Pragmatica: A VR Tool for Autonomous Practice During Language Therapy

by

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A thesis
presented to the University of Waterloo
in fulfillment of the
thesis requirement for the degree of
Master of Mathematics
in
Computer Science

Waterloo, Ontario, Canada, 2025

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Aphasia is a communication disorder that affects millions worldwide, but those affected by aphasia have limited access to in-person therapy. They compensate for this with at-home practice, but existing tools are either ineffective or require a clinician to be present. We present Pragmatica, a VR platform that enables people with aphasia to practice their communication skills independently at home through immersive, context-rich activities. In an eight-week comparative case study, we compared Pragmatica with traditional therapy (4 participants per group). With no detected difference in Quick Aphasia Battery (QAB) scores, VR participants engaged in substantial practice (31 hours, 366 activities) and described the VR experience as engaging, fun, and motivating, but had a limited variety of relevant and unique activities. Our study contributes empirical evidence of VR's feasibility for autonomous language practice, as well as design insights and considerations for accessible, aphasia-friendly VR systems (flexible controls, multi-modal prompts and inputs).

Acknowledgements

I, Karthik Prasad, am one of the developers of Pragmatica, the VR application evaluated in this study. Pragmatica was developed by my co-founder Thomas Mastantuono and I and is a commercial product as part of Pragmatica Inc. While my co-founder and I developed Pragmatica together for commercial purposes, I solely described and prepared the product for the research study.

I would like to thank Evergreen Communication Therapy and their clinicians for all their help with running the study. They helped source eligible participants, conduct assessments and were responsible for running the participant-facing activities for the study. To mitigate potential conflicts of interest, all the participant-facing activities in the study were performed by a separate speech-language pathologist who was not involved in any way of the design or development of the app, nor did they receive any monetary or other gains from the app. These activities include things like recruitment, onboarding, and administering the pre- and post-assessments, as well as conducting the semi-structured interviews. Data collection, scoring, and qualitative coding were likewise carried out by the independent clinician. These safeguards were implemented to ensure the integrity and impartiality of the study.

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Chapter 1

Introduction

Aphasia is a language disorder that typically results from stroke or brain injury and affects over two million people in the United States, with 180,000 new cases diagnosed annually [57]. It impairs language production and comprehension, often leading to substantial difficulties in communication, social participation, and quality of life. Speech and language therapy with a Speech-Language Pathologist (SLP) is the primary intervention, but access remains limited due to cost, geography, and the global shortage of SLPs [14]. High intensity and consistent practice are known to improve recovery, yet conventional therapy rarely achieves the required dosage.

Virtual reality (VR) offers immersive and interactive environments in which people with aphasia can safely practice their communication skills. It has the potential to deliver consistent, repeatable, and engaging practice, while reducing dependence on in-person sessions [1]. These advantages suggest that VR could mitigate structural barriers in speech therapy by supporting remote, autonomous practice. However, empirical evidence remains scarce: prior studies have demonstrated promise in clinical and research settings, but few have examined whether people with aphasia can independently use VR for at-home language practice without professional supervision.

This paper evaluates *Pragmatica*, a VR platform designed to support autonomous communication practice. Unlike existing tools, Pragmatica is designed for independent practice, offering a library of context-rich activities that mirror language therapy exercises. We conducted an eight-week comparative case study in which four people with aphasia used Pragmatica at home, while four others continued conventional therapy. We used Yin's case study research method [79] to combine quantitative outcome measures (Quick Aphasia Battery pre/post assessments, usage logs) with qualitative interviews to build detailed accounts of each participant's experiences. This mixed-methods case study allowed us to examine both therapeutic outcomes and the lived experience of unsupervised VR use.

In summary, we make the following contributions to HCI and digital health research:

- Present results from an eight-week comparative case study with eight people with aphasia, showing that VR can support autonomous at-home language practice with engagement levels comparable to conventional therapy.

- Report quantitative findings from Quick Aphasia Battery assessments and in-app usage logs, and qualitative findings from post-study interviews, to compare therapeutic outcomes and user experiences across VR and traditional therapy.
- Offer design considerations for aphasia-friendly VR design, including accessible (one-handed) control schemes and multi-modal prompting and inputs.

Together, these findings extend research on technology-assisted rehabilitation and highlight how immersive VR systems can support communication recovery.

Chapter 2

Related Work

Aphasia is an acquired language disorder most often caused by stroke or brain injury, affecting over two million people in the United States, with 180,000 new cases each year [69]. It can impair speaking, comprehension, reading, and writing to varying degrees [21, 59]. Speech and language therapy is the primary method of intervention [7], and evidence consistently shows that high-intensity practice leads to better outcomes. Bhogal et al. [5] found that more than two hours per week produced significantly better results than low-intensity treatment, and Brady et al. [7] stated that 8–10 hours per week yielded the strongest improvements. However, such frequency is rarely achieved in practice, as it is expensive, requires available facilities, and a therapist to be regularly available.

2.1 Aphasia-Friendly Design in HCI

Researchers in HCI have long collaborated with people with aphasia to design interactive technologies that support daily planning, conversation, reading and writing, therapy and creative self-expression. Moffatt et al. [47] created a multi-modal planner that is enhanced with sound images (ESI) and Nikolova et al. [55] developed a communication aid with a mixed initiative vocabulary for people with aphasia. Subsequent work developed contextual and tangible interfaces to facilitate conversation and personalized augmentative and alternative communication (AAC). Kane et al. [31] developed a context-aware communication tool called TalkAbout that provides users with a word list that is adapted to their current location and conversation partner, making communication easier in a wide variety of contexts. Huijbregts and Wallace [25] conducted a field study for TalkingTiles, an AAC tablet-based application and found that TalkingTiles can be effective in supporting communication.

Marshall et al. [45] explored whether a computer-based gesture therapy tool (GeST) could be used to improve communication by using gestures as a compensatory means of communication. They found that while it had some effect and was easy and enjoyable to use, gains were small and only occurred on items that were practiced with regular therapist support. Building on this, Roper et al. [63] looked at the benefits and limitations of gesture

therapy for people with aphasia. Despite the fact that GeST was augmented with GeSt+ (an additional software application), they also found modest gains that only occurred with gestures practiced with therapists.

In the past five years, CHI researchers have broadened the agenda. Neate et al. [51] presented CreaTable, a platform that enabled them to explore tangible interaction as a means of supporting digital content creation for people with aphasia. Their work was novel in combining aphasia-accessible tangible content alongside static and dynamic representations. Afterwards, Neate and his team also explored the experience of communication via a videoconferencing platform for people with aphasia, which was becoming increasingly more common due to the COVID-19 pandemic. The team and the charity they worked with found various challenges as well as creative solutions and approaches for people with aphasia using videoconferencing applications. Working with Neate, Nevsky et al. [52] explored the viewing experience of people with aphasia and found that aphasia significantly impacts viewing experience and present a taxonomy of access barriers and facilitators.

A lot of work has also been done with wearable AAC devices. For example, Curtis et al. [11] developed two AAC devices: InkTalker is a low-power and affordable eInk AAC smart-badge designed to discreetly reveal invisible disabilities while also being usable as a communication prop. The second device is WalkieTalkie, a scalable AAC app that converts smartphones into a feature-rich public display operable via multi-modal input and outputs. Bircanin et al. [6] investigated accessible audio-media features for people with aphasia and developed one low-fidelity and three high-fidelity prototypes that embody their novel accessibility interventions that they uncovered through co-design workshops with people with aphasia. Kladouchou et al. [32] explored the difficulties of information search experienced by people with aphasia and what strategies can be utilized to combat them. They came up with a variety of strategies that can not only help people with aphasia but can make information search easier for everyone.

