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Objective measurement of listening effort while using first and second language in simulated cochlear implants

GANESH A C, VIJITHA SUNNY AND SUBBA RAO T A

Dr M V Shetty College of Speech and Hearing, Mangalore, India

It is generally believed that the cognitive effort to understand speech under adverse listening conditions differs between first and second languages. The present study examined this issue with 10 native Kannada speakers who use English as a second language. Subjects listened to noise band vocoder (simulated Cochlear Implant in normal's) processed sentences in quiet, noise (-6 dB SNR) and visual reaction time conditions. The listening effort was measured using a dual task paradigm. The mean scores obtained were better for Kannada than English. Repeated ANOVA measures indicated a significant main effect of listening conditions in both languages. The listening effort was larger while using English (second language). The visual reaction time data indicated a larger reaction time for English. The data in general suggests an increased cognitive effort for the processing of the second language. Speech perception under adverse listening conditions was significantly higher for the first language and demonstrates the importance of language proficiency in everyday listening conditions. The measurement of the listening effort using the dual-task paradigm has shown that it provides an additional index of speech perception under different listening conditions beyond traditional word recognition scores for each language in bilinguals.

INTRODUCTION

The communication process involves the transduction of acoustic signal to physiological information from the Auditory Periphery to the Cognitive System. It involves not only perceptual factors like the ability to hear, but also cognitive factors like listening, comprehending and responding (Kiessling *et al*. 2003). Hearing and listening are two different processes where most of the audiologists usually fail to clearly distinguish. Hearing is a sensory process and a passive function whereas; listening is an active process that demands attention and cognitive resources to understand speech.

The Listening effort is an essential dimension of speech understanding. It can be evaluated by using subjective and objective measurements in audiology clinical practice. Subjective measurements are self reports or rating scales e.g. Speech,

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Spatial, and Qualities of Hearing Scale (SSQ), introduced by Gatehouse and Noble (2004). Objective measure of listening effort for speech in noise are always recommended rather than rely on self reports or rating scales from questionnaires because of the unknown criterion by which people assess their own listening effort (Edwards, 2007). In a dual-task paradigm, participants are asked to perform two tasks i.e. primary (speech perception) and a secondary task (memory task or digit recall) separately and then concurrently ((Bourland-Hicks and Tharpe, 2002; Choi *et al*. 2008; Downs, 1982; Downs and Crum, 1978; Feuerstein, 1992; Fraser *et al*., 2010; Rakerd *et al.* 1996; Sarampalis *et al*. 2009).

There is a scarcity of evidence about the listening effort in cochlear implant individuals. Ganesh *et al.* (2011) measured listening effort in simulated cochlear implants with and without frequency modulation and found that with fine structure cues the effort to listen was less. The language proficiency also plays an important role in the rehabilitation of Cochlear Implant (CI) individuals. The cognitive effort exerted by the listener to understand speech signals under adverse listening conditions is still unidentified in CI bilinguals.

NEED FOR THE STUDY

The interaction between factors such as hearing impairment, processing strategies in hearing aids and CI, type of listening environment and the individual's cognitive skills has received less attention. Whether current CI processing reduces or increases listening effort, either positively or negatively for first and second languages is still unknown. It is important to find out how much listening effort is required in CI patients for first language and second language. Some of the research questions are that, is there any effect of language on reaction times? Whether first language reduces listening effort at any SNR? The present study aims at comparing listening effort between two languages in quiet and noise condition in simulated CI.

METHOD

Participants

Ten native Kannada speakers with English as their second language served as the participants. LEAP-Q (Marian *et al*. 2007) was administered to evaluate the language proficiency. Audiological testing results showed pure tone threshold average (PTA) to be below 15 dB in both ears and they were reported to have no speech language or neurological problems. Their average age was 23 years (19 to 26 years).

Stimuli processing

The stimulus included sentences which were selected from both Indian English and Kannada Quick SIN test (Kumar *et al*. 2010, 2009) and were further processed with a noiseband Vocoder, implemented in Matlab which was presented in both quiet and noise condition (figure 1). The recorded sentences mixed with four-talker babble at −6 dB SNR prior to the processing. The stimuli were band passed into 8 frequency channels. The number of processing bands was selected based on the observation that an 8-band Vocoder produces performance levels most similar to that of CI users (Friesen *et al.* 2001). The temporal envelopes from each frequency band were extracted from each band. The carrier noise bands were modulated by the envelopes and resynthesized to produce the processed speech.

