 25 (continued)

3.7 I would find the Favorites helpful to use the pre-stored important sentences.	3.80	1.01
3.8 I liked using the interface of the Favorites.	3.50	1.15
3.9 I was able to complete the scenario using ICU.	4.20	.62
3.10 I would find the ICU helpful.	3.75	.72
3.11 I liked the interface of the ICU.	3.65	.88

Table 26. The Usability Study's Post Study Results

Item	**Mean**	**SD**
1. Overall, learning to operate EuTalk would be easy for me.	4.30	.57
2. Overall, I felt comfortable using EuTalk.	3.95	.51
3. Overall, I liked using the interface of EuTalk.	3.95	.76
4. Overall, I could recover from errors easily and quickly using EuTalk.	3.85	.59
5. Overall, I felt confident using EuTalk to communication with others.	3.68	.58
6. Overall, I am satisfied with EuTalk.	3.98	.39

5.1.2.4 Overall user performance

The user performance of the app was evaluated by log analysis. The log analysis attempted to understand the patterns of user activities, as well as users' performance on the task and self-exploration. Participants made 583 utterances in total, and around 30 utterances on average. Overall user performance was analyzed through users' communication rates and mean length of utterances. The purpose of this analysis is to understand if there is a significant difference in

participant performance among different demographic groups. An Independent Samples t test was used to compare participant's language performance. The results (Table 27) show that there were no significant differences in user performance between gender (p = .474), age (p = .217), and AAC knowledge (p = .982).

Table 27. User Performance on Communication Rates and Mean Length of Utterances

		Communication Rates		**Mean Length of Utterances**	
		Mean	**SD**	**Mean**	**SD**
Gender	Male	9.28	2.27	4.24	.93
	Female	10.13	4.90	3.94	.85
Age	< 31	10.55	4.26	4.27	.99
	>= 31	8.26	2.70	3.72	.49
AAC Knowledge	Familiar	8.91	3.28	4.09	.63
	Not Familiar	10.30	4.27	4.08	1.04

Overall, positive feedback was received from both able-bodied participants and PwCD. The able-bodied participants believed that the app would be easy to learn to use effectively. Also, they were able to interpret the performance report even without prior AAC knowledge. Therefore, the proposed report would be easy to understand for AAC users and their caregivers. The participants agreed that the app would be helpful for PwCD to live more independently. The main concern is that several participants were expecting to generate grammatically correct sentences. Below are some feedbacks from able-bodied participants:

- “Why some words are in certain categories confuses me, it's tricky to find certain words.”
- “I would like the option to change tenses for some of the verbs to make sentences grammatically correct.”
- “I do believe that this app would be helpful for them. It would depend on the individual's disorder but for general AAC cases, this would be an effective (a potentially cost-effective) device.”

5.1.3 Results - feasibility study

5.1.3.1 Participants

A total of four participants were recruited to participate in this feasibility study. All four participants were able to complete the assigned tasks and provide feedback through the questionnaires (n = 4). Participants were aged 23, 45, 49, and 57 (M 43.75, SD 14.55). Seventy-five percent of participants were female (n = 3); 25% were male (n = 1). One of the four participants had used dedicated AAC devices before.

5.1.3.2 Overall usability

The statements that were chosen from the IBM PSSUQ and used in the usability study were slightly modified for this feasibility study. Four participants completed two post-task questionnaires and a modified usability questionnaire with seven statements. Participants responded to all statements on a 5-point Likert scale, from 1 (strongly disagree) to 5 (strongly agree). In other words, higher numbers indicate a greater degree of satisfaction with the app.

Table 28-29 show usability assessments from the post-task questionnaires. In sum, all the usability factors were rated with an average of 3.96 of 5. Table 30 presents a breakdown of the numbers for each question.

Table 28. The Feasibility Study's Post-Task Results: Communication Board

Item	Mean	SD
1.1 I would find the Communication Board easy to use.	4.25	.50
1.2 I was able to complete the tasks and scenarios using the Communication Board.	3.50	.58
1.3 I liked using the interface of the Communication Board.	3.50	.58
1.4 I would find the Communication Board intuitive to use.	3.50	.58
1.5 I would find the page navigation easy to understand.	4.25	.50
1.6 I would find the function keys helpful using the Communication Board.	3.75	.96
1.7 I would find the history helpful when I need to look up my old sentences.	4.00	.82
1.8 I would find 1-hit Setting is sufficient to make daily conversation.	4.00	.82
1.9 I would find 2-hit Setting is sufficient to make daily conversation.	4.25	.50
1.10 I would find 1-hit Setting helpful to make more accurate sentences.	4.25	.50
1.11 I would find 2-hit Setting helpful to make more accurate sentences.	4.25	.96
1.12 I would find the vocabulary provided is sufficient to make daily conversation.	4.00	.82
1.13 I would find the display of icons helpful making sentences.	3.75	.50

Table 29. The Feasibility Study's Post-Task Results: Embedded Trainings

Item	Mean	SD
2.1 I would find the Game easy to use.	4.00	.00
2.2 I was able to complete the tasks using the Game.	4.25	.50
2.3 I liked using the interface of the Game.	4.50	.58
2.4 I would find the Game intuitive to use.	4.25	.50
2.5 I would find the Game helpful to use the Communication Board.	4.25	.50
2.6 I would find the Practice easy to use.	4.25	.96
2.7 I was able to complete the tasks using the Practice.	4.50	.58
2.8 I liked using the interface of the Practice.	4.25	.50
2.9 I would find the Practice intuitive to use.	4.00	.00
2.10 I would find the Practice helpful to use the Communication Board.	4.00	.82
2.11 I would find the achievement banner (result) motivational.	4.50	.58

Table 30. The Feasibility Study's Post-Study Results

Item	Mean	SD
1. Overall, learning to operate EuTalk would be easy for me.	4.00	.82
2. Overall, I felt comfortable using EuTalk.	4.25	.50
3. Overall, I liked using the interface of EuTalk.	4.00	.82
4. Overall, I could recover from errors easily and quickly using EuTalk.	4.25	.96
5. Overall, I felt confident using EuTalk to communication with others.	4.00	.82
6. Overall, I am satisfied with EuTalk.	3.25	1.71
7. Overall, I would like to use EuTalk to help me communication with others.	4.00	.82

5.1.4 Conclusion

Overall, the mobile AAC app received positive feedback from both able-bodied participants and PwCD. Able-bodied participants tended to have higher expectations for the accuracy of the grammar of their sentences, because they are used to speaking with grammatically correct sentences. The gap between their expectations for the communication and their experiences with the app may have led to these less favorable results. The user satisfaction was rated lower in the feasibility study, due to user frustration. One of the PwCD participants reported feeling tired because of the mental activities required during the evaluation process, and this exhaustion was mainly caused by the participant's disability. During the in-depth interview, the able-bodied participants claimed that they were very satisfied with the integrated features of the app. Furthermore, participants with strong AAC knowledge were less concerned about generating accurate sentences than the rest of the participants. Both embedded trainings and performance report were helpful for them to both learn and use the communication interface. From the perspective of the PwCD, all participants agreed that the training materials were very helpful for using the communication interface. In terms of the overall user experience, participants with communication disabilities were more satisfied with the app than the able-bodied users.

5.2 USABILITY STUDY ON WEB PORTAL

5.2.1 Methods

5.2.1.1 Recruitment

Professionals from the field of speech language pathology were recruited for this study, including certified speech language pathologists and graduate students from the communication science and disorders program. All participants had ages between 18 and 65. Ten individuals who meet the inclusion criteria were selected from a pool of volunteers recruited via the following procedures: (1) a recruitment script was sent to the speech language pathology communities via email; (2) word of mouth. Individuals who were interested in participating in the usability study received an email from the principal investigator to confirm the event.

5.2.1.2 Procedures and tasks

The session started from the principal investigator explaining the study purpose and evaluation procedures to the participant. Then the participant was asked to sign the informed consent form agreeing to participate in this study. Afterward, the participant had to complete a questionnaire regarding background information including age, clinical experience, computer experiences, and other demographic information. Next, the participant was introduced to three different data collection and reporting approaches on AAC technologies. To obtain real experience from these three approaches, the principal investigator went through each approach with the participant. Different tasks were designed accordingly and two after-scenario questions were asked after each single task. Upon completion of all assigned tasks after the hands-on session, the participant

was asked to complete a post-task questionnaire on their overall perception and satisfaction of the system. All activities during the hands-on session were logged and analyzed afterward in order to evaluate the proposed approach. Once the evaluation process was completed, the principal investigator reviewed three approaches with the participant. After the review, the participant was asked to complete a post-study questionnaire to compare the three approaches. The entire study took one hour to complete. Figure 39 shows the flow of this usability study.

