1.1 BACKGROUND

Aphasia is an acquired language disorder that has severe implications for those affected, as well as for their loved ones. Usually the result of a stroke, brain trauma, a progressive neurological disorder, or a brain tumour, it can impair all aspects of language, such as speaking, comprehension, reading, and writing (see e.g. Bastiaanse, 2011). Aphasia is thought to affect between 33 and 52 people per 100,000 each year (Engelter et al., 2006). Importantly, the incidence of stroke and aphasia are expected to rise over the next decades in countries such as Australia (Stroke Foundation, 2020) and The Netherlands (Rijksinstituut voor Volksgezondheid en Milieu, 2018), largely due to the ageing population.

Aphasia symptoms can improve through adequate speech and language therapy (Brady et al., 2016). During such therapy, speech and language therapists assess people with aphasia using language tests and provide individually tailored therapy to their clients. Therapists also tend to prescribe home-based language activities to their clients, which can be used for further practice of therapy content (see e.g. Sze et al., 2021). Research has repeatedly found face-to-face speech and language therapy to be effective for people with aphasia for a range of language skills, such as spoken word retrieval (e.g. Harnish et al., 2014; Mason et al., 2011), spoken sentence production (see Poirier et al., 2021), reading (Kim & Beaudoin-Parsons, 2007; Stadie & Rilling 2006) and writing (Thiel et al., 2015). Speech and language therapy for aphasia has been argued to be particularly effective when administered at high intensity, high dose, and potentially for a relatively long duration (Brady et al., 2016). As these goals can be difficult to achieve through regular speech and language therapy sessions only, there is a long-standing research tradition investigating the use of digital aphasia therapy in addition to regular therapy.

Interest in the use of computer technology as a potential addition to regular speech and language therapy first emerged in the 1980s and 1990s. In this period, a number of digital aphasia therapy programmes were described in the literature. Katz and Nagy (1983), for example, described FLASH, a reading treatment programme in which people with aphasia...
were asked to identify (through typing or multiple-choice options) a written word that was briefly flashed on the screen. While Katz and Nagy concluded there was little treatment effect after testing their software with five people with aphasia, this is a clear example of early adoption of computer technology in the field of aphasiology. Similarly, Van Mourik and Van de Sandt-Koenderman (1992) introduced Multicue, a computer programme that taught people with aphasia which cues to use when faced with word-finding difficulties. Their preliminary results from four people with aphasia showed that all of them benefited from the treatment, albeit to varying degrees. To the best of our knowledge, however, neither programme (nor many others from this era, as described in for example Bruce & Howard (1987), Burton et al. (1988), and Rubin & Bollinger (1983)) was subsequently made clinically available on a larger scale.

In the early 2000s, more sophisticated digital aphasia technology started to appear, with some software becoming commercially successful. A notable example is StepByStep, which was first described by Mortley et al. (2003). StepByStep offers a range of therapy exercises (e.g. word naming, repetition, spelling, word-picture matching, semantic association) and has been reported on extensively in the literature (e.g. Harrison et al., 2020; Latimer et al., 2021; Mortley et al., 2004; Palmer et al., 2012). Its clinical efficacy has been well-established through studies such as Palmer et al. (2019). After conducting a large randomised control trial involving 219 people with chronic aphasia, Palmer et al. (2019) concluded that retrieval of personally relevant words improved significantly more when usual aphasia care was combined with StepByStep computer therapy compared to usual care alone. This result was maintained at six-months follow up. The StepByStep software is still currently commercially available for people with aphasia. Another example of software that appeared in this period is MossTalk Words, which is also well represented in the literature, with several studies showing its effectiveness for improving word retrieval, both in stroke-related aphasia, as well as in primary progressive aphasia (see e.g. Fink et al., 2002; Jokel et al., 2006; Ramsberger & Marie, 2007). MossTalk Words is also still commercially available. Both StepByStep and MossTalk Words, however, are currently only computer-based. This comes with some disadvantages (e.g. reduced portability and relatively high price points) compared to more recent technology such as tablets.