The works above have found several valuable lessons for designing for people with aphasia: simplifying interactions, using icons and symbols, allowing personalized pace and feedback, and designing for one-handed use:

2.1.1 Simplifying Interaction

Simplifying interactions is essential in designing for aphasia because complex navigation and multitasking overwhelm users. Designers remove hierarchical menus, minimize steps, and use large, accessible controls so that essential functions remain straightforward. Research shows that context-aware prompting [31], tile-based interfaces [25], AI-driven communication aids [73], wearable badges [11], tactile tables [51], and visual vocabularies [55] can reduce text entry and cognitive load, thereby simplifying communication.

2.1.2 Using Icons and Symbols

Icons and symbols aid comprehension and expression in aphasia by pairing images with speech or text and allowing users to select pictorial vocabularies. Sample solutions with

these features include a mixed-initiative visual vocabulary [55], a sound and image enhanced daily planner [47], personalized tile interfaces [25], a tangible table mapping objects to digital content [51], and a comic-based storytelling tool [71]. Wearable smart badges [11] and audiovisual-media accessibility work [52] extend icon-driven interaction. These approaches bypass linguistic deficits through visual cues, reduce cognitive load and enable self-expression.

2.1.3 Personalized Pace and Feedback

Because aphasia slows language processing and response generation, applications for people with aphasia often allow users to control the pace of interaction and receive timely feedback. EVA Park and virtual word-retrieval therapy support self-paced practice [18, 44], while tablet-based home practice programs with telepractice [35] and inclusive digital therapy for acquired reading impairments [37] couple adaptive pacing with prompts. Mobile VR speech rehabilitation apps [8], videoconferencing tools requiring extra time and multimodal cues [50] and AI-assisted AAC interfaces such as "The less I type, the better" [73] provide clear, immediate feedback. These systems emphasize adjustable timing, self-paced practice and clear feedback.

2.1.4 One-handed control

Many people with aphasia acquire hemiparesis after stroke, where one side of their body may be weak or paralyzed. HCI research has therefore emphasized the use of interfaces that can be operated with one hand and placing controls on the non-affected side. For example, recent co-designed tools such as *CreaTable* [51] and *TalkingTiles* [25] feature large, easily accessible buttons that can be manipulated with a single hand. One-handed controls appear frequently across HCI for aphasia, reflecting the need to accommodate motor impairments alongside language difficulties [25, 47, 51, 71, 74].

2.1.5 Multi-modal interfaces

Multi-modal interfaces are a consistent theme in HCI work for aphasia. Early projects like the sound and image enhanced daily planner [47] and the *ViVA* [55] visual vocabulary showed how combining photos, icons and audio cues could support planning and conversation. The CHI community has continued this exploration with *Comic Spin* for storytelling [71], *Breaking Badge* wearable AAC smart-badges [11] and the *Lights, Camera, Access* project on audiovisual media accessibility [52]. These multimodal representations allow people with aphasia to express ideas without relying solely on speech or text, reduce cognitive load and accommodate varying abilities.

2.2 Virtual Reality for Aphasia Rehabilitation

VR has emerged as a promising modality for speech and language therapy. There have been several papers published recently that look at how Virtual Reality can be used in aphasia rehabilitation.

2.2.1 EVA Park

One of the most notable studies was conducted by Marshall et al. [44] when they developed EVA Park: a virtual world where people with aphasia can speak with others in a safe space in order to practice their conversational skills. They reported significant improvements in functional communication and word-finding abilities over just a five-week intervention period. Something to note here was that participants were able to use the VR application by themselves at home without a therapist next to them. Accordingly, the users spent an average of 40 hours on EVA Park, while only an average of 5 hours in traditional therapy. However, the application was mainly an online chat platform rather than specifically practicing communication skills similar to what is done in in-person speech therapy sessions with SLPs.

Galliers et al. [18] also conducted a qualitative study to explore the user experience of the participants using EVA Park. It demonstrated that people with aphasia can successfully navigate and communicate within a virtual environment. The themed environments enabled situated, functional communication practice that may support generalisation to real-world scenarios. They found the application to be accessible and usable with positive emotional social outcomes. The virtual world supported rich, varied conversations that allowed users to take greater initative in interactions, which suggested greater potential benefits for confidence and agency.

2.2.2 SIM:Kitchen

Furthermore, Vaezipour et al.[72] evaluated SIM:Kitchen, an immersive VR environment for people with acquired communication disorders. They found that participants considered the system enjoyable, realistic, and potentially useful, while also noting usability barriers such as the need for more intuitive hand controllers. Together, these studies highlight both the therapeutic potential of VR and the importance of designing for accessibility and user acceptance.

2.2.3 VR-based Naming Therapy

In addition, Kurland and Stokes [35] utilized VR-based naming therapy with ten chronic aphasia patients. They found that the immersive nature of VR led to better retention of learned vocabulary compared to traditional flashcard methods.

Overall, there has been a lot of promising work done with these innovative approaches that could potentially reduce the workload of speech therapists and improve long-term recovery outcomes for individuals with aphasia. However, there are still some challenges and difficulties exposed by gaps in current research that need to be explored and resolved to improve the effectiveness of VR in speech and language therapy and aphasia. Few studies directly compare VR-based therapy with conventional therapy, and it is unclear whether people with aphasia can engage with VR independently at home.

Additionally, existing research has not adequately addressed the potential of VR to provide intensive therapy options that can be accessed remotely or with minimal therapist supervision, which would effectively address the limitations faced by speech therapy today. Brady et al. [7] showed that the most effective recovery is associated with frequent, functionally tailored practice delivered at higher intensity than standard clinical care. Enabling autonomous home use could mitigate reliance on limited clinician availability, supporting the dosage levels known to drive recovery, but we also have little understanding of how known usability issues might impact long-term use [72]. In 2023, Devane et al. [13] performed a systematic review of 14 studies with a combined 229 participants, and showed positive results regarding improvements in language impairment and activity, but also stated that there is a need for future studies to strengthen the evidence supporting VR for speech therapy and explore the particular benefits of VR over other technologies, such as autonomous and context-rich practice.

Together, this work suggests that VR platforms could supplement or extend conventional therapy, but empirical evidence of unsupervised use is still scarce. Our comparative case study of Pragmatica addresses this need, examining whether autonomous VR can support independent practice while maintaining therapeutic value.

Chapter 3

Pragmatica

Pragmatica is a commercially developed VR application designed to support autonomous practice for speech and language therapy. Unlike prior research systems such as EVA Park [44], Pragmatica was built to be used independently at home on various VR headsets like the Meta Quest 2 and 3, requiring minimal setup and no clinician supervision. The application offers a library of immersive activities that mirror everyday communication tasks, such as ordering food in a café, visiting a pharmacy, or asking for assistance in a repair shop. Each scenario embeds therapeutic exercises into functional interactions with non-player characters, with increasing levels of complexity (e.g., ordering more complicated meals or correcting an incorrect order). This contextual, situated practice aims to make therapy both engaging and transferable to daily activities.