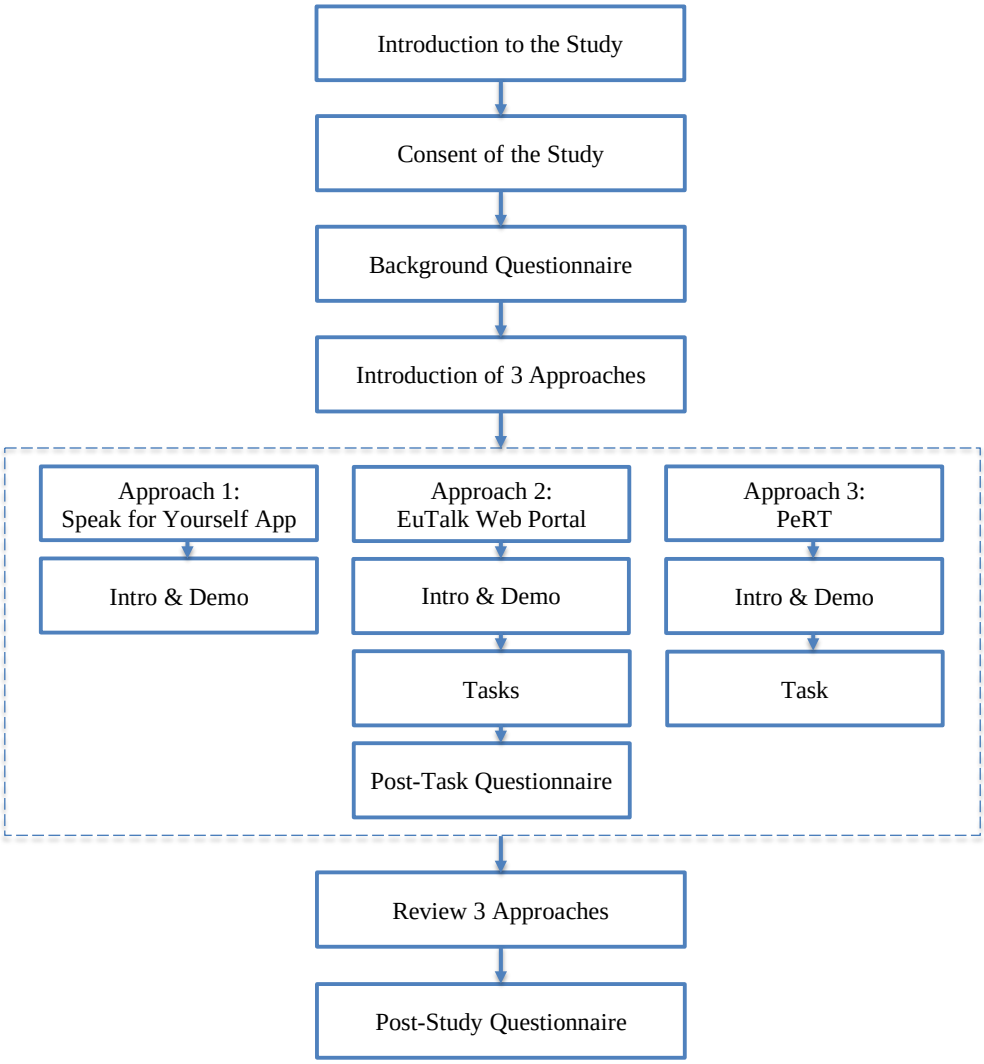


Figure 39. Study Flow Chart: Web Portal

A total of five tasks were designed in order to cover all features in the web portal:

Task 1: Manage Client List

1.1 Please add clients to your list with the information below:

Client Name	**Date of Birth**
Ryan Brooks	3 / 28 / 1966
Jessica Freeman	5 / 12 / 1987

1.2 Please remove the client from your list with the information below:

Client Name	**Date of Birth**
Bryan Benish	4 / 30 / 1993

Task 2: Report Overview

2.1 Please answer the following questions with **Jessica Freeman**'s last 45 days of performance

a. What's the most used method of generating utterance? How many words were generated with this method?
b. How many complete utterances did Jessica generate on the week of 8/30?
c. What's the most used utterance structure?
d. How many different words did Jessica use on the week of 9/6? What's the percentage of target vocabularies?
e. How many minutes did Jessica spend on AAC on the week of 8/23?
f. What's the percentage of using "Training" on the app?

Task 3: Review Performance Report

3.1 Please answer the following questions with **Ryan Brooks**' performance report, and put your answers in the note (Add Note)

a. Outcomes measurement – Review mean length of utterance from 8/5/2015 to 8/31/2015. What's the MLU (keystrokes) vs. MLU (words) on 8/25/2015?
b. Summary Measures – Review Ryan's performance at home on total number of utterances and communication rate from 9/1/2015 to 10/1/2015. What's the number of total completed utterances? What's the average communication rate by keystrokes?
c. Language Samples – Review list of words from 8/20/2015 to 10/5/2015. What are the top five most used words?

Task 4: Patient Profile - Manage Language Data

4.1 Manage Raw Data for **Jessica Freeman**

a. Please review utterance data from 7/16/2015 to 7/31/2015, and remove the utterances that you feel are incorrect.
b. Please review deleted utterance data from 8/1/2015 to 8/31/2015, and put back the utterances that you feel were wrongfully deleted.

4.2 Define target vocabularies for **Jessica Freeman**

a. Please list the current target vocabularies:
b. Please add the words "say", "work", and "learn" under Page Verb to the target vocabularies.

c. Please remove all words under Page Home from the target vocabularies.

Task 5: Patient Profile - Manage Patient Record

5.1 Manage Patient Appointments for **Jessica Freeman**

a. Please cancel the appointment for Jessica on 2/8/2016.

b. Please add a new appointment for Jessica on 2/12/2016 at 3:00pm.

c. Please add a visit report for 1/15/2016 appointment with the content below:

Title: Jessica's visit report

Description: Description version 1.0

5.2 Manage Clinical Records for **Jessica Freeman**

a. Please update Jessica's visit report on 1/5/2016 with the content below:

Title: Jessica's visit report

Description: Description version 2.0

5.2.2 Results

5.2.2.1 Participants

A total of 10 participants were recruited to participate in this usability study, including five SLPs and five graduate students from the Department of Communication Science and Disorders. Ten participants were able to complete the tasks and provide feedback through the questionnaires (n = 10). Participants had ages between 22 and 61 (M 28.40, SD 11.71). Eighty percent of participants were female (n = 8) and 20% were male (n = 2). The length of time that each participant has provided AAC clinical services ranged from half a year through 30 years of experience (M 4.35, SD 8.65).

5.2.2.2 Overall usability

The IBM After-Scenario Questionnaire (IBM ASQ) was adopted to measure each participant's perception of the portal's usability of each designed feature (Lewis, 1995). Two statements were chosen from the IBM ASQ and were slightly modified:

Q1: Overall, I am satisfied with the ease of completing this task.

Q2: Overall, I am satisfied with the amount of time it took to complete this task.

All 10 participants completed the after-scenario questionnaire. Participants responded to all statements on a 5-point Likert scale, from 1 (strongly disagree) to 5 (strongly agree). In other words, higher numbers indicate greater satisfaction with the portal. On average, both statements were rated at 4.28 out of 5. Table 31 shows a breakdown of the numbers for each task.

Table 31. The Usability Study's After-Task Results

	ASQ	**Mean**	**SD**
Task 1: Manage Client List	Q1	4.70	.48
	Q2	4.70	.48
Task 2: Report Overview	Q1	4.40	.70
	Q2	4.40	.70
Task 3: Review Performance Report	Q1	4.40	.52
	Q2	4.20	.42
Task 4: Patient Profile	Q1	3.90	1.20
- Mange Language Date	Q2	4.00	.94
Task 5: Patient Profile	Q1	4.00	.94
- Manage Patient Record	Q2	4.10	.74

The IBM Post Study System Usability Questionnaire (IBM PSSUQ) was adopted to measure a participant's perception of the portal's overall usability (Lewis, 1995). Fourteen statements were chosen from the IBM PSSUQ and were slightly modified, since others are not relevant to this particular study; we also believe that the questions became more relevant if we used the actual name of the web-based portal in the question, instead of referring it as 'the system.' All ten participants completed the usability questionnaire. Participants responded to all statements on a 5-point Likert scale, from 1 (strongly disagree) to 5 (strongly agree). In other words, higher numbers indicated greater satisfaction with the portal. On average, all the usability factors were rated at 4.18 out of 5. Table 32 presents a breakdown of the numbers for each question.