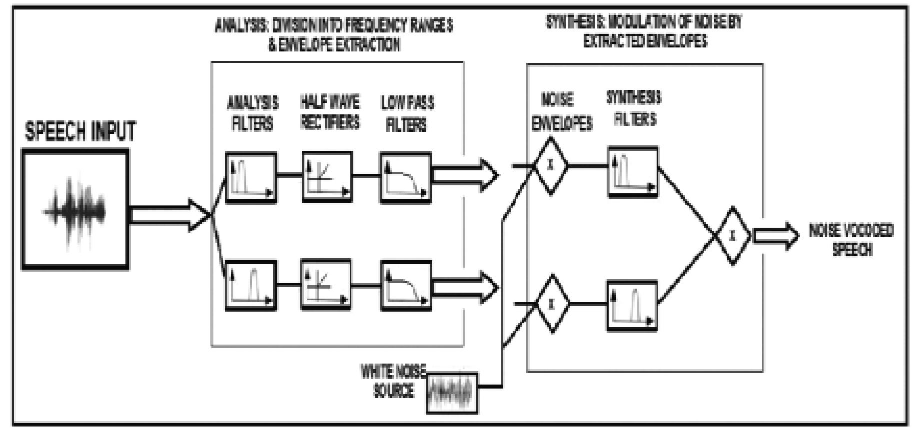

Fig. 1: Representation of the signal processing of the stimuli

Procedure

To measure listening effort a Dual–Task paradigm was used which involved two experimental conditions. The Primary Task includes measurement of speech perception in quiet, in noise (−6 dB SNR) and a visual reaction time separately. The Secondary Task included a visual reaction-time task which was given concurrently to the auditory task in order to measure speed of processing combined in quiet and noise (−6 dB SNR). Primary task and secondary tasks were carried out for both language sentences. Speech stimuli were presented using high fidelity Tech-Com Digital Sound stereo headphones (SSD-HP 202) at the level of 50-70 dB SPL and speech recognition scores were obtained verbatim for both conditions. Reaction time data recorded for detection of odd or even digit blocks using 'DMDX' software (figure 2)

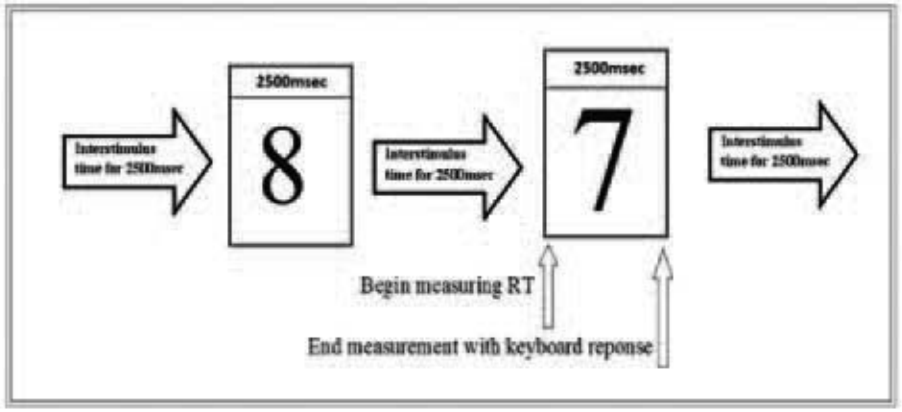

Fig. 2: Block diagram of the visual reaction time task used as stimulus for the primary and secondary task.

RESULTS AND DISCUSSION

The speech perception scores and reaction time data were obtained for both languages. The mean scores were better for first language [mean value for (quiet in primary task=84.5% and secondary task=82.1%) and mean value for (noise in primary task=40.6% and secondary task=37.9%)] compared to second language [mean value for (quiet in primary task=56.8% and secondary task=60.0%) and mean value for (noise in primary task=30.0% and secondary task=23.0%)]. A separate two factorial repeated measure ANOVA test was used to assess the significant differences between the two languages. Results indicate a significant main effect of quiet and noise condition in Kannada language and in English language. No significant difference was found for speech recognition scores during primary task when importance was given to secondary task. Figure 3 shows the speech recognition scores as a function of SNR across the participants in first language and second languuge in both primary and secondary tasks.

