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CHAPTER 1

Introduction

The limits of my language are the limits of my world.

Ludwig Wittgenstein
1.1 Communication and its disorders

Communication is the dynamic foundation of human interaction, and the drive behind our development as a social species. We exclaim, describe, argue, joke, tease, explain, protest, question, laugh, and express all other urges of our inner world through communication. It is a deep need of a human being to communicate, as well as a basic human right. For communication to be successful, people must be able to generate, exchange, and understand messages of one another. Although we all use many different forms of communication, natural language and speech are the predominant channels of interacting with our environment.

For those people who have difficulties with processing language, or with producing and comprehending speech, communication can be a significant challenge. Speech and language difficulties may be temporal or permanent; they may be due to congenital impairments, or result from brain injury or illness. The general term referring to these conditions is communication disorders. Individuals with communication disorders may face difficulties with social inclusion, with access to services and information, resulting in an overall decreased quality of life. Particularly, children who have difficulties speaking may need a great deal of support to overcome the challenges on their way towards learning to communicate. In order to provide this kind of support and, more generally, improve the quality of life of people with communication disorders, clinical professionals are trained in the area of speech-language therapy.

The scope of communication disorders which speech therapists treat may differ between countries and health insurance systems. Disorders in which speech and language functions are affected directly may include: hearing impairment; voice and resonance disorders; articulation disorders; fluency disorders; aphasia; Motor Speech Disorders; specific language impairment (SLI) and language delay. In certain cases, speech and language functions may become affected as a consequence of the following conditions: cognitive impairment and disability; behavioral and emotional disabilities (e.g., autism, attention deficit); psychiatric disabilities (e.g., schizophrenia, the dementias); structural abnormalities, including congenital (e.g., cleft palate) and acquired abnormalities (e.g., laryngectomy); cerebral palsy and other neuro-motor impairment; swallowing disabilities.

Clinicians make use of a large variety of methods, techniques and tools for treating patients with communication disorders, among them technology-based methods. This thesis explores a number of ways in which technology can support the work of speech-language therapists in dealing with one type of communication disorders, namely Motor Speech Disorders (MSD) (dysarthria, apraxia, and stuttering). In this chapter, we shortly introduce the field of speech-language therapy, the role of technological innovation in that field, and outline the research and development activities described in this thesis.
Speech and Language Therapy

Originally, the term Logopedics was used to identify the professional area of treating communication disorders. Currently, the term most commonly used in Europe is Speech Language Therapy (SLT), and in the United States, Australia and Canada - Speech Language Pathology (SLP). Throughout this thesis, when referring to professionals in the field of communication disorders, the terms 'speech clinician' and 'speech therapist' will be used interchangeably.

In the process of treating patients with Motor Speech Disorders, a significant aspect of the work of speech therapists consists of teaching, training, rehearsing and sustaining new speech and language skills with their patients. In order to perform these tasks, clinicians (and respectively, their patients) may have the following needs:

» Have the means to demonstrate the desired speech targets to their patients, in a consistent and systematic way.

» Have access to detailed and objective information about the speech productions of their patients.

» Have access to standardized diagnostic and treatment methodologies.

» Have the means to engage patients in repeated drill exercises, especially with young children.

» Have the means to effectively measure treatment results, and follow treatment progress in the course of time.

» Have methods to enable autonomous training, and management of communication outside the clinic.

» Have possibilities to effectively exchange clinical experience with other specialists, and share best-practice information.

The need for systematic, effective, objective, engaging and autonomous features of treatment delivery have led researchers to consider the ways in which technological tools can support the process of providing speech language therapy. The inertia of technological innovation in the field has been driven by a number of considerations. First, the large amount of time spent on mass-practice drills with patients may not be an efficient use of clinician’s time, which is, by default, in shortage. Clinical time could be better spent if patients could perform the routine drill elements of their treatment semi independently, under the guidance and supervision of the clinician. Second, computer-based methods allow the creation of conceptually novel tasks, which may go beyond the paper-based training methods (Hubbard, 2006).
1.2 Technological innovation in SLT

Technological developments have had a considerable impact on the area of health care. Speech-language therapy practice is relatively not heavily based on technology, although increasingly more technological developments have been introduced into the field over the last decade. Broadly speaking, technological innovation in the area of communication disorders can be associated both with the field of assistive technology (AT), as well as with Computer-Aided Language Learning (CALL).¹ AT devices are tools for enhancing the independent functioning of people who have physical limitations or cognitive impairments. CALL includes a wide range of applications and tools for learning languages. Technology in the field of SLT can be roughly categorized into several types:

Prosthetic devices aim at the rehabilitation of hearing functions, include hearing aids and cochlear implants.

Altered Auditory Feedback devices manipulate the user’s speech signal, so that the altered signal is fed back to the person throughout the act of speech. AAF devices are mostly used by individuals who stutter for the enhancement of speech fluency.