With computers and tablets becoming more widespread and accessible since the 2010s, there has been a surge in research articles in this field. The introduction of the iPad tablet in 2010 and subsequent popularisation of tablets contributed to this trend (as is evident from the large volume of available studies involving tablets, such as De Cock et al., 2021; Kearns et al., 2012; Kiran et al., 2014; Nef et al., 2018; Stark & Warburton, 2018). Software overviews maintained by aphasia organisations (e.g. Aphasia Software Finder, n.d.; Apps & Hulpmiddelen, n.d.) provide a clinically relevant overview of the available resources for those interested. With many aphasia therapy apps available in the Google Play Store and Apple Store, and more research on its way (see for example the study protocols by Kim et
al., 2021; Uslu et al., 2020), digital aphasia therapy has shown itself to be a well-established and clinically relevant research field in its own right.

It is noteworthy, however, that not all aspects of language are equally researched within this field. More specifically, it seems that there is a relative lack of aphasia treatment software that focuses on the use of verbs in sentences. It appears that other aspects of language (such as word retrieval at the single-word level (e.g., Kim et al., 2021; Laures-Gore et al., 2021; Lavoie et al., 2019; Weill-Chounlamountry et al., 2013) and reading (e.g. Cherney et al., 2021; Woodhead et al., 2018) have received more attention. This is a problem, as verb and sentence processing is frequently impaired in people with aphasia (see e.g. Bastiaanse & Jonkers, 1998). Verb and sentence processing is complex and assumed to consist of several levels that are necessary in order to go from a mental concept to a spoken message. Levelt (1989), for example, describes how this process first requires lemma retrieval, in which the appropriate lemma (a lexical representation of a word, as well as its grammatical information) is retrieved from the mental lexicon. This in turn activates the lexeme (the phonological form of the word that is required for pronunciation). The grammatical information attached to the lemma is used to create a grammatically correct sentence, in a process that is known as grammatical encoding (Levelt, 1989). Subsequent phonological encoding results in a phonetic plan, which can be verbally produced by the speaker, leading to a spoken message (Levelt, 1989).

The little research that does describe software that focuses on verbs and/or sentences has shown some promising results. Furnas and Edmonds (2014), for example, introduce a digital version of Verb Network Strengthening Treatment (VNeST; Furnas & Edmonds, 2014), an aphasia therapy programme that focuses on verbs and their corresponding thematic roles in sentences. Two people with chronic aphasia were found to improve lexical retrieval at the word, sentence, and discourse level after eight weeks of computerised VNeST therapy. Similarly, Thompson et al (2010) concluded that a computerised version of Treatment of Underlying Forms (TUF; which focuses on sentences with complex, non-canonical word order; Thompson & Shapiro, 2005) was as effective as clinician-led therapy for six people with chronic aphasia (Thompson et al., 2010). Despite Furnas and Edmonds’ (2014) and Thompson et al.’s (2010) promising results, with these treatment options targeting only limited elements of verb/sentence processing (rather than all of the steps described in, for example, the Levelt (1989) model), combined with the generally limited clinical availability of verb/sentence-focused software, it seems that there is a gap for evidence-based digital aphasia therapy that targets the use of verbs and sentences at varying levels of difficulty.

Despite the decades-long research tradition relating to aphasia therapy software that we described above, questions about such software and its development remain. For example, we know little about the clinical availability of software that is introduced in the literature and about researchers’ and developers’ experiences while developing aphasia therapy
software. This information would be helpful for researchers who are planning to develop aphasia therapy software and could make clinical implementation easier. Improving the translation of aphasia therapy software from research to clinical practice would lead to more therapy software being clinically available. This would mean that the aphasia community could benefit more directly from research funds and efforts, as the software resulting from research could be used in a wider clinical context, as well as independently by people with aphasia. Similarly, not much is currently known about speech and language therapists’ experiences and preferences regarding aphasia software. This is problematic, as knowing users’ preferences is essential for designing and developing software that meets their needs (see e.g. Bannon, 1986). User-centred design is particularly relevant in the case of aphasia therapy software considering that clinician acceptance has been found to play a major role for software reaching people with aphasia (Wade et al., 2014). We therefore argue that further research into these topics is essential in order to maximise the benefit of aphasia therapy software research for people with aphasia. In this dissertation, we aim to address these specific gaps while also reporting on a newly developed therapy app (focusing on verbs and sentences) and a subsequent pilot study involving two people with aphasia.

1.2 GOALS OF THIS DISSERTATION

The aims of the research presented in this dissertation were to:
1. Create an overview of aphasia therapy software described in the research literature and determine their current clinical availability.
2. Investigate the experiences of researchers and developers with regards to the development of aphasia therapy software, and gather advice from researchers/developers for those who are looking to develop such software.
3. Investigate the experiences and preferences of speech and language therapists with regards to using aphasia therapy apps.
4. Create a new aphasia therapy app that focuses on treating verb and sentence processing, following experiences and preferences of stakeholders.
5. Conduct a pilot treatment study to test the efficacy and usability of the newly developed therapy app.