Table 32. The Usability Study's Post-Task Results: Web Portal

Item	Mean	SD
1. Overall, I am satisfied with how easy it is to use this web-based portal.	4.40	.52
2. It was simple to use this web-based portal.	4.30	.48
3. I could effectively complete the tasks using this web-based portal.	4.40	.52
4. I was able to complete the tasks quickly using this web-based portal.	4.00	.47
5. I was able to efficiently complete the tasks using this web-based portal.	4.50	.53
6. I felt comfortable using this web-based portal.	3.80	.63
7. I believe I could become productive quickly using this web-based portal.	4.50	.53
8. Whenever I made a mistake, I could recover easily and quickly.	4.00	.67
9. It was easy to find the information I needed.	3.80	.79
10. The organization of information on this web-based portal was clear.	3.90	.88
11. The interface of this web-based portal was pleasant.	4.10	.32

Table 32 (continued)

12. I liked using the interface of this system.	4.20	.42
13. This web-based portal has all the functions and capabilities I expect it to have.	4.30	0.67
14. Overall, I am satisfied with this system.	4.30	0.48

5.2.2.3 Evaluation of integrated platform

After participants were introduced to three data collection and reporting approaches, the participants were asked to compare the integrated platform with another two existing data collection and reporting approaches. Five statements were developed in order to evaluate the five key characteristics that were identified in Chapter 3 (comprehensive, automatic, real-time, clinically relevant, and easily accessible). In sum, the results show that the participants agreed that our integrated mHealth platform could better support data collection and reporting in AAC service delivery. Table 33 shows the responses from the participants:

Table 33. Comparison of Three Data Collection and Reporting Approaches

	#1 Mobile AAC App	**#2 Integrated Platform**	**#3 Dedicated AAC Device**
1. Which of the data collection and reporting approaches do you like the most?	10%	**80%**	10%
2. Which one of the approaches would you feel provides more comprehensive data collection?	0%	**90%**	10%
3. Which one of the approaches would you feel provides the most automatic data collection and reporting workflow?	0%	**10%**	0%
4. Which one of the approaches would you feel provides the easiest access to the information you need?	20%	**70%**	10%
5. Which of the approaches would you prefer to use?	0%	**90%**	10%

Overall, 90% of the participants selected the integrated platform as the approach that they would prefer to use for supporting clinical intervention, while 10% selected the dedicated AAC device as the preferred approach. Furthermore, 90% of the participants selected the integrated platform as the approach that they would recommend the organizations to adopt, while 10% selected the dedicated AAC device. Below is some feedback from the participants:

- “Quickest, easiest and nicest to look at, user friendly, easy to teach, nice graphic.”
- “Data is always available on the clinician portal. The data was clearly divided into categories and was very comprehensive. The ability to search for specific time periods was very helpful.”
- “I think that the web-based portal provided the most comprehensive information in the most efficient manner. I also thought that the user interface was simple and intuitive. The PeRT approach also appeared comprehensive but the interface was too busy and the selection of utterances seems labor-intensive. For the Speak for YourSelf app, I didn't like that the detailed utterance data was lost when the performance report was emailed (e.g., just the summary was emailed).”
- “Web based clinical portal is easy to use, data is collected in real time and clinicians have access to information at any time.”
- “Provides all date needed for intervention purposes.”
- “Ability to gather data before the client’s therapy session.”

5.3 SUMMARY

The usability and feasibility studies of the mobile AAC app were conducted with both able-bodied individuals and with PwCD. The study results show that the participants believe EuTalk is beneficial for PwCD, as it could help them to say what they want to say. Furthermore, the embedded training methods are able to support the ease of use of the mobile AAC app. All participants agreed that the app establishes an alternative treatment protocol for communication rehabilitation, which incorporates AAC intervention with self-learning and real-time monitoring.

The usability study of the integrated platform was conducted with health professionals. Overall, the study results confirm that the integrated platform provides the ability to collect comprehensive clinical evidence, analyze collected data automatically in real-time, and generate clinically relevant performance measures at an easily-accessible web portal. The evaluation concluded that the integrated platform offers a better clinical data analytics approach for AAC clinical service delivery.

6.0 CONCLUSION AND DISCUSSION

6.1 SUMMARY OF THE RESULTS

The main goal for this dissertation was to develop an mHealth platform to streamline the workflow of clinical service delivery. We proposed to integrate AAC service delivery with mHealth by extending traditional clinical intervention with a mobile AAC app and a web-based clinician portal. This work was divided into three studies (Table 34). In study 1, a mixed method, including a literature review, clinician interviews, and clinician surveys, was used to design the system architecture and identify design specifications. In the second study, a mobile AAC app, EuTalk, and a web-based clinician portal were implemented. EuTalk integrates a communication interface with embedded training materials and provides an in-app performance report. The portal provides clinician with easy access to patient performance reports. In the last study, usability and feasibility studies were conducted to evaluate the system's overall usability. Overall, the participants gave positive feedback on the usability of both the mobile app and the web portal. Over 80% of the participants agreed that our mHealth platform supports a better data collection and reporting approach than another two existing approaches.

Table 34. Summary of the Dissertation Work

Study 1: Exploration	• The clinical needs and IT requirements were identified through the mixed approach, including literature review, clinician interview, and clinician survey. • The system architecture was designed based on the research findings. • The system architecture was designed to capture the identified requirements.
Study 2: Design & Implementation	• The mHealth platform was implemented based on the designed architecture and verified requirements. • The platform integrating the mobile AAC app and the web-based portal with data analysis procedures.
Study 3: Evaluation	• Design errors were discovered and fixed in the first phase of the study, and the app's overall usability was evaluated by the end-users in the second phase of the study. • The portal's overall usability was evaluated in the third phase of the study. • Overall, participants had very positive experiences on the new data collection and reporting approach that the mHealth platform provides to support AAC clinical service delivery.

A usability study of the EuTalk app was conducted with able-bodied individuals and health professionals. The study aimed to discover system errors, navigation and overall user

satisfaction. This study served to identify and fix both human and system errors. Participants' responses to the questionnaires show that the design of EuTalk provides an easy way to help PwCD to communicate with others. The analysis of the collected language data during the study also confirms that the design of EuTalk does not limit its use by people of different backgrounds, age groups, and genders. All participants agreed that the app establishes an alternative treatment protocol for communication rehabilitation.

Tests on the overall feasibility of the EuTalk app were conducted with PwCD to evaluate its usability with potential end users. The feedback from the participants confirmed that the design of the app is easy to use, and that the embedded training materials were helpful for them to learn how to use the communication interface more efficiently. All participants agreed that the app serves as a communication tool for them to communicate with others.

Tests on the overall usability of the web portal were conducted with health professionals. Participants' responses to the after-scenario questions show that they were satisfied with the ease of completing the tasks, as well as with the amount of time that it took to complete each task. The overall results confirm that an integrated platform provides the ability to collect comprehensive clinical evidence, automatically analyze collected data in real-time, and generate clinically relevant performance measures. The evaluation concluded that the integrated platform offers a better clinical data analytics approach for AAC clinical service.

6.2 DISCUSSION

The research-based design strongly supports the capabilities of the integrated mHealth platform. The features in the app provide PwCD an opportunity to use the app as an AAC intervention tool efficiently and conveniently; the features in the portal also provides SLPs with an effective supporting tool for data collection and reporting. Since the rehabilitation process is usually long and frustrating, the performance reports can not only help SLPs to design appropriate treatment plans but can help PwCD to gain confidence, which fulfills the desired outcome of EBP. Moreover, the valuable evidence (namely, the full collection of user language data) can benefit researchers in the field of communication science. Figure 40 illustrates a review of the integrated platform and addresses the interactions between people and technology, as well as the opportunities for data analytics that occur throughout the process. Our mHealth platform can improve user engagement, as well as help SLPs to adjust the treatment plans, support their clinical evaluation, and ultimately streamline the workflow and improve service delivery.