Augmented Alternative Communication (AAC) devices are used to supplement or replace speech for individuals with impairments in the production of spoken language. AAC is used by people with a wide range of speech and language impairments, such as cerebral palsy, autism, amyotrophic lateral sclerosis and Parkinson’s disease.

Computer Aided Speech Language Therapy (CASLT) tools provide speech clinicians with a platform for teaching and training speech and language skills of individuals with speech impairments, which is the most common form of technological support in the treatment of MSD.

Sign language learning systems provide support for the education of sign languages, as well as automatic sign language recognition and translation.

Communication stimulating systems are designed to assist individuals with intellectual impairment and autism to explore communicative interactions in a safe and controlled environment, as well as to promote collaborative and social skills.

Tele-health systems utilize advanced telecommunications technologies for providing remote speech-language therapy services in the treatment of fluency, voice, swallowing and childhood speech and language disorders.

¹In this context we do not include technologies underlying various research instruments in the study of communication disorders (such as Electromagnetic Articulography (EMA), Ultrasound Tongue Imaging (UTI) or brain imaging techniques), but rather refer to technologies employed in the work of speech therapists.
New approaches to innovation in SLT

While some scientific fields have been traditionally involved in the support of communication disorders (such as language technologies, phonetics and clinical linguistics), new approaches and combinations are steadily taking form. In recent years, there has been an increasing interest in applying methods from the field of computational linguistics (CL) to the management of communication disorders. For example, advanced language models have been utilized for improving automatic speech recognition of speakers with dysarthria (Sharma and Hasegawa-Johnson, 2010), Natural Language Generation techniques have been applied to support narrative capabilities of children with complex communication needs (Black et al., 2010), and n-gram language prediction models were shown to improve the rate of binary switch typing on Augmentative and Alternative Communication (AAC) devices (Roark et al., 2010).

Original applications may not be limited to the linguistic domain. For example, Brundage (2007) examined the potential of using the cognitive aspects of interactions in virtual reality environments for the assessment and treatment of stuttering. Light and Lindsay (1991) have applied insights from cognitive science (the limitations of working memory, the knowledge structures of long-term memory) for improving the design of AAC systems. Developments of this kind point out the advantage of a wide-angle view on the process of innovation in SLT, which concurrently considers the abilities of several expertise areas in advancing development, as well as the prospect of integrating different solutions into broader, more systematic treatment platforms.

Challenges for technological innovation in the field

A number of challenges are encountered in the process of developing technological innovation in the field of communication disorders. First, the inherent diversity among disorder manifestations and individual patients makes it difficult to develop generic tools and products. Since innovative tools in this field often rely on speech and language technologies, their development involves a considerable investment of resources, which becomes harder to justify if eventually products can not be generalized and widely used (Ruiter et al., 2010).

Second, innovation efforts in the field of communication disorders occur rather sporadically, as there are only few dedicated research and development structures to advance these efforts. This stands in stark contrast to other fields of assistive technology (e.g., physical rehabilitation) for which ongoing research activities are organized within special interest groups, research consortia, specialized centers and laboratories. This situation is, perhaps, the main obstruction in propelling innovation in the field. Therefore, this thesis strives to complement efforts towards establishing an ongoing scheme of innovative development for supporting the management of communication disorders.
1.3 Project overview

The aim of this thesis is to apply and examine technological innovation in the delivery of treatment for patients with Motor Speech Disorders (MSD). This aim is pursued from two complementary perspectives. Firstly, this thesis explores the question of how new computer-based tools can refine current methodologies in the treatment of MSD. On a second, and broader level, this thesis aims at examining the necessary ingredients for a durable process of innovation in the field, in terms of an interdisciplinary research and development framework.

The purpose of activities on the first level is to investigate the challenges and opportunities of technology-based innovation, when considering a range of steps in the delivery of treatment procedures. Specifically, the work in this thesis addresses the following three main phases in the treatment delivery of MSD:

The preparation of treatment programs. In the first stages of MSD treatment delivery, speech clinicians need to plan and design the treatment program according to the needs of individual patients. Within a treatment program, linguistic items must be selected which best target the relevant aspects of the speech disorder (background information on this topic is provided in Chapter 2.2). Assisting clinicians with the selection of speech treatment targets involves two steps - obtaining relevant linguistic materials, and providing the means for an effective generation of targets.