At a high level, Pragmatica consists of three main components: the VR application, a backend database, and a clinician-facing data dashboard. The primary user accesses the Pragmatica VR application, where they can practice their communication skills in a wide variety of activity modules. These activities are rendered in immersive 3D environments built using the Unity Engine and contain scripted storylines to follow and characters to interact and converse with. A low-poly 3D art style was used in the activities to avoid any "uncanny valley" scenarios while still allowing actions, gestures and body language to be clearly visible. All the activity data and metrics are stored securely in a database and are accessed by the data dashboard, which visualizes all the information from the backend database to help secondary users like clinicians and admins understand how well the primary user is practicing their communication skills, as well as adjusting different settings and parameters as needed.

The Pragmatica activities consist of a wide variety of different communication skills and contexts (Table 3.1). These communication skills are selected based on what is normally used in speech and language therapy and mixed and matched with different contexts to construct activities that help users practice their communication skills in many different scenarios. For example, the communication skill of "Daily Living Activities" with the context of "Mall" corresponds to ordering lunch at a restaurant in the food court of a mall, and involves the social cues and nuances that the user must understand to proceed through all the steps in ordering a burger at the mall.



(a) Friend asks user to order a burger



(b) User approaches restaurant



(c) User is asked what they want to order



(d) User orders the burger



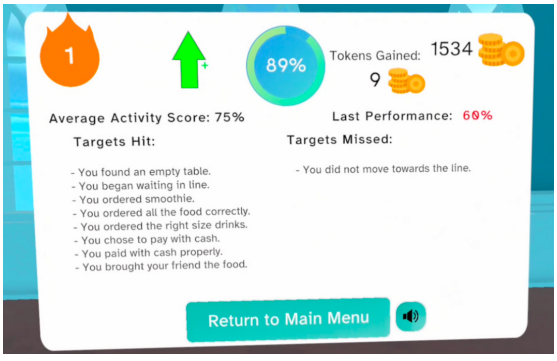
(e) User is asked how to pay



(f) User chooses cash



(g) User brings food to friend



(h) Activity summary screen

Figure 3.1: "Order a Burger" activity walkthrough (Daily Living Activities x Mall)

Table 3.1: Pragmatica Activities: Communication Skills and Contexts

Communication Skills				Contexts		
Social Skills	Emotional Regulation	Sarcasm		Mall	Classroom	Dental Office
Critical Thinking	Perspective Taking	Prosody		Park	Library	Grocery Store
Boundaries	Executive Functions	Safety	×	Neighborhood	Gym	Backyard
Self-Advocacy	Daily Living Activities	Initiative		School	Restaurant	Drive Thru
				House	Pharmacy	Mechanic Shop

These activities aim to enable patients to have more practice of their functional communication skills. Studies discuss how repeated, structured functional communication practice leads to significant gains [7, 9], and the activities from Pragmatica allow people with aphasia to greatly increase the amount of practice they have access to.

Figure 3.1 walks through a sample activity of ordering a burger in a restaurant in the food court of a mall for the user's friend. Panels a-g show the key points of the activity, consisting of approaching the restaurant, ordering the food, paying for it, and bringing it to the user's friend. These panels depict key points in activities inspired by conventional speech and language therapy, as they mimic the exercises conducted by speech-language pathologists with their clients. The final frame shows the activity summary screen, which shows the user their activity score, how they performed compared to their previous attempt, and what specific targets they hit and missed. Plus, it also shows some other gamification features like the tokens they gained and their current streak. The activity scores are a score out of 100 determined by targets hit and missed throughout the activity.

The Pragmatica VR application also includes several features catered specifically for its target audience of the aphasia population, which were created in the initial stages of Pragmatica's development. Pragmatica collaborated and consulted with speech-language pathologists in the earlier stages of development before the thesis had begun, where they were advised on design decisions and features like the ones below. Features were also added from asks and recommendations from clients.

3.1 One-Handed Controls

Pragmatica offers flexible control schemes where users can use the VR app entirely with only their left or right hand. Fig 3.2a exhibits the one-handed mode feature that was developed when Pragmatica onboarded a client who had severe motor impairments in one hand, and they developed the one-handed mode to make it more accessible to clients like



(a) One-handed mode toggle to use with left/right hand for people with motor difficulties

(b) Multi-modal prompting with visual (on-screen) and auditory (spoken) components

(c) Multi-modal inputs with multiple choice menu and audio narration of each choice

Figure 3.2: Accessibility Features

them. The primary control scheme is with two controllers, where the left joystick controls movement and the right joystick controls looking around. The other buttons work the same on both controllers to select buttons, pause, grab objects, etc. In the one-handed mode, the controller's joystick is used for movement and the player must manually look around by turning their head, with the other buttons staying the same. Thus, two-handed mode is preferred when possible, but one-handed mode allows users to fully use Pragmatica with either controller while looking around with their head.

3.2 Multi-Modal Prompting

The app includes multi-modal prompting at all points in the application to accommodate visual and auditory impairments that are common in people with aphasia. All prompts and instructions are visually displayed in front of the user, regardless of where they are facing, and also spoken aloud. Buttons and menus come with clear text and a speaker icon next to them that will speak the text out loud when they are clicked (Figure 3.2b). Pragmatica included this due to advice from speech-language pathologists, where the importance of multi-modal prompting was emphasized. Therefore, this was baked into the development structure as all the components for instructions and prompts in activities and buttons in menus all required and contained support for visual and auditory sources of information for the users. Accordingly, this design decision allows the application to adapt to most of the users' visual and auditory difficulties.

3.3 Multi-modal Inputs

Pragmatica primarily uses speech recognition as the main input modality for interacting with activities and non-player characters (NPCs). However, recognizing that some users may struggle with speech production, the application also includes visual buttons that users can click to respond as well. For instance, when the user is interacting with an NPC in an activity, they will wait for user input through voice recognition. If some time passes

without any reply (usually 10-30 seconds based on the current context), a multiple-choice menu will pop up with 1 correct and 3 incorrect responses for the user to choose from by pointing and clicking with their controller (Figure 3.2c). Accordingly, all user responses that require speech recognition will eventually provide some buttons to click to respond instead. Similar to the prompting, the multi-modal inputs were also highly recommended by speech-language pathologists, and the application was built with this in mind. By providing both auditory and visual interface options, the application accommodates the variability in communication abilities that is common in people with aphasia, supporting engagement and accessibility for a broader range of users.

Chapter 4

Method

To evaluate Pragmatica's potential for home use, we conducted a mixed-methods evaluation. We asked a group of four people with aphasia to use Pragmatica at home over an eight-week period, and compared their experiences to four individuals participating in traditional language therapy. We adopted a mixed-methods case study design [10, 79] to compare autonomous Virtual Reality (VR) language therapy with conventional language therapy. We compared participants' pre- and post-study performance using the Quick Aphasia Battery (QAB) assessment. We also analyzed post-study interviews using Yin's "ground up" strategy, incorporating pattern matching, explanation building, and cross-case synthesis to better understand how Pragmatica was used over the study period.

Our research study received full clearance from our institution's research ethics board (REB) to recruit people with aphasia for the study and have them use the Pragmatica VR application on a VR headset daily for 2 months. In addition, we received clearance to conduct QAB assessments and interviews, as well as collect their usage data (no sensitive health information) on Pragmatica. We have also received consent from the participants to use their data anonymously in the study.