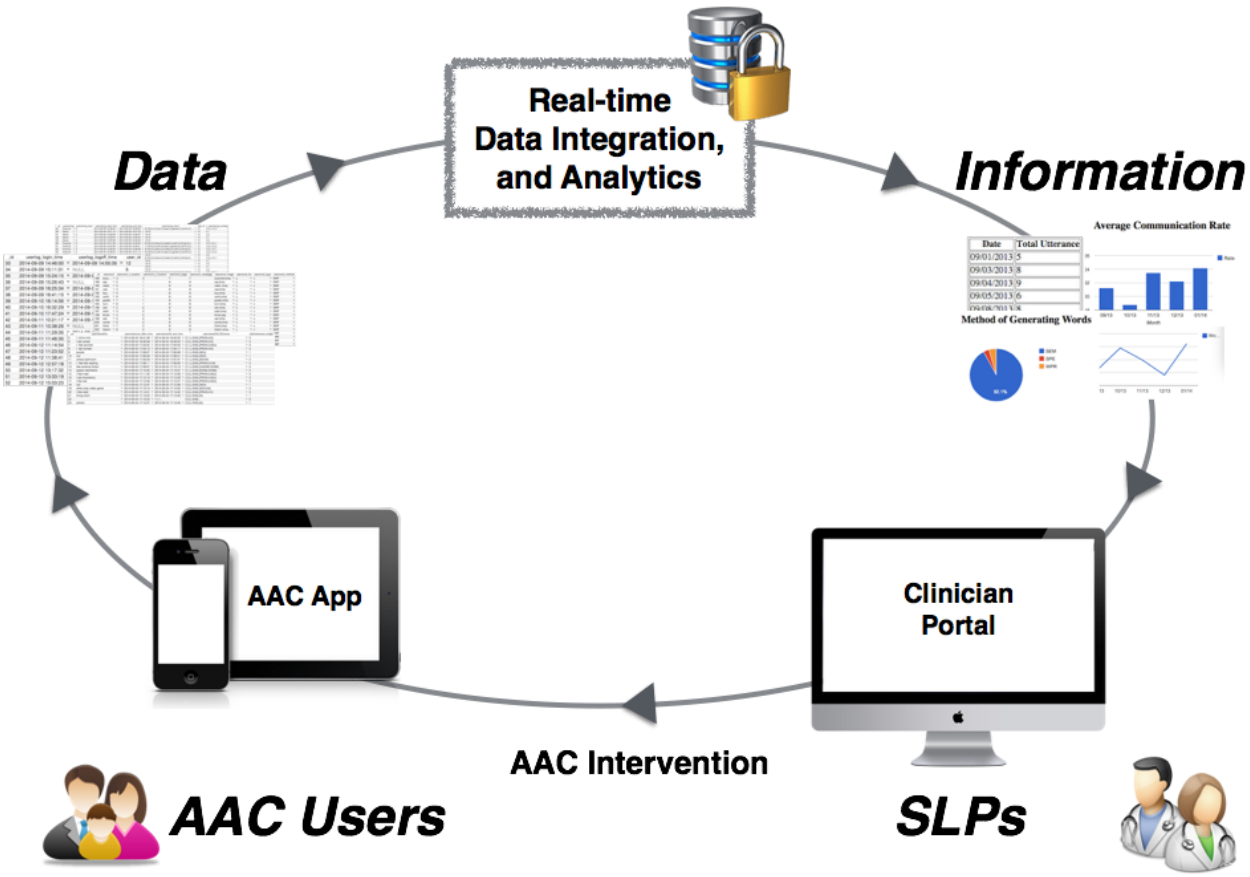


Figure 40. The mHealth Platform for AAC Data Integration

6.3 LIMITATIONS AND FUTURE WORK

There are some limitations of this project, as discussed below:

1. In this work, only usability and feasibility studies of the system were conducted. Patients' clinical performance were not evaluated. Also, because of the recruitment criteria of the feasibility study, the sample size may not be sufficient to evaluate the system. A larger scale study may need to be conducted to fully assess the system.

2. The usability study of the web portal focused on evaluating the viability of the system,

and comparing the system with existing approaches. However, the quantitative study on user satisfaction with each approach was not evaluated. Although the overall result showed the integrated platform offers a better analytics approach, the statistical difference was not evaluated.

3. The design of the mobile AAC app focused on the needs of adult AAC users. The studies conducted were also targeted to adults. To better serve a younger population, the overall design may need to be adjusted.

Future research is planned to conduct a larger-scale study, which will seek to evaluate all capabilities of the integrated platform. The proposed clinical trial will include both PwCD and SLPs. A full AAC treatment will be provided from SLPs to PwCD over a longer time period. During the study period, PwCD will use EuTalk, while SLPs review their performance through the web portal. Meanwhile, SLPs will be asked to adjust their treatment plans and to make clinical decisions, based on the performance reports provided in the web portal. In this study, PwCD's clinical performance will be evaluated, and SLPs will also be asked to evaluate the performance measures provided on the portal.

Another potential area of future research is to move the platform from lab discoveries to the marketplace for the benefits of PwCD, SLPs, and researchers. Furthermore, the platform will be extended for all clinicians to easily access a summary of patient health data that is collected from multiple mHealth apps. The platform will be improved with sophisticated data analysis and data integration algorithms. Figure 41 shows the proposed enhanced mHealth data integration platform that will enable customized, precise health care. It will maximize mobile communications between healthcare professionals, individual patients and caregivers.

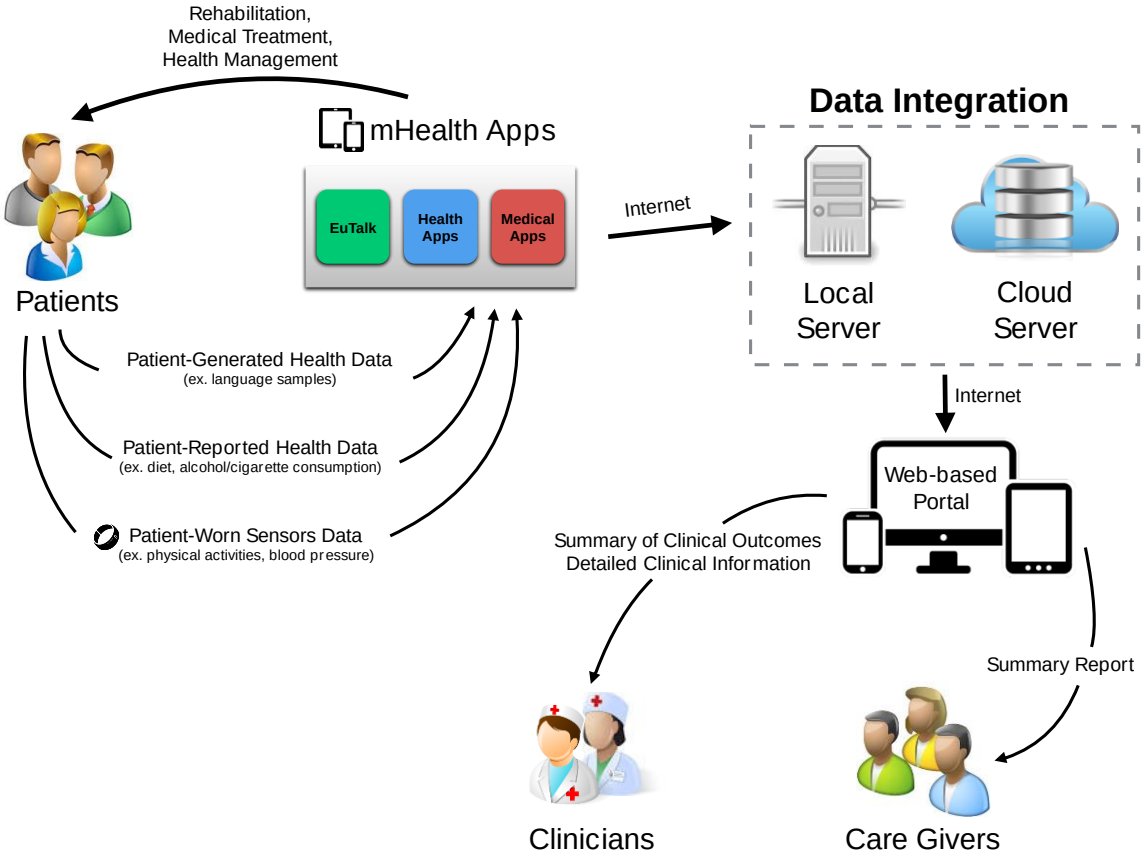


Figure 41. An Integrated mHealth Platform

APPENDIX A

CLINICIAN SURVEY QUESTIONNAIRE

Our work attempts to combine the idea of mobile health and AAC intervention by implementing an integrated system to support data collection and reporting and streamline the workflow of AAC clinical service delivery. The proposed system is designed to integrate a mobile AAC application (app) and a web-based clinician portal. It is aimed to help clinicians to implement evidence-based practice in AAC service delivery with a better data collection and reporting approach.

This survey is part of an investigation to determine the types of information gathered from language sampling and transcript analysis that clinicians feel are important to AAC clinical intervention and outcomes measurement. Clinical input from speech language pathologists is sought to incorporate within the future design of performance monitoring for clinical applications and the support of evidence based practice

Please respond to the following questions that should take about 20 - 30 minutes of your time to complete. No response will be associated with a particular individual. The data will be tabulated and analyzed to insure confidentiality of participants. Your cooperation and assistance are most sincerely appreciated.

This part of the survey deals with questions on background and your perspectives on language sampling methods. Language sampling methods involve personal observations and charting, audio/video recording, and automatic data-logging.

Q1) How long have you been providing AAC clinical services? (years)

_____

Q2) Please check all age groups that apply to your AAC clinical practice.