1.3 OUTLINE OF THIS DISSERTATION

Chapter 2 – Aphasia therapy software: An investigation of the research literature and the challenges of software development

This chapter relates to Aims 1 and 2. It firstly describes a systematic search of literature related to aphasia therapy software and then presents the resulting overview of digital aphasia
therapy software as described in the literature. It also reports on the clinical availability of these pieces of software, which was determined through reading literature, conducting internet searches, and by contacting the researchers/developers who were associated with the software. As part of this chapter, we reached out to the authors/developers of the pieces of software to ask about their experiences with software development. This chapter describes responses from the 35 participants who responded to our request, which were thematically analysed into recurring themes and subthemes (Braun & Clarke, 2006; Clarke & Braun, 2017). These responses provide insight regarding participants’ experiences with software development, as well as advice that they have for people that are looking to develop aphasia therapy software.

Chapter 3 – Understanding user needs for aphasia therapy software: Experiences and preferences of speech and language therapists

Chapter 3 addresses the third aim of this dissertation. After providing background information regarding the importance of user research and describing previous research into therapist feedback related to aphasia therapy software, the results of a survey are presented. This survey asked questions related to the experiences and preferences of speech and language therapists (SLTs) with regards to aphasia therapy apps. The survey was conducted online and consisted of 9 closed-ended and 3 open-ended questions. We collected a total of 64 responses from Australia (n = 29) and The Netherlands (n = 35). The results are reported using descriptive statistics for closed-ended questions and thematic analysis (Braun & Clarke, 2006; Clarke & Braun, 2017) for open questions. Additionally, the influence of demographic factors (age, country, SLT availability in client’s hometown) on participants’ attitudes towards aphasia therapy apps were investigated. This chapter thus describes clinician user experience, which is essential for translating research on digital aphasia therapy software to practice.

Chapter 4 – Description of the Action! App

In this chapter, the Action! app (Aim 4) is described. Action! was developed specifically for this dissertation and is an iPad-based mobile application that is intended for independent use by people with aphasia. Using as a starting point four existing therapy programmes (Werkwoordsproductie op Woord en Zinsniveau/ACTIE! (see e.g. Bastiaanse et al., 1997, 2016; de Aguiar et al., 2015), Mapping Therapy (see e.g. Byng, 1988; Mitchum et al., 2000; Schwartz et al., 1994), Verb Network and Strengthening Treatment (Edmonds, 2016), and Treatment of Underlying Forms (Thompson & Shapiro, 2005)), Action! focuses on treatment of verb and sentence processing. With Action!, we aimed to create an evidence-based aphasia therapy app that incorporates tasks to practice each of the levels of sentence processing described by Levelt (1989), while meeting users’ needs and being customisable and therefore maximally relevant for users. Chapter 4 further outlines the theoretical background that Action! was based on, elaborates on the objectives for Action!, the
software development process, the app’s user interface, the development and evaluation of the treatment items, and the nine treatment steps that Action! comprises.

**Chapter 5 – The efficacy and usability of Action!: A pilot study of an aphasia therapy app focusing on verbs and sentences**

Focusing on Research Aim 5, this chapter describes a pilot treatment study that aimed to determine the efficacy and usability of the Action! app. Two people with chronic aphasia and varying extents of impairment to verb and sentence processing used the app at home for a two-week period, with treatment content customised to their specific therapy needs as determined by a range of pre-therapy assessments. Through comprehensive pre- and post-treatment testing, we measured and subsequently analysed treatment effects for our participants. This chapter describes and comments on participants’ treatment fidelity, their usability ratings for Action!, and any improvements in verb and sentence processing that occurred as a result of the treatment. It also elaborates on the implications of these results for the future development of Action!, and provides suggestions for future research that would be necessary in order to eventually release the app to a wider clinical audience.

**Chapter 6 – General discussion**

This chapter collates the findings from Chapters 2-5 and reflects on how these findings relate to the aims of this dissertation. The results from Chapters 2-5 and their implications for research in this field are discussed in relation to the wider research literature. I also describe the practical and clinical implications of the results. The potential limitations of the current research are outlined and future research to overcome these limitations described.