4.1 Participants

Eight adults with aphasia were recruited from a local speech-language therapy clinic. Inclusion criteria were mild to moderate communication disorders, English proficiency, and no history of other neurological conditions. Exclusion criteria were severe cognitive impairments or the inability to put on a VR headset due to physical disability. Screening and recruitment were conducted by clinicians before informed consent.

4.2 Procedure

4.2.1 VR Group

Participants used the Pragmatica VR application on Meta Quest 2 headsets over eight weeks. A clinician provided them with the Meta Quest 2 headsets as well as detailed guides from Pragmatica on how to use the VR headset, how to open the Pragmatica app, how to connect to Wi-Fi, etc. The app automatically started with a tutorial to help them understand the VR controls, after which they progressed to the regular VR activities to practice their communication skills.

4.2.2 Control Group

Control group participants attended conventional speech therapy sessions once per week for 45–60 minutes over eight weeks, consistent with clinical guidelines. Their sessions would consist of exercises like word finding and contextual conversation, typical of most language therapy sessions for people with aphasia.

4.3 Data Collection & Analysis

Quantitative outcomes were assessed with the Quick Aphasia Battery (QAB) [77], administered pre- and post-intervention. The QAB assessment consists of 58 items across eight domains (word comprehension, sentence comprehension, word finding, grammatical construction, speech motor programming, repetition, reading, and overall score), each scored from 0–10. We compared VR and control groups using independent two-sample, two-tailed t-tests, and used paired t-tests to assess within-group pre/post changes.

The VR application logged usage data, including the number of activities, the duration of play, and activity scores. These were aggregated into three metrics: (1) number of activities played, (2) total minutes of play, and (3) average activity score. These metrics were used to assess engagement and performance over time.

Qualitative data were collected through semi-structured post-intervention interviews. Fifteen usability questions (see Appendix A) were organized into five domains: general experience, usability, effectiveness, comfort, and suggestions for improvement. Interviews were thematically analyzed using Yin's strategies of pattern matching, explanation building, and cross-case synthesis [79]. A thematic synthesis was developed for each VR participant to capture impressions, usability challenges, and perceived benefits.

Chapter 5

Results

We first report group-level quantitative outcomes, followed by qualitative themes from post-study interviews. We then present detailed case analyses of each VR participant, integrating assessment scores, usage patterns, and interview data. To preserve anonymity, the participants are provided with pseudonyms: VR participants are referred to as Percy, Leo, Frank, and Hazel, and control participants as Jason, Piper, Nico, and Reyna.

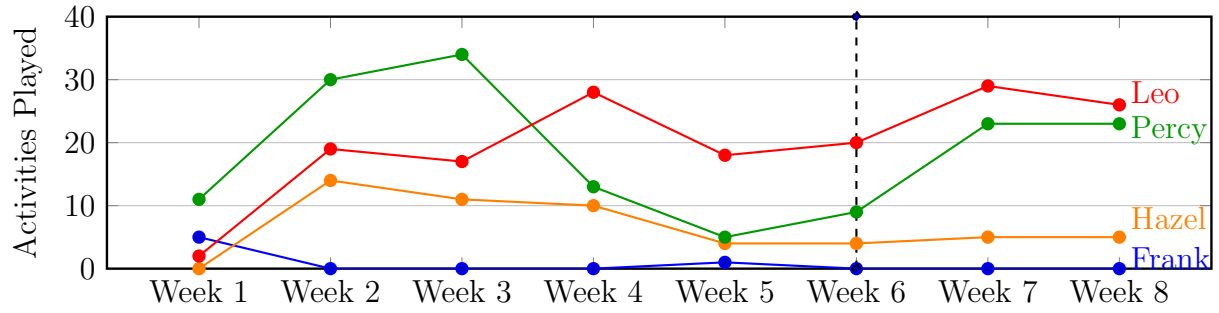
5.1 Quantitative Analysis

All participants completed pre- and post-intervention assessments using the Quick Aphasia Battery (QAB), measuring word comprehension, sentence comprehension, word finding, grammatical construction, speech motor programming, repetition, reading, and overall score, each scored 0–10. Change scores were calculated for each participant, and group means and standard deviations were derived. An independent two-sample, two-tailed t-test comparing overall change between the VR and control groups yielded no statistically significant difference ($t = 1.71$, $p = 0.1248$).

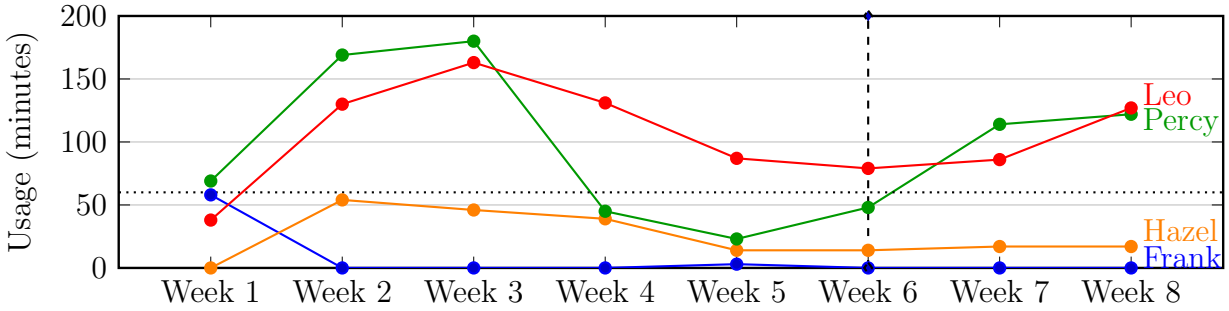
Across the study, VR participants completed 366 activities over 31 hours of usage. As shown in figures 5.1a and 5.1b, three participants (Percy, Leo, Hazel) accounted for 97%

Table 5.1: Changes between pre- and post-assessments for VR and control group

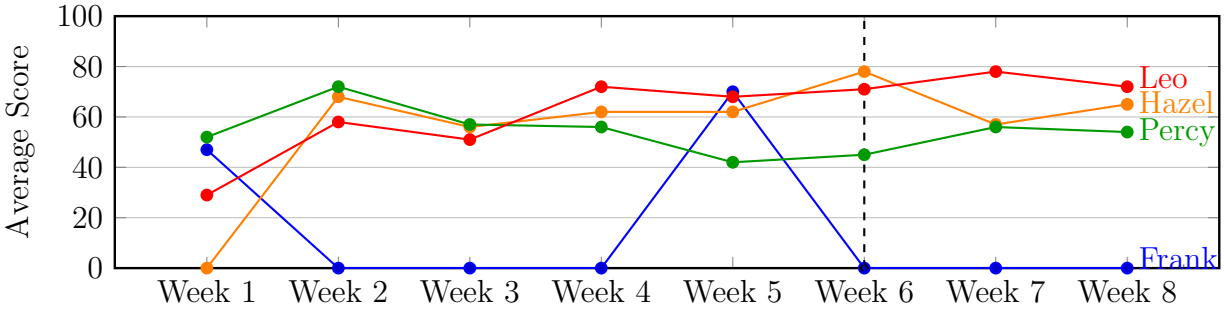
Domain	**VR Group**						**Control Group**				
	Percy	Leo	Frank	Hazel	Mean	SD	Jason	Piper	Nico	Reyna	Mean
Word comp.	0.42	0.00	0.00	0.00	0.11	0.18	0.42	0.00	0.00	0.00	0.11
Sentence comp.	0.42	-1.67	-0.83	0.00	-0.52	0.80	2.92	0.83	0.00	0.00	0.94
Word finding	0.00	0.00	1.00	0.00	0.25	0.43	0.50	0.75	0.92	1.50	0.69
Grammar constr.	-0.50	0.25	0.00	0.00	-0.06	0.27	-0.38	0.25	0.00	0.25	0.03
Speech motor prog.	0.00	0.00	2.50	0.00	0.63	1.08	0.00	0.00	0.00	0.00	0.00
Repetition	-0.42	0.83	1.66	-0.42	0.42	0.88	-0.83	0.00	0.00	1.67	0.21
Reading	-0.83	0.00	-0.83	0.00	-0.42	0.42	0.00	-0.42	0.00	1.67	0.31
QAB overall	-0.02	-0.20	0.26	-0.03	0.00	0.16	0.55	0.26	0.18	0.51	0.33