- ☐ Infant / toddler
- ☐ Preschool
- ☐ Elementary school
- ☐ Middle / high school
- ☐ Adults
- ☐ Geriatric

Q3) Please check your type of employment. (check all that apply)

- ☐ Self-employed
- ☐ Public school
- ☐ Rehabilitation facility
- ☐ Hospital / Clinic
- ☐ Private agency
- ☐ College / University
- ☐ Manufacturer
- ☐ Other (please specify) _____

Q4) Please list all dedicated AAC devices your clients / students presently use.

_____

Q5) Please list all mobile AAC apps your clients / students presently use.

_____

Q6) Indicate your typical use of the traditional methods listed to collect language samples for AAC.

	disagree	disagree somewhat	agree somewhat	agree
I always collection handwritten samples.	◯	◯	◯	◯
I always audio record language samples.	◯	◯	◯	◯
I always video record language samples.	◯	◯	◯	◯

Q7) Indicate your typical use of the automatic methods listed to collect language samples for AAC.

	disagree	disagree somewhat	agree somewhat	agree
I always collect language samples generated by dedicated AAC devices.	◯	◯	◯	◯
I always collect language samples generated by mobile AAC Apps.	◯	◯	◯	◯

Q8) How often do you collect language samples for an AAC user on your caseload?

- ◯ Only for Initial Assessment
- ◯ Once a week
- ◯ Twice a month
- ◯ Once a month
- ◯ Once every two months
- ◯ Never
- ◯ Other _____

Q9) Please indicate how often you use the various methods to gather language samples on AAC users.

	never	sometimes	always
Observation in natural setting	◯	◯	◯
Play in structured environment	◯	◯	◯
Interview / Conversation	◯	◯	◯
Picture / Object description	◯	◯	◯
Story retelling	◯	◯	◯
Other	◯	◯	◯

Q10) What activities that occur in the natural environment elicit the best communication opportunities for an AAC user to use an AAC system. Please check the top 3 activities.

- ☐ Giving directions to caregiver
- ☐ Ordering food
- ☐ Telephoning
- ☐ Preparing food
- ☐ Shopping
- ☐ Providing medical information
- ☐ Toileting / grooming activities
- ☐ Exchanging money
- ☐ Making introduction
- ☐ Interviewing for a job
- ☐ Other _____

Q11) Please indicate how often you use language sampling to collect information on the following.

	never	sometimes	always
pathology	◯	◯	◯
semantics	◯	◯	◯
morphology	◯	◯	◯
syntax	◯	◯	◯
pragmatics	◯	◯	◯

Q12) Please indicate how often you use the various techniques to evaluate language samples.

	never	sometimes	always
Standard analysis systems: Paper-based	◯	◯	◯
Standard analysis systems: Computer-based	◯	◯	◯
Self-designed analysis systems: Paper-based	◯	◯	◯
Self-designed analysis systems: Computer-based	◯	◯	◯

The second part of the survey deals with questions on innovative data analysis approach that is designed to facilitate data collection and reporting. Automated data logging records language and non-language events that occur during AAC device / app use. Because of the time stamps, the captured data provides information not available to clinicians using traditional language sampling procedures. Consequently, automated log files will contribute additional data not previously documented to support evidence-based practice. Clinician input to determine the importance of various available summary measures is being solicited.

Q13) Please indicate and rank the utterance-based summary measures that you consider to be of interest in monitoring an AAC user. (Please, select all that apply and rank them)

Utterance-based Summary Measures	Select	Rank
Total Utterances	☐	
Percentage of Complete Utterances	☐	
Method of Generating Utterances (SNUG)	☐	
Mean Length of Utterances in Words	☐	
Mean Length of Utterances in Morphemes	☐	
Mean Length of Utterances in Keystrokes	☐	
Average Communication Rate in Words	☐	
Average Communication Rate in Keystrokes	☐	
Peak Communication Rate in Words	☐	
Peak Communication Rate in Keystrokes	☐	
Utterances Structure	☐	
List of Generating Utterances	☐	

Q14) What utterance-based summary measures would you perform that are not listed above? Or any comments regarding above summary measures?

_____

Q15) Please indicate and rank the word-based summary measures that you consider to be of interest in monitoring an AAC user. (Please, select all that apply and rank them)

Word-based Summary Measures	Select	Rank
Total Number of Words	☐	
Total Number of Different Words	☐	
Different Word Roots	☐	
Percentage of Core Vocabulary	☐	
Method of Generating Words	☐	
Sentence Part of Generating Words	☐	
Communication Rate by Language Representation Method	☐	
Selection Rate	☐	
Rate Index	☐	
Errors per Selected Word	☐	
Errors per Spelled and Predicted Word	☐	
Deletions per Error	☐	
List of Generating Words	☐	
List of Customized Words	☐	
List of Spelled Words	☐	

Q16) What word-based summary measures would you perform that are not listed above? Or any comments regarding above summary measures?

_____

Q17) Below are the types of information that can be automatically generated by a mobile AAC App. Please indicate and rank the information that you consider to be of interest in monitoring an AAC user. (Please, select all that apply and rank them)

App-based Summary Measures	Select	Rank
Usage Frequency of the App	☐	
Usage Frequency of Different Activities (AAC, training, etc.)	☐	
User Progress in Embedded Training Materials	☐	
User Performance in Embedded Training Materials	☐	
User Language Performance at Home	☐	

Q18) Any other summary measures would you perform that are not listed above? Or any comments regarding above summary measures?

_____

Q19) Please indicate how useful analyzed performance data from language sampling would be for clinical decision-making:

	disagree	disagree somewhat	agree somewhat	agree
Would provide for more effective therapy.	◯	◯	◯	◯
Would benefit people who rely on AAC.	◯	◯	◯	◯
Would provide faster progress in the intervention process.	◯	◯	◯	◯
Would provide better clarity of needs for people who rely on AAC.	◯	◯	◯	◯
Would lead to more effective communication.	◯	◯	◯	◯
Would provide more effective data to justify the selection of an AAC system.	◯	◯	◯	◯
Would provide more effective data to support the funding process.	◯	◯	◯	◯
The use of an add-on device for data collection is easy and practical.	◯	◯	◯	◯

Q20) Please indicate your responses to the following statements:

	disagree	disagree somewhat	agree somewhat	agree
The use of data logging as a built-in feature of an AAC app is easy and practical.	○	○	○	○
I would be more likely to use data logging as a built-in feature to an AAC app.	○	○	○	○
I would not be likely to supplement my data collection with video or audio recording.	○	○	○	○
The availability of automated performance monitoring tools will allow for more frequent collection of language samples.	○	○	○	○
More efficient performance monitoring tools are needed to improve the analysis process.	○	○	○	○
Performance monitoring tools are needed to be easy and user-friendly for me to integrate them into my intervention program.	○	○	○	○
I would collect more performance data on my clients if I had automated tools that made the process easy and efficient.	○	○	○	○

I would use analyzed performance data more often if the performance monitoring tools were available as an entire packet of materials.	○	○	○	○
Adequate education and training is needed before I would use performance monitoring tools.	○	○	○	○
Distance learning would be an acceptable approach to receive training on performance monitoring.	○	○	○	○
Pre-service training is needed to support the widespread application of performance monitoring.	○	○	○	○

Q21) How would you like to see training occur on performance monitoring? (check all that apply)

- ☐ Major AAC Conferences
- ☐ Webinars
- ☐ Internet-based (online) Courses
- ☐ Local Regional Training Seminars

APPENDIX B

USABILITY STUDY – MOBILE AAC APP

B.1 RECRUITMENT FLYER

Participants Needed

Communication App for People with Communication Disabilities – Usability Study

You may be eligible to participate in this research study if you …

Speak English as your native language

Age between 18-65

Are able to operate a mobile device

Do not have communication disabilities

This research study is to evaluate EuTalk, a tablet-based mobile application for people with communication disabilities. This application integrated communication, learning, and feedback into the design. EuTalk combines communication board, interactive training materials, and visual feedback to support comprehensive speech rehabilitation.

We are also recruiting people who have knowledge of assistive technology for people with communication disabilities. We'd like to hear opinions from you as well.

The study will be conducted at 6028 Forbes Tower. We estimate the whole session to take roughly 2 hours. You will be compensated $10.00 / hour.

If you are interested in participating or learning more about the study, please contact **Reina Wang** at **erw39@pitt.edu**

B.2 PHONE SCREENING

Verbal Consent Script:

Hi, my name is Reina. Can I speak with xxx (name of the perspective subject)? (This is he/she). I am calling because I am conducting a study about the usability of a mobile-based communication app and you expressed your interest in participating this study as a research subject. I would like to ask you a few questions to make sure you are eligible for our study. This screening process will take roughly 5 to 10 minutes. The information you provide will only be used in this research study and we will keep it in a secure place. This conversation is not being recorded but notes will be taken. You may choose not to answer any question. Do you have any questions before we get started? *(no)* Do I have your permission to start my questions and make notes for your answers? *(yes)*

Screening Questions:

- What is your native language?
- How old are you?
- Do you have any experience using mobile devices, such as smartphones or tablets?