In Chapter 3 we address the first step, and demonstrate how techniques of computational linguistics can be brought into service for obtaining valuable linguistic materials. We obtain the syllabic inventory of Dutch by means of automatic syllabification of the spoken language data. Consequently, we analyze the suspected discrepancy between the spoken and canonical syllabic inventories, and prove insights on the applicability of the two data sets as speech training materials. The content of this chapter is partially extracted from the following publication:


The work described in Chapter 4 demonstrates how theoretical advancements in the field of Apraxia of Speech (AOS) can be applied to the development of a new computer application for allowing clinicians to generate customized treatment materials for their patients. We outline research evidence for the benefits of a systematic manipulation of speech targets based on syllabic parameters for the treatment of AOS. Based on these insights, an application for generating word-lists according to clinically relevant parameters is developed and evaluated.
Learning and practicing speech motor skills. Throughout the treatment process, much time is spent on practicing speech motor skills. The challenge of clinicians in engaging patients in training consists of a systematic demonstration of the desired speech targets, providing adequate feedback on the quality of speech productions, and stimulating patients to perform a large amount of exercises (background information on this topic is provided in Chapter 2.3).

In addressing these challenges, in Chapter 5 we examine the possibilities of using a computer game to support the training of timing skills in speech of children with MSD. To this end, we investigate what are the elements necessary for constructing a training system, in terms of exercise methodology, the required technology, and usability factors. We implement timing accuracy exercises within a computer game, and evaluate the feasibility of the game as a supplementary therapeutic tool. The content of this chapter is partially extracted from the following publication:


The autonomous management of communication. After a treatment period, individuals may need to maintain the acquired skills, and manage their communication independently. One example of technology supporting this process is the utilization of Altered Auditory Feedback (AAF) devices by some adults who stutter, in order to retain improved fluency in everyday speech. The limitations and challenges associated with current AAF procedures are described in Chapter 2.4.

In Chapter 6, we address these limitations, and propose a refinement to the current AAF procedures for the enhancement of speech fluency. For this purpose, an adaptive feedback procedure is proposed, which utilizes digital signal processing techniques for real-time analysis of the speech signal, and the dynamic activation of auditory feedback. The proposed AAF procedure is evaluated with adults who stutter, in terms of fluency enhancement, as well as comfortability with the auditory cues. The content of this chapter is partially extracted from the following publication:

Umanski, D. and Schiller, N. O. How do adaptive auditory feedback procedures affect the speech of adults who stutter. Stem-, Spraak- en Taalpathologie 17 (supplement), p.82
Methods and approach

In addressing each of these steps, the process of development is grounded on the frameworks of Instructional Systems Design (ISD) (Peterson, 2003), and User-Centred Design (Gould and Lewis, 1985; Hersh, 2010). According to the principles of these models, the following basic steps are involved in the process:

Analysis Phase involves the identification of a problem, a need, or an improvement opportunity, in regard to a specific methodology or procedure in the treatment of MSD. This phase may include observations of clinical practice, interviews with clinicians and patients, and literature research.

Design Phase involves the consideration of alternative strategies for solving the identified problem, while considering the areas of expertise, whose methods can contribute to attain the solution. This phase may include the specification of requirements, preparation of user scenarios, use cases, task flows and navigation structure.

Development Phase involves the implementation of the proposed solution strategy, usually on a level of a prototype, where the core functionality can be tested. It is considered a good practice to present users with early prototypes for evaluation, and iterate by re-designing in order to account for problems identified in user testing.

Evaluation Phase involves the testing of the developed solution, either by evaluating the performance of the developed techniques directly, or by means of a study with the user group. This step proceeds with the analysis of quantitative and qualitative results, in order to generate insights about the feasibility of the proposed solution, and provide recommendations for further research and development.

Quite naturally, upon reading about ‘new methods for speech therapy’, some readers might expect to find reports about the e fects of these methods on the speech impairment of patients. However, the methods proposed in this thesis are not comprehensive clinical interventions, but rather experimental and complementary solutions. Therefore, before these methods can be fully developed and undergo ef icacy testing, preliminary studies are necessary to evaluate the feasibility of the developed methods as valuable therapeutic tools.
By definition, the purpose of a feasibility study is to evaluate and analyze the potential value of a proposed new method, in order to determine if the investment of resources in this method is likely to generate a desirable result. This is important to keep in mind when interpreting the reported results. The objective of this thesis is not to provide conclusive evidence for specific e fects of the proposed methods, but rather to delineate the limitations and potentials of these methods.
**Introduction**

Finally, this thesis is concerned with the ways in which future efforts of innovation in the field may become more productive, efficient and sustainable, by examining the ingredients necessary for an effective process of development. Through the studies described in this thesis, we hope to provide evidence for the benefits of a collaborative approach to providing support for the field. Furthermore, in order to contribute to the ongoing efforts of creating structured frameworks for technological innovation in the field of SLT (Cucchiariini et al., 2008), we will propose a model of interdisciplinary collaboration, and outline a possible workflow for such a framework.

**Personal motivation**

The urge for dealing with technological innovation for the support of speech and language therapy arises from my personal experience with both domains. Being a person who stutters, I am aware of the importance of advancing speech therapy methodologies. Coming from a background of computer science and interaction design, I am aware of the many opportunities of applying technology for enhancing the ability of people to communicate. The intersection of these experiences has driven me to identify innovation potentials in various methods of treatment delivery, and work on new solutions to problems in the field.