(a) Activities played per week with dotted line representing when new activities were added



(b) Time spent using Pragmatica per week with dotted lines representing when new activities were added and 60 mins of usage



(c) Average score per week with dotted line representing when new activities were added

Figure 5.1: VR Group Usage Data

activity, while Frank contributed minimally. Weekly activities and total minutes of usage were strongly correlated, reflecting the time-based design of tasks. Participants ease into and increase their use of the application in weeks 1–3, with increasing activity counts and usage as participants became familiar with the system. Usage declined around weeks 4–5, then increased from week 6 onward, coinciding with new activities being released in the Pragmatica app. Performance patterns mirrored the usage as the activity scores were initially low at around 30-50 but increased along with application usage upto 60-80, as shown in figure 5.1c.

5.2 Qualitative Findings

Following Yin's [79] case study method, we conducted a detailed analysis of each participant's usage metrics and patterns, alongside their responses to our semi-structured interview questions. We now present a case study for each participant who used Pragmatica, including direct quotes from the interviews.

5.2.1 Percy

Percy was one of the study's most active users as he quickly became engaged with the VR application, showing the fastest initial uptake among all participants. In just his first week, he logged 11 activities, rapidly climbing to a peak of 34 activities in week 3. During this third week, his usage time peaked at slightly over 180 minutes, and he had a strong average activity score exceeding 70 points by only the second week. This indicated how quickly Percy had adjusted and become comfortable with using the VR application and the headset.

Percy described his overall impressions positively, noting, "goggles are good" and "games good as well." During these first few weeks, Percy established a weekly routine where he would regularly use the VR application in short but consistent sessions, typically on "every week Sundays." He stated that he specifically liked using the VR application in short sessions, as he expressed "short times... I'm comfortable." Usability feedback from Percy revealed mixed impressions. While he noted that some navigation tasks were "easy," he also acknowledged encountering "difficult" aspects requiring assistance from his son. Another important usability factor for Percy was the difficulty he experienced with the right-hand controller due to his hemiplegia. Before he tried one-handed mode, he said "left hand... easy," but the right-hand controller was notably uncomfortable and challenging. Hence, he switched to using one-handed mode, which greatly improved his experience and tripled his weekly usage from 1 hour in week 1 to 3 hours in week 2. In addition, Percy said he liked the clarity and the clear instructions in the app and reported no software glitches or technical failures. Percy's initial enthusiasm saw a noticeable dip during weeks 4 and 5, where his activity sharply declined to just 13 and then 5 activities, corresponding to approximately 45 and 25 minutes of usage respectively. This lull suggested temporary disengagement or possible external constraints limiting his usage. During this period, his activity scores dropped below 50, reflecting the drop in engagement. In week 6, Percy rebounded, recommitting to the application with renewed motivation. His activity level surged back from 6 activities to an average of 23 activities per week, accumulating about 120 minutes weekly. His activity scores recovered above 50 afterward.

Despite physical challenges posed by hemiplegia, Percy's experience with the VR product was largely positive. He enthusiastically praised the application's features, specifically valuing the audio playback feature, as he said, "can read," but enjoyed "listening" to the content in the app. This enjoyment likely supported his consistent routine and overall positive engagement with the application. Percy consistently engaged with the application, albeit occasionally with some slow periods, suggesting he might benefit from additional

external motivation strategies. He also mentioned that he would ask his son for help whenever he got stuck in the app. His reliance on his son for occasional assistance underscores the importance of accessible design and suggests that further improvements can be made to make the app more intuitive and easier to use. Ultimately, Percy's VR journey can be characterized as enjoyable, helpful, and well-integrated into his routine, reflecting significant potential for continued use and therapeutic benefit.

5.2.2 Leo

Leo's journey with the VR application reflected the highest overall engagement levels of all participants in the study. Although he started off slowly with only 2 activities logged in week 1 and an average score of 30, his usage rapidly ramped up. Over the next few weeks, Leo steadily increased his engagement to between 15–30 activities per week, maintaining weekly usage times of 80–160 minutes. His performance improved alongside his usage, with average scores starting out around 50 and climbing to 65–80 by week 4. Hence, this consistent and heavy engagement translated directly into higher activity scores and exemplified the ideal usage curve: an initially slow start, followed by consistent use and gradual performance gains. Leo described his overall experience with the app positively, stating, "I liked the app," although he acknowledged it "took some getting used to... but in the long run I was able to help [sic] out with everything." This adjustment period did not deter his motivation, as he used the app "almost every day" over the study period. His strong engagement was reflected in the cumulative metrics: a total of 160 activities and 840 minutes of usage, the highest among all VR participants. He consistently praised the clarity of the on-screen instructions, saying, "That was very easy. Yeah, I found it almost too easy to use," and mentioned that there weren't any difficulties using the controls: "That was no problem at all."

Despite his overall fluency with the system, Leo did encounter challenges in specific activities, particularly the Chef scenario, where the user has to line up, order, and pay for food at a fast food restaurant. He explained, "For the Chef one, I just couldn't do that one ... at the end I would have to choose the... how you pay." Leo had some trouble understanding how to do the "payment" part of that VR activity where you have to pick up your card and pay for your food, which he seemed to struggle with. He found the responsiveness of the item pickup feature to be inconsistent, stating, "When you're picking up... some of them were confusing because they would not give you the right answer right away." However, these moments of confusion did not significantly detract from his experience as he continued to regularly use the app but are indicative of potential areas for improvement in the app's interactivity.

Leo appreciated the effectiveness of the application but also highlighted a key issue in the repetition of its content. As someone who used the app daily, he quickly exhausted the available content and began repeating the same activities and questions. He commented, "It was very repetitive" and suggested, "If you have different aspects of the questions, it would be better... but it was the same stuff all over again." This sentiment carried over into his feedback for improvement. He recommended more question variety and a shift

in the app's thematic focus: "You need different questions to answer... not the same stuff all over again". Leo did not report any issues with comfort and seemed satisfied with the physical experience of using the VR system. His overall high motivation and consistent use suggest strong intrinsic engagement with the application, but his comments on content repetition reveal that even highly engaged users can encounter limitations when the content doesn't evolve. Leo's usage pattern of starting slow, ramping up to daily use, and eventually slowing again after content exhaustion highlights both the strengths and the developmental opportunities of the VR app.

