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REPORT

Human language technology and communicative disabilities: requirements and possibilities for the future

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Abstract For some years now, the Nederlandse Taalunie (Dutch Language Union) has been active in promoting the development of human language technology (HLT) applications for speakers of Dutch with communicative disabilities. The reason is that HLT products and services may enable them to improve their communication skills and verbal autonomy. We sought to identify a minimum common set of HLT resources that is required to develop tools for a wide range of communication disabilities. In order to reach this goal, we investigated the specific needs of communicatively disabled people and related these needs to the underlying HLT software components. By analysing the availability and quality of these essential HLT resources, we were able to identify which of the crucial elements need further research and development to become usable for developing applications for communicatively disabled speakers of Dutch. The results obtained in the current survey can be used to inform policy institutions on how they can stimulate

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the development of HLT resources for this target group. In the current survey results were obtained for Dutch, but a similar approach can also be applied to other languages.

Keywords Human language technology (HLT) · Communicative disabilities · Requirements · Future development

1 Introduction

People with communicative disabilities are typically hampered in their ability to express their communicative intention adequately and fluently in their mother tongue. Similarly, it may be difficult for them to understand spoken or written language. For some years now, the Dutch Language Union has been active in promoting the development of Human Language Technology (HLT) applications for speakers of Dutch with communicative disabilities. The reason is that HLT products and services may improve their verbal autonomy and communication skills; however, developing HLT-based tools for these users is challenging.

Whereas verbally autonomous users may benefit from HLT-based tools that take speech or writing as in- or output, language and speech disorders may hinder persons with a communicative disability in using HLT tools with verbal modalities effectively. Verbal communication disorders may have to be contended with, for example by using simplified language or non-verbal modalities (e.g., pictures and gestures). What is more, communicatively disabled persons typically show considerable inter- and intra-subject variability in language production and speech characteristics (e.g., Kolk 2007). As a result, extensive amounts of data are necessary in order to adapt HLT-based applications to pathological speech and language production.

Despite the technical challenges, Rietveld and Stolte concluded in 2005 that the needs of people with communication disorders in The Netherlands and Flanders could be fulfilled by HLT applications. Although several HLT applications have been developed over the last 6 years, anno 2011, their HLT needs are not yet completely satisfied. At least in part, this seems to be due to the diversity of the

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disorders underlying the communication disabilities, which makes it difficult to develop products that can be used by relatively large numbers of users. This is especially true for communicatively disabled speakers of a so-called medium-sized language like Dutch (Pogson 2005a, b), because language companies are not always eager to invest in developing HLT applications for a language with a relatively small market (Rietveld and Stolte 2005).

The current study investigated whether the diversity issue can be overcome—at least for the greater part—by identifying a set of HLT resources that can be used to develop HLT tools for a wide range of communication disabilities. This research aim can be subdivided into several sub-questions:

(a) Which HLT applications should be developed for speakers of Dutch with communicative disabilities in order to meet their communication needs?
(b) Which HLT software components underlie the applications that are most needed by speakers of Dutch with communicative disabilities?
(c) Are the essential HLT resources available, and—if so—does the quality suffice?
(d) If the HLT resource is not available yet or if the quality of an essential HLT resource does not suffice, what is the research effort necessary to improve its quality (or to develop the resource)?

In this article, we discuss both the method and procedures used and the results obtained across the various subgroups of persons with a communication disorder.

2 Method and procedures

The present study followed an approach that was similar to the one adopted in preparation of the Dutch-Flemish HLT programme STEVIN (a Dutch acronym for Essential Speech and Language Technology Resources) (Cucchiarini et al. 2008). An important element of the STEVIN programme was the definition of the Basic Language Resources Kit for Dutch (BLARK; Daelemans and Strik 2002). The BLARK concept (Krauwer 1998) has also been used to specify a basic language resources kit for other languages, such as Arabic (e.g., Maegaard et al. 2009) and Swedish (Elenius et al. 2006).

In the Dutch BLARK, the basic software components that are essential for developing HLT applications were specified. By analysing the availability and quality of the various components, it could be determined which essential elements were missing or did not meet the requirements. As a consequence, it was possible to establish which software components have to be developed with priority (Binnenpoorte et al. 2002).

Since the BLARK concept can be used to identify the software components underlying different applications, it was used in the present survey. Put differently, it fitted our *multiple-usability* criterion best. The following paragraphs will discuss how this approach was applied in the current study.