B.3 CONSENT FORM

CONSENT TO ACT AS A PARTICIPANT IN A RESEARCH STUDY

TITLE: Communication App for People with Communication Disabilities – Usability Study

PRINCIPAL-INVESTIGATOR: **Erh-Hsuan Wang, MS**

Doctoral Student

Department of Health Information Management

University of Pittsburgh

6028 Forbes Tower, Pittsburgh, PA 15260;

Phone: 412-641-9955; e-mail: erw39@pitt.edu

SOURCE OF SUPPORT: SHRS Research Development Fund

Why is this research being done?

The purpose of this study is to develop and evaluate EuTalk, a mobile Augmentative and Alternative Communication (AAC) application for people with communication disabilities. EuTalk combines communication board, interactive training materials, and visual feedback to support comprehensive speech rehabilitation. You are being asked to help us to evaluate this application. EuTalk runs on a Samsung 10.1-inch tablet with Android platform. EuTalk allows you to use this application as a communication aid to communicate with others. The embedded trainings are aimed to enhance communication rate and improve language ability. The real-time visual feedback is automatically generated to motivate users, as well as help clinicians to monitor the progress.

Who is being asked to take part in this study?

You are invited to participate in this research study because you are between 18-65 years of age, with English as your native language, able to operate a mobile device, and not having communication disabilities. Twenty participants will be recruited to participate in this study.

What are the procedures of this study?

If you decide to take part in this research study, you will participate in the following procedure:

You will be asked to complete a questionnaire regarding your demographic information including age, education level, mobile devices experiences, etc. Thereafter you will be introduced into the mobile device, as well as a brief orientation and demonstration of the application running on the device.

To get the real experience of using the application, first, you will be asked to perform a number of tasks; such as using the communication board to make a conversation based on given scenarios. During the evaluation process, the researcher will encourage you to think out loud. Upon completion of assigned tasks after each session, you will be asked to complete a short post-task questionnaire. Second, you will be left alone in the study site to test the application following a guideline provided by the researcher. In the mean time, the researcher will monitor your real-time activities via the remote server. Your activities such as communication board usage, training experiences, etc. will be logged and analyzed afterwards in order to evaluate the application.

Once the evaluation process is complete, you will be asked to complete a customized usability questionnaire to provide feedback on the overall perception and satisfaction of the application. The researcher will ask your opinions concerning the application. The audio

recording without facial feature will be taking place for only spoken responses. These tasks will take you less than 2 hours to complete. The study will be conducted in Department of Health Information Management on the 6th floor of Forbes Tower at University of Pittsburgh.

What are the possible risks and discomforts of this study?

There is no more than minimal risk involved in this study. No invasive procedures or medications are included. The major potential risk is a breach of confidentiality. To reduce the likelihood of a breach of confidentiality, all researchers have been thoroughly trained to maintain your privacy. Every effort will be made to make sure that the information about you obtained from this study will be kept strictly confidential. Any copies that contain information that could be used to identify you (such as your name, address, date of birth, etc.,) will be stored separately from any information that does not contain identifiers. Only those individuals who are authorized to review your information will have access to it.

Another potential risk associated with your participation is the frustration some people experience when they attempt to solve difficult problems. This is not an uncommon experience, and if you like, we will discuss your feelings and concerns when you have completed the tasks. The potential risk involved in this study may also include inconvenience of the length of time required to participate. You may discontinue the study at any time.

Will I benefit from taking part in this study?

You will receive no direct benefit from participating in this study. The benefit to society in general is that this information will be useful in the development and evaluation of Augmentative and Alternative Communication (AAC) communication application for people with communication disabilities.

How much will I be paid if I complete this study?

You will not incur any direct costs as a result of your involvement in this study. You will be compensated $10.00/hour for completing the study.

Will anyone know that I am taking part in this study?

All records pertaining to your involvement in this study are kept strictly confidential (private) and any data that includes your identity will be stored in locked files. Your identity on these records will be indicated by a case number rather than by your name, and the information linking these case numbers with your identity will be kept separate from the research records. Your identity will not be revealed in any description or publications of this research. Audio recordings will be only be used by the researcher if information seems to be missing from the notes. We may share your data with other researchers outside of this research project who are also interested in studying activity monitors, but they will not receive any of your personal identifiers.

At the end of this study, any records that personally identify you will remain stored in locked files and will be kept for a minimum of seven years. In unusual cases, your research records may be released in response to an order from a court of law. It is possible that authorized representatives from the University of Pittsburgh Institutional Review Board (IRB) may review your data for the purpose of monitoring the conduct of this study.

Is my participation in this study voluntary?

Yes! Your participation in this study is completely voluntary. You may refuse to take part in it, or you may stop participating at any time, even after signing this form. Your decision will not affect your relationship with the University of Pittsburgh, nor will you lose any benefits that you might be eligible for because of what you decide. To formally withdraw your consent for participation in the research study, you should provide a written and dated notice of this decision

to the principal investigator of this research study at the address listed on the first page of this form.

How can I get more information about this study?

If you have any further questions about this research study, you may contact the investigators listed at the beginning of this consent form. If you have any questions about your rights as a research participant, please contact the Human Subjects Protection Advocate of the IRB office, University of Pittsburgh (1-866-212-2668).

****

VOLUNTARY CONSENT

- I have read the consent form for this study and any questions I had, including explanation of all terminology, have been answered to my satisfaction. A copy of this consent form will be provided to me.
- I understand that I am encouraged to ask questions about any aspect of this research study during the course of this study, and that those questions will be answered by the researchers listed on the first page of this form.
- I understand that my participation in this study is voluntary and that I am free to refuse to participate or to withdraw my consent and discontinue my participation in this study at any time without affecting my future relationship with this institution.
- I agree to participate in this study.

_____ _____

Subject's Signature Date

CERTIFICATION OF INFORMED CONSENT

I certify that I have explained the nature and purpose of this research study to the above-named individual, and I have discussed the potential benefits and possible risks of study participation. Any questions the individual has about this study have been answered, and we will always be available to address future questions as they arise.

_____ _____

Printed Name of Person Obtaining Consent Role in Research Study

_____ _____

Signature of Person Obtaining Consent Date

B.4 QUESTIONNAIRES

B.4.1 Background Questionnaire

Participant #: _____

Q1) Area of Study/Work (e.g. department, job function):

_____

Q2) Gender

◯ Male

◯ Female

Q3) Age:

_____

Q4) Highest academic degree earned:

◯ High School

◯ Bachelor's

◯ Master's

◯ PhD

Q5) On average, the amount of time spent per day using a mobile device (e.g. smartphones, tablets)

◯ Less than 1 hour

◯ 1 hour to less than 3 hours

◯ 3 hours to less than 5 hours

◯ More than 5 hours

Q6) Which of the following mobile devices have you used before? (please select all that apply)

☐ iPhone

☐ iPad

☐ Android Phone

☐ Android Tablet

☐ Others _____

Q7) How confident are you in your abilities using a mobile device?

◯ Not confident at all

◯ Not really confident

◯ Neither confident or unconfident

◯ Confident

◯ Very confident

Q8) Please indicate which of the following activities do you regularly do on your mobile devices. (please select all that apply)

☐ Email

☐ Health & Fitness

☐ Games

☐ Searching on the Internet

☐ Shopping

☐ Social Networking

☐ Others _____

Q9) Are you familiar with the term “People with Communication Disabilities?”

◯ Yes

◯ No

Q10) Are you familiar with the term “Augmentative and Alternative Communication (AAC)?”