5.2.3 Frank

Frank's experience with the VR application was markedly different from the other participants, characterized by very limited use and a general dissatisfaction with the product. He only used the application for a total of 5 activities and 60 minutes throughout the entire 2-month period. Most of this engagement occurred during the first week, after which there was a long pause in usage until week 5, when he tried the application once more. His comments reflected this usage pattern: "In the beginning ... I used once, and then again after some weeks." Despite the very limited time spent in the app, it's noteworthy that his score during his week 5 session was around 70, indicating he had the capacity to perform well, but simply did not enjoy or feel that the application met his needs. This was summed up in his own words: "For me, ... I was not happy ... to help with my aphasia." Frank's low engagement appeared to be rooted in a misalignment between the app's content and his specific therapeutic goals. He emphasized, "Not readily for me. I needed to practice ... my speech" expressing a need for more targeted conversational practice rather than functional communication activities. While acknowledging that the app may be "better for others", he felt that it was not suited for his personal rehabilitation needs.

Frank's difficulties extended beyond content alignment. Physically, he faced challenges due to his impairment in his right hand, stating, "I have a problem using my right hand. ... I could not use my right hand." He said the controls were "not easy, not easy." Accordingly, Frank had trouble using the app even with the one-handed mode, indicating that further improvements may be needed for the flexible control schemes. While he acknowledged that the app's instructions were clear and understandable, technical issues such as lag added to his frustration as he said "Sometimes it would freeze". Comfort was also a concern for Frank. He experienced discomfort when having to move his character while seated, as he noted, "Yes. For me, the movement ... I was sitting." It didn't seem intuitive to him to have to move in a virtual space while he was actually stationary in the real world. Furthermore, when asked to rate the headset comfort on a scale, he gave it a low "In from one to ten, I say four." This discomfort likely compounded the other challenges he faced with the application. Overall, all these usability barriers discouraged Frank from sustained use of the application.

When suggesting improvements, Frank wanted activities that focused specifically on speech clarity and word-finding, areas more directly aligned with his rehabilitation goals. Overall, Frank's limited interaction with the VR application revealed a mismatch between

the app's offerings and his expectations and needs. Although his week 5 performance showed he could succeed within the app's framework, his disinterest and discomfort ultimately led to minimal use. His feedback highlights the importance of tailoring VR therapy experiences to meet a range of user needs, especially for those seeking more speech-focused rehabilitation content.

5.2.4 Hazel

Hazel's experience with the VR application was characterized by moderate and steady engagement, placing her in the middle of the participant group. She did not use the application at all in the first week, but then began to use it consistently in the weeks that followed. She maintained a cadence of 4–11 activities and 15–50 minutes per week, totaling 53 activities and approximately 200 minutes over the entire study. Although her usage gradually declined after week 5, her performance improved steadily, with her average scores climbing to a peak of 78 in week 6, the highest in the VR group. This trend suggested that Hazel's engagement was more targeted and efficient, resulting in strong outcomes despite relatively less usage. Hazel described her experience with the application as generally positive. She remarked, "I have some good experience... They have good answers and stuff" and "Yeah. Yeah. Good." In the early stages, she used the application every couple of days, showing strong initial motivation. However, her usage decreased over time as she became busier with other responsibilities, stating, "I used to do them like every couple of days... now I was busy doing stuff."

In terms of usability, Hazel found navigation and control generally manageable. She said, "Easy. Easy... I have to rethink... what buttons you were pressing," suggesting that while the controls were not difficult, they did require some conscious effort to remember them. She praised the clarity of the instructions, describing them as "Easy... very easy to follow." However, she did face some technical issues, noting that one activity "froze," and she struggled in the grocery shopping activity, where it was "difficult to put down the list of the items." Hazel felt that the application was effective in supporting her rehabilitation goals, but it occasionally failed to work smoothly. She commented, "It does help... but sometimes it kind of stuck." Despite the occasional technical setbacks, she was enthusiastic about her introduction to VR, saying, "It's very interesting... this is my first time doing this." With respect to comfort, Hazel reported no major issues, although extended use did cause some eye strain. She explained, "I can't stand that long... my eyes start to... blur." This suggests that while short sessions were fine, the headset was less suitable for prolonged use.

For future improvements, Hazel suggested fixing technical bugs, "You could fix some bugs", and recommended more activities that involved speaking with in-app characters: "More... talking to people. More conversation." She was interested in more conversational practice as part of the experience, aligning with her specific goals. Overall, Hazel's usage of the VR application was consistent and moderately frequent. Although her time in the app was less than Percy or Leo, she was able to achieve high scores through focused and effective sessions. Her feedback underscores the importance of minimizing technical bugs and enhancing adult-oriented, conversational content to maintain long-term engagement.

Chapter 6

Discussion

Our findings highlight how VR can drive engagement and make speech and language therapy accessible to people at home without the need of a clinician to be present. Conventional therapy typically involves 45-60 minutes of therapy per week, whereas Brady et al. [7] recommends 8-10 hours of prescribed practice per week. That amount of practice is often impractical with in-person therapy due to factors like cost and access, but the use of VR for autonomous at-home practice can make that amount of practice feasible. Our log data showed that 2 of our 4 participants used the VR application for about 2 hours per week on average. We interpret that finding as a positive indication that VR can allow some participants to practice on their own schedule from the comfort of their own home for long periods of time and mitigate dependence on clinicians. However, it is also a sign that improvements are needed to make at-home VR speech and language therapy a reality, especially to reach 8-10 hours of weekly practice.

6.1 Leverage generative tools to scale content, but ensure relevancy for the user

Our data strongly points to novel content as a driver of engagement. Three out of the four participants were highly engaged at the start of the study, followed by a drop in usage to less than 45 minutes per week as they completed the activities available to them. As new activities were added six weeks into the study, their usage increased again. The simplest explanation is that available content was a driver of practice, and that we did not develop enough material to engage participants for the full study period. In practice, this finding underscores the importance of having a large amount of contextually meaningful and unique activities to sustain long-term use of the VR application.

Past research already points to methods for creating the content needed by Pragmatica. For instance, Mao et al. [42] showcase how content can be procedurally generated using generative artificial intelligence through the creation of various types of content, including terrains, items, and even storylines. Furthermore, this procedural generation of content has been applied in the creation of dynamically generated VR libraries in Safikhani et al. [65],

and has been shown to increase user engagement and make using the system feel more rewarding. Purohit et al. [62] show how AI chatbots can be used to make NPCs more dynamic and interesting, or even to fully simulate social situations. This research lays the foundation for novel content generation that can keep people engaged with language therapy in a home setting to reach the goal of 8-10 hours of practice per week.

Overall, our study has shown the potential of VR activities for communication practice for aphasia and existing research has already shown several promising methods for how to fill the platform with a high quantity of varied, unique activities. Akin to what the past literature suggests, generative AI can be used to procedurally generate activity structures and flows in many different environments, which can then be constructed in VR. On top of this, all activities (new and previously created) can be fed into large language models and can be used to create a wide variety of variants for each scenario with different characters, responses, and outcomes to provide a myriad of unique activities for the users to go through. Thus, the path forward is clear for sustainable application usage.

6.2 Provide flexible (one-handed) control schemes in VR

Pragmatica highlights the significance of utilizing VR for one-handed VR controls to provide an intuitive experience for those only able to use one hand. The incorporation of this feature showed promising results, as it enabled two participants with hemiplegia to use the VR application. Participants using the one-handed controls generally liked using it. Leo and Hazel both complimented the easy controls, and Percy said, "I like using the left-hand controller one-handed". In fact, the VR headset actually provides a novel opportunity to improve one-handed interaction by allowing users to control looking around with the headset. Normally, one controller would control locomotion while the other controlled camera rotation with the directional joysticks. Without the VR headset, both directional actions would somehow have to be mapped to a controller with only one joystick. However, the inclusion of a VR headset allows users to look around, resulting in more intuitive control mapping on the single controller.