2.1 Inventorying and describing HLT-based communication needs

A dual-route approach was followed to investigate how HLT can support communicatively disabled speakers of Dutch. Firstly, experts from the HLT as well as the clinical sector were asked to formulate an answer to this question during the round table conference that was organised by the Dutch Language Union on September 28, 2007. Secondly, telephone interviews were held with another group of 20 experts, among which were speech-language therapists, researchers, as well as representatives of business organisations involved in the development, production, or sale of HLT devices for the target group.

In describing the HLT applications that appear to be needed by speakers of Dutch with communicative disabilities, we distinguished the following four aspects: the purpose of the application (e.g., augmentative and alternative communication, AAC); the communication function which has to be fulfilled (e.g., reading); the target group as defined by the underlying impairment (e.g., aphasia); age of the target group (e.g., children and youngsters).

Table 1 presents the (sub)groups of people with communication disorders that were included in the present study and the verbal modalities these people typically experience difficulty in. It is important to note that although different subgroups may

Table 1 Subgroups of persons with communication disorders (and their verbal difficulties) subcategorised according to the underlying functional impairment

Communication disorder in	Hampered to a greater or lesser extent in (a combination of) the following verbal communication modalities			
	Understanding spoken language	Understanding written language	Speaking	Writing
Mental/cognitive functions				
Aphasia	X	X	X	X
Dyslexia/dysorthographia		X		X
Mental retardation	X	X	X	X
Sensory functions				
Blindness/impaired vision		X		X
Deafness/hearing impairment[a]	X	(X)	X	(X)
Deafblindness	X	X	X	X
Voice and speech functions				
Dysarthria/anarthria			X	
Stuttering			X	
Voice disorder			X	
Movement related functions				
Repetitive strain injury				X
Dyspraxia/apraxia			X	X
Physical impairment			X	X

[a] Difficulties understanding spoken language can lead to delayed and/or deviant language development, which may cause additional problems with reading, speaking, and writing

be hampered in the same verbal modality, their HLT-needs typically differ due to differences in underlying impairment. For example, both aphasic and dysarthric speakers have trouble speaking and indicated to be in need of a HLT-based application to practice speaking (i.e., a therapy programme). Whereas the latter may benefit from repetitive auditory feedback in order to improve their speech, the former typically need to be facilitated in word retrieval and sentence production in order to improve spoken language.

2.2 Spelling out the essential HLT software modules

In order to be able to spell out the essential HLT software components, we specified for each application the modality of input as well as the modality of output, using the following communication modalities: (1) spoken language, (2) written language, (3) non-verbal: images, animations, symbols, gestures, or agents, (4) tactile: Braille or 3D-images (with relief), (5) concepts: data, pictures, or key words, such as stock market reports printed in newspapers. The following example may clarify the relation between conversions of modalities and (classes of) technologies: Conversion 2 → 1: speech synthesis, which produces speech (an acoustic signal) from text.

During the round table conference and in the interviews, 65 different HLT-based products and services were put forward that either did not meet the target group's requirements or were not yet commercially available. For each of these products, the underlying conversions were established. As some HLT applications will require more than one conversion in order to be beneficial to the target groups, in total, 97 conversions were derived. Quantitative analysis of these 97 conversions yielded a hierarchy of conversions. As the aim of the current survey is to define a set of resources that is required to develop as many different tools as possible, only the HLT resources underlying the five most frequently occurring conversions were used for further analysis: *speech synthesis* (32%), *speech recognition* (26%), *text modification* (12%), *non-verbal to speech* (8%), and *text to non-verbal* (7%) (cf. Table 2).

Subsequently, we specified the HLT software modules that are needed to execute each of the five most frequently occurring conversions (cf. the first column of Table 2). A module either addresses a conversion of modality in a particular case (e.g., speech-to-text for dysarthric speech) or it is a software component that is required for such a conversion (e.g., grapheme-to-phoneme conversion). Most of the software modules were derived from the BLARK (Daelemans and Strik 2002); however, since not all conversions could be realised with the BLARK modules, we defined the following additional modules: *text-to-gestures*, *recognition of gestures* (i.e., gestures-to-text), *text-to-symbols*, *recognition of symbols* (i.e., symbols-to-text), *generation of facial expression and articulation on talking heads* (i.e., text-to-facial expression and articulation), as well as *recognition of pathological speech* (i.e., pathological speech-to-text).