◯ Yes

◯ No

B.4.2 Post-task Questionnaires

Communication Board & Training

Participant #: _____

Please answer the following questions, as they relate to the Communication Board.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
1) I would find the Communication Board easy to use.	◯	◯	◯	◯	◯
2) I was able to complete the tasks and scenarios using the Communication Board.	◯	◯	◯	◯	◯

3) I liked using the interface of the Communication Board.	○	○	○	○	○
4) I would find the Communication Board intuitive to use.	○	○	○	○	○
5) I would find the page navigation easy to understand.	○	○	○	○	○
6) I would find the function keys helpful using the Communication Board.	○	○	○	○	○
7) I would find the history helpful when I need to look up my old sentences.	○	○	○	○	○
8) I would find 1-hit Setting is sufficient to make daily conversation.	○	○	○	○	○
9) I would find 2-hit Setting is sufficient to make daily conversation.	○	○	○	○	○
10) I would find 1-hit Setting helpful to make more accurate sentences.	○	○	○	○	○

11) I would find 2-hit Setting helpful to make more accurate sentences.	○	○	○	○	○
12) I would find the vocabulary provided is sufficient to make daily conversation.	○	○	○	○	○
13) I would find the display of icons helpful making sentences.	○	○	○	○	○

Please write down any other comments:

_____

Please answer the following questions, as they relate to the Training.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
1) I would find the Game easy to use.	○	○	○	○	○
2) I was able to complete the tasks using the Game.	○	○	○	○	○
3) I liked using the interface of the Game.	○	○	○	○	○

4) I would find the Game intuitive to use.	○	○	○	○	○
5) I would find the Game helpful to use the Communication Board.	○	○	○	○	○
6) I would find the Practice easy to use.	○	○	○	○	○
7) I was able to complete the tasks using the Practice.	○	○	○	○	○
8) I liked using the interface of the Practice.	○	○	○	○	○
9) I would find the Practice intuitive to use.	○	○	○	○	○
10) I would find the Practice helpful to use the Communication Board.	○	○	○	○	○
11) I would find the achievement banner (result) motivational.	○	○	○	○	○

Please write down any other comments:

_____

Report, Favorites, and ICU

Participant #: _____

Please answer the following questions, as they relate to this specific topic.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
1) I was able to complete the scenario using the Report.	○	○	○	○	○
2) I liked the interface of the Report.	○	○	○	○	○
3) I would find the information provided in Report easy to understand.	○	○	○	○	○
4) I would find the information provided in Report helpful.	○	○	○	○	○
5) I would find the Report helpful to use the Communication Board.	○	○	○	○	○
6) I was able to complete the scenario using Favorites.	○	○	○	○	○

7) I would find the Favorites helpful to use the pre-stored important sentences.	◯	◯	◯	◯	◯
8) I liked the interface of the Favorites.	◯	◯	◯	◯	◯
9) I was able to complete the scenario using ICU.	◯	◯	◯	◯	◯
10) I would find the ICU helpful.	◯	◯	◯	◯	◯
11) I liked the interface of the ICU.	◯	◯	◯	◯	◯

Please write down any other comments:

_____

B.4.3 Post Questionnaire

Participant #: _____

Please answer the following questions.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
1) Overall, learning to operate EuTalk would be easy for me.	○	○	○	○	○
2) Overall, I felt comfortable using EuTalk.	○	○	○	○	○
3) Overall, I liked using the interface of EuTalk.	○	○	○	○	○
4) Overall, I could recover from errors easily and quickly using EuTalk.	○	○	○	○	○
5) Overall I felt confident using EuTalk to communicate with others.	○	○	○	○	○
6) Overall, I am satisfied with EuTalk.	○	○	○	○	○

Do you have any suggestions to improve the app?

_____

Do you have any other comments to the app based on your experience today?

_____

Do you have experiences working/interacting with people with communication disabilities? If yes, do you think this app would be helpful for them?

_____

APPENDIX C

FEASIBILITY STUDY – MOBILE AAC APP

C.1 RECRUITMENT FLYER

Recruitment for Research Project
- Feasibility Study of a Tablet-based AAC App

I am a PhD student from Department of Health Information Management, School of Health & Rehabilitation Sciences at University of Pittsburgh.

I'm currently seeking feedback from people with communication disabilities. The purpose of this study is to evaluate the feasibility of a tablet-based AAC app designed for people with communication disabilities.

Individuals may be eligible to participate in this study if they..

- Are people with communication disabilities
- Have English as their Native language
- Age between 18 – 65
- Able to follow oral instructions
- Able to operate a mobile device

The study will be conducted at Forbes Tower or a private place at participants' preference. We estimate the whole session to take roughly 1.5 hours. The participant will be compensated $20.00 for completing the study.

If you know any individuals who may be interested in participating or learning more about the study, please share the information and have them contact me at **erw39@pitt.edu** . Thank you!!!

C.2 CONSENT FORM

CONSENT TO ACT AS A PARTICIPANT IN A RESEARCH STUDY

TITLE: Communication App for People with Communication Disabilities – Feasibility Study

PRINCIPAL-INVESTIGATOR: **Erh-Hsuan Wang, MS**

Doctoral Student

Department of Health Information Management

University of Pittsburgh

6028 Forbes Tower, Pittsburgh, PA 15260;

Phone: 412-641-9955; e-mail: erw39@pitt.edu

SOURCE OF SUPPORT: SHRS Research Development Fund

Why is this research being done?

The purpose of this study is to develop and evaluate EuTalk, a mobile Augmentative and Alternative Communication (AAC) application for people with communication disabilities. EuTalk combines communication board, interactive training materials, and visual feedback to support comprehensive speech rehabilitation. You are being asked to help us to evaluate this application. EuTalk runs on a Samsung 10.1-inch tablet with Android platform. EuTalk allows you to use this application as a communication aid to communicate with others. The embedded trainings are aimed to enhance communication and improve language ability. The real-time visual feedback is automatically generated to motivate users, as well as help clinicians to monitor the progress.

Who is being asked to take part in this study?

You are invited to participate in this research study because you are between 18-65 years of age, with English as your native language, able to follow the oral instructions, able to operate a mobile device, and have communication disabilities. Five participants will be recruited to participate in this study.

What are the procedures of this study?

If you decide to take part in this research study, you will participate in the following procedure:

First of all, you will be asked to take the vocabulary test, and try an Android app "Mole Hammer – whack a Mole" to verify that you meet the inclusion criteria of this study.

After the screening procedure, you will be asked to complete a questionnaire regarding your demographic information including age, education level, mobile devices experiences, etc. Thereafter you will be introduced into the mobile device, as well as a brief orientation and demonstration of the application running on the device.

To get the real experience of using the application, you will be asked to perform a number of tasks; such as using the communication board to make a conversation based on given scenarios. During the evaluation process, the researcher will encourage you to think out loud. Upon completion of assigned tasks after each session, you will be asked to complete a short post-task questionnaire. Your activities such as communication board usage, training experiences, etc. will be logged and analyzed afterwards in order to evaluate the application.

Once the evaluation process is complete, you will be asked to complete a questionnaire to provide feedback on the overall perception and satisfaction of the application. The entire study will take you less than 2 hours to complete. The study will be conducted in Department of Health

Information Management on the 6th floor of Forbes Tower at University of Pittsburgh, or a private space at your convenience.

What are the possible risks and discomforts of this study?

There is no more than minimal risk involved in this study. No invasive procedures or medications are included. The major potential risk is a breach of confidentiality. To reduce the likelihood of a breach of confidentiality, all researchers have been thoroughly trained to maintain your privacy. Every effort will be made to make sure that the information about you obtained from this study will be kept strictly confidential. Any copies that contain information that could be used to identify you (such as your name, address, date of birth, etc.,) will be stored separately from any information that does not contain identifiers. Only those individuals who are authorized to review your information will have access to it.

Another potential risk associated with your participation is the frustration some people experience when they attempt to solve difficult problems. This is not an uncommon experience, and if you like, we will discuss your feelings and concerns when you have completed the tasks. The potential risk involved in this study may also include inconvenience of the length of time required to participate. You may discontinue the study at any time.

Will I benefit from taking part in this study?

You will receive no direct benefit from participating in this study. The benefit to society in general is that this information will be useful in the development and evaluation of Augmentative and Alternative Communication (AAC) communication application for people with communication disabilities.

How much will I be paid if I complete this study?

You will not incur any direct costs as a result of your involvement in this study. You will be compensated $10.00/hour for completing the study.

Will anyone know that I am taking part in this study?

All records pertaining to your involvement in this study are kept strictly confidential (private) and any data that includes your identity will be stored in locked files. Your identity on these records will be indicated by a case number rather than by your name, and the information linking these case numbers with your identity will be kept separate from the research records. Your identity will not be revealed in any description or publications of this research. Audio recordings will be only be used by the researcher if information seems to be missing from the notes. We may share your data with other researchers outside of this research project who are also interested in studying activity monitors, but they will not receive any of your personal identifiers.

At the end of this study, any records that personally identify you will remain stored in locked files and will be kept for a minimum of seven years. In unusual cases, your research records may be released in response to an order from a court of law. It is possible that authorized representatives from the University of Pittsburgh Institutional Review Board (IRB) may review your data for the purpose of monitoring the conduct of this study.

Is my participation in this study voluntary?

Yes! Your participation in this study is completely voluntary. You may refuse to take part in it, or you may stop participating at any time, even after signing this form. Your decision will not affect your relationship with the University of Pittsburgh, nor will you lose any benefits that you might be eligible for because of what you decide. To formally withdraw your consent for participation in the research study, you should provide a written and dated notice of this decision

to the principal investigator of this research study at the address listed on the first page of this form.

How can I get more information about this study?

If you have any further questions about this research study, you may contact the investigators listed at the beginning of this consent form. If you have any questions about your rights as a research participant, please contact the Human Subjects Protection Advocate of the IRB office, University of Pittsburgh (1-866-212-2668).