Our study outlined the importance of the one-handed mode feature through Pragmatica's flexible control settings. This maps to well-documented needs in aphasia, where motor deficits such as hemiparesis are common. Prior systems and studies have either struggled without one-handed operation or explicitly recommended it for this population. Daemon [12] and Huijbregts [25] expressed the importance of allowing people with aphasia to use products with one hand. Sandt-Koenderman [74] created a computerized communication aid for people with aphasia and ensured that their device is easy to operate with one hand, stating its importance for people with aphasia. There has been a lot of previous work regarding one-handed VR interaction. Osawa [58] comparatively evaluated one-handed techniques with traditional two-handed methods for manipulating virtual 3D objects, Schäfer [67] evaluated the same for teleportation-based locomotion, and Hassan [24] compared them for text entry using handheld controllers. Applications with one-handed

text entry were developed like H4VR [16] and HiFinger [29]. However, we found no studies addressing one-handed VR controls tailored to people with aphasia. Our study explores how these flexible control schemes that have been used in previous VR applications can be utilized in VR programs for aphasia like Pragmatica.

However, future work can still be done on improving one-handed VR controls. Currently, the user still needs to manually look around, and one of the participants had trouble doing so while sitting in their chair. The participants in the study could look 90 degrees to the left and right, but could not fully turn around to look behind them while sitting, which limited their mobility in some activities where they needed to walk in different directions in some activities. One potential solution is to make the activities more linear and not require turning around, but this restricts the immersion and dynamicity of the activities, as users would not be able to turn around and talk to people behind them or walk back and forth in the environment. Hence, a better solution is to accommodate looking in every direction within the one-handed controls. Studies by Sargunam [66] and Wang [75] have explored seated view-rotation and have suggested that the yaw of the head rotation can be amplified to allow users to fully look behind them without too much neck discomfort. Other ideas include a button that would turn you around 180 degrees so that the user can now cover the whole 360 degrees of visual range, or a button that toggles the joystick between movement and camera rotation, so that the user can freely look around with their controller when needed [34]. All of these potential solutions can be tested in the future to understand which solution feels the most intuitive and easy to pick up. Overall, future VR applications designed for people with aphasia should ensure that they are easy to use with one hand and should take advantage of the fact that the inclusion of a VR headset can provide more intuitive one-handed controls.

6.3 Offer multi-modal VR interfaces

Pragmatica maintained multi-modal inputs and outputs throughout the application in all activities and menus. Pragmatica paired every prompt with spoken instructions, on-screen text, and icons. All buttons and menus included a speaker icon to trigger text-to-speech. Participants consistently praised the multi-modality. Percy said, "The app's instructions were clear and easy to follow", and Leo and Hazel also complimented the prompts and appreciated having both visual and auditory cues. Even Frank, who had trouble using the VR application, still said, "while the controls were hard, the instructions were clear and easy to follow." On the other hand, speech input was also supported with clickable buttons as a fallback at all points where speech recognition was used in the application. This allowed participants to still progress when speech was unreliable, making it more independently usable.

This feature is particularly important considering the target audience of the application, as people with aphasia often have co-occurring sensory deficits [15, 23, 36, 38], which makes this input and output redundancy essential. Multi-modal tools for aphasia are well established [39, 61], with recent systems again foregrounding multi-modality [6, 41, 78].

There's been a large number of papers that have looked at multi-modal interaction specifically in VR [19, 46, 80]. Moreover, several prior VR systems for aphasia, such as EVA Park [18, 44], have incorporated multiple modes of input and output, such as combining speech communication with typed text or manual navigation. However, these multi-modal features are typically used only in isolated parts of the experience and are not implemented consistently across the entire application. Furthermore, existing studies rarely emphasize or evaluate the importance of maintaining multi-modal interaction and continuous fallbacks (e.g., alternative input when speech recognition fails), which are critical for ensuring accessibility and sustaining engagement for users with aphasia. Our work demonstrates the importance of having both multi-modal inputs and outputs with fallbacks in VR applications. By giving the users these redundant channels of information, varied language deficits can be accounted for. Moreover, allowing users to interact and respond with both visual and auditory modalities helps accommodate a wider range of users who may be only able to do one or the other.

The current multi-modal systems in Pragmatica can also be improved in various ways. For output, richer cues like haptics can be incorporated to provide more diverse options for multi-modality. Vibrotactile haptics are a viable option to provide confirmation and error signals throughout activities and feedback for interacting with UI elements in order to add even more redundancy and multi-modality to improve user experience. Past work has shown that vibrotactile feedback is a practical, low-latency method of improving immersion in VR [28, 68]. Empirical evaluations indicate that adding vibrotactile cues can boost presence, user experience and sometimes even task performance in VR applications [20, 48]. Studies demonstrate that vibrotactile haptic cues can effectively orient attention without increasing cognitive load, suggesting tangible benefits for users with sensory or cognitive challenges [64]. There has been rehabilitation work that states that coupling VR tasks with vibrotactile guidance can better facilitate self-monitored therapy, which aligns with our aim to provide better multi-modality to support more independent therapeutic practice [30]. For input, whenever speech recognition fails, the system currently immediately provides the same pre-programmed options regardless of what the user said. This could be further refined to provide dynamic options based on what the user spoke, or even have the NPCs ask clarifying questions based on what was said, which would improve the immersion and dynamicity of the activities. This can be accomplished by pairing the NPCs with generative artificial intelligence to provide those more dynamic responses and interactions that was previously discussed when talking about novel content generation. Future VR applications should strive to have multiple modalities of prompting consciously used in all stages of the application (activities and menus), as well as multiple methods of input, ensuring that users are not hindered from using the application due to their visual or auditory impairments.

Chapter 7

Conclusion

This study examined the feasibility of a home-based VR application for adults with aphasia by comparing autonomous VR practice with traditional therapy over an eight-week period. Participants were able to use Pragmatica independently, without requiring a clinician next to them, which is a major step toward truly scalable home rehabilitation. Participants also described the VR experience as engaging, motivating, and easy to navigate. The accessibility features played a big role in that. From a quantitative perspective, there was no statistically significant difference in QAB outcomes between the VR and control groups, but the increased amount of communication practice through the at-home usage of the VR app is very promising. Additionally, we saw strong qualitative evidence that VR can be a feasible and promising complement to traditional therapy, one that gives people more opportunities to practice in a safe, controlled, and motivating manner. We learned that sustained engagement requires a much larger and more varied activity library, as participants were enthusiastic early on but wanted more content to stay motivated over time. The study also highlighted the importance of accessibility features, as the one-handed mode enabled two participants to use the app, and the multimodal interfaces bolstered participants to use the app intuitively and independently. Looking forward, future systems should incorporate those flexible controls and multi-modal interfaces similar to Pragmatica and even improve upon them using the strategies mentioned previously. Accordingly, there are so many avenues of extending this study to further delve into how VR can be used for speech and language therapy. Ultimately, this study demonstrates that VR has the potential to remove key barriers of traditional therapy and shows a lot of potential to support autonomous, at-home communication practice for people with aphasia.