2.3 Achieving consensus

A working group of experts achieved consensus on the software modules needed to realise the top 5 conversions and also agreed on the availability and quality of these

Table 2 HLT resources underlying the conversions

HLT software modules	Hierarchy 5 most frequently occurring conversions					Availability		Quality	Complexity
	1 (32%) Speech synthesis 2 → 1	2 (26%) Speech recognition 1 → 2	3 (12%) Text modification 2 → 2	4 (8%) Non-verbal to speech 3 → 1	5 (7%) Text to non-verbal 2 → 3	C	E		
BLARK for language technology									
Grapheme-to-phoneme conversion	X			X	X	y	y	G	n/a
Text pre-processing	X		X		X	y	y	I	L
Lemmatising and morphological analysis	X		X		X	y	y	G	n/a
Morphosyntactic disambiguation	X		X		X	y	y	G	n/a
Syntactic analysis	X		X	X	X	y	y	S	n/a
Semantic and pragmatic analysis	()		X	X	X	n	n	P	H
Text generation			X	X		n	n	P	A
Language-pair dependent translation modules			()			y	y	I	H
BLARK for Speech technology									
Prosody recognition		()				n	n	P	A
Prosody generation	X			X	X[a]	y	y	S	n/a
Complete speech synthesis	X			X	X[b]	y	y	G	n/a
Complete speech recognition		X				y	y	I	A
Phone string edit distance		()				y	y	G	n/a
Robust speech recognition		X				y	y	P	H
Speaker identification		()				y	y	S	n/a
Language and dialect identification		()				n	n	S	n/a
Adaptation		X				y	y	S	n/a

Table 2 continued

HLT software modules	Hierarchy 5 most frequently occurring conversions					Availability		Quality	Complexity
	1 (32%) Speech synthesis 2 → 1	2 (26%) Speech recognition 1 → 2	3 (12%) Text modification 2 → 2	4 (8%) Non-verbal to speech 3 → 1	5 (7%) Text to non-verbal 2 → 3	C	E		
Confidence measures and utterance verification		X				y	y	I	A
Additional modules									
Text-to-gestures					X	n	y	I	A
Recognition of gestures				X		n	y	I	H
Text-to-symbols					X	y	n	I	A
Recognition of symbols				X		n	n	P	L
Generation of facial expression and articulation on talking heads					X	n	y	I	L
Recognition pathological speech		X				n	n	P	H

Essential (X) and optional () HLT resources underlying the five most frequently occurring conversions, including availability of each software module (*C* commercially, *E* experimentally accessible), its quality (*G* good, *S* sufficient, *I* insufficient, or *P* poor), as well as its complexity (i.e., the research effort anticipated to develop or improve the HLT software module: *L* low, *A* average, or *H* high). [a,b] Prosody generation and complete speech synthesis are necessary for converting text to spoken language supported by gestures

software modules. An HLT resource was considered available if it was either commercially or experimentally accessible. Quality was rated at a 4-point rating scale: *good* (G), *sufficient* (S), *insufficient* (I), or *poor* (P). Only the HLT software resources rated as *sufficient* or *good* qualified to be considered beneficial to communicatively disabled speakers of Dutch. Lastly, the working group made an estimation of the research effort needed to develop or improve the HLT software modules whose quality appeared not to be up to the standards required. The complexity of a specific module was rated as *low* (L) if a relatively small research effort was expected to be needed in order to improve quality, to make it more suitable for a specific application, or to develop the application. Conversely, whenever substantial research effort was anticipated to improve quality, the complexity was rated as *high* (H). The label *average* (A) was given if an average research effort was anticipated (cf. Table 2).

3 Results

Since the subgroups of persons with communication disabilities, as given in Table 1, were evenly represented in the survey, the immediate goal of the present survey was met: inventorying the HLT-based communication needs of people with communicative disabilities in The Netherlands and Flanders. However, the ultimate goal was to define the availability and quality of a set of HLT resources that is required to develop as many different tools as possible for the wide range of communication disabilities. The main results relating to this research questions are summarised in Table 2. This table for example shows that *speech synthesis* is the most frequently occurring conversion underlying the tools needed by communicatively disabled speakers of Dutch. All seven essential modules are available and—except for *text pre-processing*—have sufficient or good quality. A relatively small research effort is anticipated to improve the quality of the latter module. Thus, by improving the quality of only one module, applications based on speech synthesis can be developed.

4 Conclusions

The question which HLT resources need to be developed or improved first to optimally fulfil the needs of communicatively disabled speakers of Dutch is an important one. However, we are well aware that the answer is more difficult than the question itself. In part this is due to the fact that several criteria can be used in providing an answer. By spelling out (and specifying the availability and quality of) the software modules that are essential in the HLT tools that are most needed by speakers of Dutch with communicative disabilities, we identified priorities for technology development. Although *multiple-usability* was used as a criterion in this survey, we sought to present the results in such a way that other criteria could also be applied in analysing the results obtained. Accordingly, these results can be used

to inform policy institutions on how they can stimulate the development of HLT resources for this target group.

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