****

VOLUNTARY CONSENT

- I have read the consent form for this study and any questions I had, including explanation of all terminology, have been answered to my satisfaction. A copy of this consent form will be provided to me.
- I understand that I am encouraged to ask questions about any aspect of this research study during the course of this study, and that those questions will be answered by the researchers listed on the first page of this form.
- I understand that my participation in this study is voluntary and that I am free to refuse to participate or to withdraw my consent and discontinue my participation in this study at any time without affecting my future relationship with this institution.
- I agree to participate in this study.

_____ _____

Subject's Signature Date

CERTIFICATION OF INFORMED CONSENT

I certify that I have explained the nature and purpose of this research study to the above-named individual, and I have discussed the potential benefits and possible risks of study participation. Any questions the individual has about this study have been answered, and we will always be available to address future questions as they arise.

_____ _____

Printed Name of Person Obtaining Consent Role in Research Study

_____ _____

Signature of Person Obtaining Consent Date

C.3 QUESTIONNAIRES

C.3.1 Background Questionnaire

Participant #: _____

Q1) Gender

◯ Male

◯ Female

Q2) Age:

_____

Q3) Highest academic degree earned:

◯ High School

◯ Bachelor's

◯ Master's

◯ PhD

Q4) On average, the amount of time spent per day using a mobile device (e.g. smartphones, tablets)

◯ Less than 1 hour

◯ 1 hour to less than 3 hours

◯ 3 hours to less than 5 hours

◯ More than 5 hours

Q5) Which of the following mobile devices have you used before? (please select all that apply)

- ☐ iPhone
- ☐ iPad
- ☐ Android Phone
- ☐ Android Tablet
- ☐ Others _____

Q6) How confident are you in your abilities using a mobile device?

- ◯ Not confident at all
- ◯ Not really confident
- ◯ Neither confident or unconfident
- ◯ Confident
- ◯ Very confident

Q7) Please indicate which of the following activities do you regularly do on your mobile devices. (please select all that apply)

- ☐ Email
- ☐ Health & Fitness
- ☐ Games
- ☐ Searching on the Internet
- ☐ Shopping
- ☐ Social Networking
- ☐ Others _____

Q8) Have you used any Augmentative and Alternative Communication (AAC) technology before? (e.g. dedicated devices, mobile apps)

◯ Yes

◯ No

If yes, which of the following Augmentative and Alternative Communication (AAC) technology have you used before? (please select all that apply)

☐ Dedicated Devices

☐ Mobile Apps

☐ Others _____

If yes, how confident are you in your abilities using an AAC technology?

◯ Not confident at all

◯ Not really confident

◯ Neither confident or unconfident

◯ Confident

◯ Very confident

C.3.2 Post Questionnaire

Participant #: _____

Please answer the following questions.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
1) Overall, learning to operate EuTalk would be easy for me.	○	○	○	○	○
2) Overall, I felt comfortable using EuTalk.	○	○	○	○	○
3) Overall, I liked using the interface of EuTalk.	○	○	○	○	○
4) Overall, I could recover from errors easily and quickly using EuTalk.	○	○	○	○	○
5) Overall, I am satisfied with EuTalk.	○	○	○	○	○
6) Overall I felt confident using EuTalk to communicate with others.	○	○	○	○	○

7) Overall, I would like to use EuTalk to help me communicating with others.	○ ○ ○ ○ ○

APPENDIX D

USABILITY STUDY – INTEGRATED PLATFORM

D.1 RECRUITMENT FLYER

Recruitment for Research Project
- Usability Study of a Web-based Clinical Portal

I am a PhD student from Department of Health Information Management, School of Health & Rehabilitation Sciences at University of Pittsburgh.

I'm currently seeking feedback from professionals in the field of speech language pathology. The purpose of this study is to evaluate the usability of a web-based clinical portal designed for speech language pathologists and compare different data collection and reporting approaches of AAC technologies.

You may be eligible to participate in this study if you ..

- Graduate students from Department of Communication Science & Disorders *OR* Certified Speech Language Pathologist
- Have clinical experience

The study will be conducted at Forbes Tower. We estimate the whole session to take roughly 1 hour. You will be compensated $20.00 / hour.

If you are interested in participating or learning more about the study, please contact me at **erw39@pitt.edu** . Thank you!!!

D.2 VERBAL INFORMED CONSENT SCRIPT

Thank you for coming for this study. The purpose of this study is to develop and evaluate a web-based clinical portal for speech language pathologists. This system is designed to improve data collection and reporting process of AAC technology and therefore support clinical intervention and outcomes measurement. You are being asked to help us to evaluate this system and compare with existing approaches. This clinical portal gives you an easy access to monitor/review your clients' performance. The portal provides clinical information based on the data collected from the mobile AAC app. Other features, such as scheduling, report writing, are also included in order to streamline the entire AAC clinical service delivery.

This is a one-time study. The study will take around 1 hour. I will need your help to evaluate this system and compare with existing approaches. During the study, you will be asked to complete several tasks, and fill up usability questionnaires to help us to understand your experience. Your performance in this study will not be evaluated. Your personal information will be kept confidential and will not be linked to your performance.

Do you have any other questions? (no) Do you agree to participate in this study? (yes)

D.3 QUESTIONNAIRES

D.3.1 Background Questionnaire

Participant #: _____

Q9) Gender

◯ Male

◯ Female

Q10) Age:

_____

Q11) How long have you been providing AAC clinical services? (years)

_____

Q12) On average, the amount of time spent per day using a computer

◯ Less than 1 hour

◯ 1 hour to less than 3 hours

◯ 3 hours to less than 5 hours

◯ More than 5 hours

Q13) How confident are you in your abilities to look for specific information on a web site (portal)?

- ◯ Not confident at all
- ◯ Not really confident
- ◯ Neither confident or unconfident
- ◯ Confident
- ◯ Very confident

Q14) Do you have access to a computer in your working environment?

- ◯ Yes
- ◯ No

Q15) Do you have access to Internet in your working environment?

- ◯ Yes
- ◯ No

Q16) Have you had any experience using any web-based clinical portal?

- ◯ Yes
- ◯ No

If yes, how confident are you in your abilities using web-based clinical portal?

- ◯ Not confident at all
- ◯ Not really confident
- ◯ Neither confident or unconfident
- ◯ Confident
- ◯ Very confident

Q17) Have you had any experience using Performance & Reporting Tool (PeRT)?

◯ Yes

◯ No

If yes, how confident are you in your abilities using PeRT?

◯ Not confident at all

◯ Not really confident

◯ Neither confident or unconfident

◯ Confident

◯ Very confident

D.3.2 Post-task Questionnaire

Participant #: _____

Please answer the following questions:

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
1) Overall, I am satisfied with how easy it is to use this web-based portal.	◯	◯	◯	◯	◯
2) It was simple to use this web-based portal.	◯	◯	◯	◯	◯

3) I could effectively complete the tasks using this web-based portal.	○	○	○	○	○
4) I was able to complete the tasks quickly using this web-based portal.	○	○	○	○	○
5) I was able to efficiently complete the tasks using this web-based portal.	○	○	○	○	○
6) I felt comfortable using this web-based portal.	○	○	○	○	○
7) I believe I could become productive quickly using this web-based portal.	○	○	○	○	○
8) Whenever I made a mistake, I could recover quickly and easily.	○	○	○	○	○
9) It was easy to find the information I needed.	○	○	○	○	○
10) The organization of information on this web-based portal was clear.	○	○	○	○	○

11) The interface of this web-based portal was pleasant.	○	○	○	○	○
12) I liked using the interface of this system.	○	○	○	○	○
13) This web-based portal has all the functions and capabilities I expect it to have.	○	○	○	○	○
14) Overall, I am satisfied with the system.	○	○	○	○	○

Do you have any suggestions to improve the portal?

_____

Do you have any other comments to the portal based on your clinical experience?

_____

D.3.3 Post Questionnaire

Participant #: _____

Please answer the following questions.

	Approach #1 Speak for Yourself	Approach #2 Web-based Clinician Portal	Approach #3 PeRT
1) Which of the data collection and reporting approach you like the most?	◯	◯	◯
2) Which one of the approaches would you feel providing more comprehensive data collection?	◯	◯	◯
3) Which one of the approaches would you feel providing the most automatic data collection and reporting workflow?	◯	◯	◯
4) Which one of the approaches would you feel providing the easiest access to the information you need?	◯	◯	◯

5) Which one of the approaches would you prefer to use?	◯	◯	◯

As a SLP, which one of the approaches would you prefer to use for supporting clinical intervention and decision making? And why?

◯ Approach #1: Speak for Yourself

◯ Approach #2: Web-based Clinician Portal

◯ Approach #3: PeRT

Reason: _____

As a SLP, which one of the approaches would you recommend your organization to adopt? And why?

◯ Approach #1: Speak for Yourself

◯ Approach #2: Web-based Clinician Portal

◯ Approach #3: PeRT

Reason: _____

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