7.1 Limitations

This study has several limitations that constrain the strength and generalizability of its findings. The most significant was the small sample size (4 participants per group), which limited statistical power, increased the risk of Type II errors, and made it difficult to detect subtle between-group differences. The intervention period was also relatively short at eight weeks, restricting our ability to evaluate long-term retention or transfer of skills

to everyday communication contexts. In addition, the limited activity library meant that participants who used the VR application a lot frequently repeated the same activities after a few weeks, leading to reduced motivation and usage. A longer intervention window could have revealed whether the observed benefits are sustained over time or continue to accumulate with extended exposure to the VR environment. Resolving these limitations would enable researchers to draw more definitive conclusions about the efficacy of VR-based interventions for aphasia rehabilitation.

7.2 Future Work

Each limitation suggests avenues for future work. First of all, further development of the activity library is essential, both to provide richer and more varied scenarios and to support sustained use over months rather than weeks. A larger randomized controlled trial with an extended study period would improve statistical power, strengthen internal validity, and allow assessment of sustained outcomes. Such trials could also compare different modes of delivery, including in-person therapy, fully remote VR therapy, and hybrid approaches. Replication with other communicative disorders, such as autism spectrum disorder or social communication disorder, would test the broader applicability of VR-based interventions. Research should also explore advanced features, including multiplayer VR environments, as well as gamification elements (e.g., achievements, leaderboards, adaptive challenges) that may further enhance engagement. Together, these directions would build the empirical and design foundation needed to evaluate VR as a sustainable and generalizable tool for autonomous at-home rehabilitation.

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APPENDICES

Appendix A

Interview Questions

General Experience

1. What were your overall impressions of using the app?
2. How often did you use the app during the 3 months?
3. Did you encounter any challenges when starting to use the app?

Usability

1. How easy or difficult was it to navigate the app?
2. Were the instructions for using the app clear and easy to follow?
3. Did you experience any technical issues while using the app? If yes, please describe them.
4. How intuitive did you find the app's controls?

Effectiveness

1. Do you feel the app helped you achieve the goals it was designed for? Why or why not?
2. Was the content or functionality of the app engaging and useful?
3. Were there any features you found particularly helpful or unnecessary?

User Comfort

1. Did you experience any discomfort (e.g., motion sickness, eye strain) while using the app?
2. How comfortable were you with wearing and using the VR headset for extended periods?

Suggestions for Improvement

1. Is there anything you would add or change about the app to improve its usability?
2. Are there additional features you wish the app had?
3. Is there anything else you would like to share about your experience?

Appendix B

Participant Case Analyses

B.1 Percy

Assessment Analysis. Out of all the participants in the VR group, Percy was the quickest to get started with the app and used it the most in the first few weeks. Activity counts jumped from 11 in week 1 to a peak of 34 in week 3, with usage time cresting just above 180 min. It is important to note that he achieved an average score of over 70 in just the second week, making it clear that he got adjusted to the VR headset and application quite quickly. However, a sharp lull followed with a week 4–5 drop to 13 and 5 activities respectively with only ∼45 and ∼25 min of use. Right after the midway point, Percy started to heavily use the application again, climbing back to an average of 23 activities and 120 min per week. The activity scores had a strong correlation with how much Percy used the application as it started off around 70, dipped to below 50 around the middle, and then went above 50 again. Overall, Percy logged about 770 minutes of use with 148 activities played, the second highest in the group.

General Experience. Percy really emphasized that he liked the app and that the experience was good with quotes like "goggles are good" and "games good as well." He used the VR application on a weekly basis and typically did short sessions, often on Sundays and weekends, saying he would play it "every week Sundays." He sometimes encountered difficulties with the activities and needed help from his son to get through them.

Usability. Percy had mixed impressions with navigation: some parts felt "easy" while others felt "difficult" and required his son's assistance. He said the app's instructions were clear and that there were no software glitches. He liked using the left-hand controller one-handed and found it "easy," but the right-hand controller was uncomfortable and required help due to his hemiplegia.

Effectiveness. Percy felt the app helped achieve his speech and language goals. He described the experience as fun and useful. He especially liked the audio playback feature, noting that although he "can read," he liked "listening" as well.

User Comfort. Percy did not report motion sickness or strain. He said "short times

. . . I'm comfortable." The right-hand controller remained uncomfortable due to his hemiplegia.

Suggestions for Improvement. He suggested having all controls operable from one side so that he could fully use the app with one hand.

Overall. Percy maintained a consistent weekly routine that led to sustained use. He performed very well, though was prone to occasional burnout. Despite his physical limitations, he described the experience as fun and useful.

B.2 Leo

Assessment Analysis. Leo was the most engaged participant, logging 160 activities over 840 minutes. Starting with just 2 activities in week 1, his usage ramped to 15–30 activities per week (80–160 minutes). His scores steadily improved from an average of 30 to 65–80 by week 4. This usage curve exemplified rapid adoption, consistent practice, and strong gains.

General Experience. Leo liked the app overall, though it "took some getting used to." He used it "almost every day" during the study.

Usability. He reported no difficulties with navigation or controls, saying "That was no problem at all." He praised the on-screen instructions as "very easy." However, he struggled in the Chef activity when paying for food, and found object pickup feedback sometimes slow.

Effectiveness. Leo found the app effective but repetitive, saying "it was very repetitive." He suggested having more varied questions.

User Comfort. Leo reported no comfort issues.

Suggestions for Improvement. He recommended more varied and adult-focused activities.

Overall. Leo demonstrated the strongest engagement and motivation. His sustained use highlighted both the app's strengths and the limits of its content variety.

B.3 Frank

Assessment Analysis. Frank had minimal engagement, using the app for only 5 activities (60 minutes). Most usage was in week 1, with one more attempt in week 5. His performance (score $\sim$70) showed capacity, but he reported disinterest.

General Experience. Frank did not feel the app helped with his aphasia: "For me, . . . I was not happy . . . to help with my aphasia." He felt it might help others but not his needs.

Usability. Frank could only use his left hand due to impairment. He said controls were "Not easy. Not easy," though instructions were clear. He reported lag: "Sometimes it would freeze."

Effectiveness. He wanted more speech-focused, conversational practice rather than gamified activities.

User Comfort. Frank experienced discomfort when moving his character while seated, rating the headset a 4/10.

Suggestions for Improvement. He requested advanced conversational topics (e.g., TV news) and activities targeting speech clarity and word-finding.

Overall. Frank disengaged due to a mismatch between app content and his rehabilitation needs, combined with physical difficulties.

B.4 Hazel

Assessment Analysis. Hazel logged 53 activities over ∼200 minutes, starting in week 2. She averaged 4–11 activities per week. Usage declined after week 5, but her scores improved to the highest in the VR group (∼78 in week 6). This suggests efficient and targeted practice.

General Experience. Hazel had a positive impression: "I have some good experience . . . They have good answers." She used the app every couple of days initially, but less as she became busy.

Usability. She found navigation generally easy, though one quiz activity was difficult. She occasionally forgot controls, but said instructions were "very easy to follow." Some activities froze, and she had trouble with the grocery shopping activity.

Effectiveness. Hazel felt the app helped her speech but 'tch'sometimes it kind of . . . stuck." It was her first time using VR, which she found "very interesting." She felt the content was somewhat "kid-friendly."

User Comfort. No major issues, though she reported eye strain after long sessions.

Suggestions for Improvement. She suggested fixing bugs and adding more conversational activities.

Overall. Hazel maintained moderate engagement, achieved high scores, and suggested improvements around technical stability and adult-oriented content.