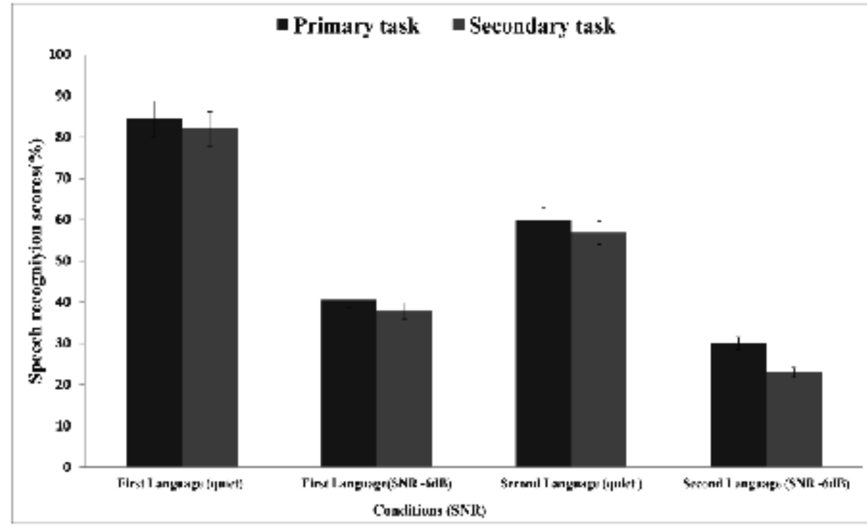

Fig. 3: Percentage of the speech recognition scores as a function of SNR across the participants in first language and second language in both primary and secondary tasks**.**

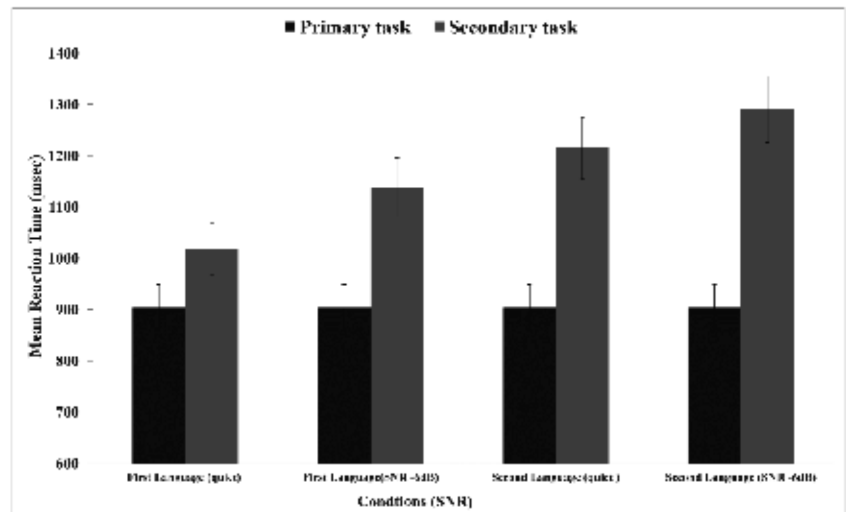

Fig. 4: The mean reaction time task as a function of SNR across the participants in first and second language in both primary and secondary tasks.

One way ANOVA test was used to assess the significant differences between reaction time data. The primary task had lesser reaction time (M=904.3 ms) followed by first language in quiet (M=1018.1 ms) and noise (M=1138.2 ms). Secondary task in second language in quiet (M=1214.7 ms) and in noise (M=1289.6 ms). Figure 4 represents mean reaction times across different SNR for each language in both conditions. The Post hoc test using Pair wise comparisons with Boneferroni's adjustments revealed statistical significance ($p < 0.05$) when the primary task was compared with other secondary task reaction time data except for primary and secondary between languages. So from the reaction time data it is clear that for second language they took more processing time.

The mean scores were better for first language compared to that of second language. There is strong evidence that bilinguals have a deficit in speech perception for their second language compared with monolingual speakers under unfavorable listening conditions in normal's (Rogers *et al*. 2006). This difficulty will further increase in individuals with hearing aids and CI. For such individuals the listening effort will be more while using second language. The present findings shows that more mental effort exerted for the perception of second language compare to first language.

The reason for the present results can be explained as with the dual-task paradigm, the primary speech perception task here utilizes the required mental capacity, and performance on any secondary task i.e. reaction time task utilizes any spare or left-over mental capacity. When an individual performs two tasks simultaneously, there will be competition for cognitive resources. As the demand for one task increases, the allocation of the resource also increases, resulting in reduced resources available for the competing task (Kahneman, 1973). In this study as the demand increased for speech perception the performance on reaction time decreased where the individual cognitive load was more for primary task. Accordingly, any increase in effort or load associated with performing the primary task (e.g., adding noise to a listening task) leads to decreases in performance on the concurrent secondary task. Whenever there is decline in the secondary task performance, this can be interpreted as increases in listening effort (Downs, 1982). The present results indicates that second language requires more listening effort and attention by reducing the speech perception ability whereas first language requires less listening effort and hence better speech perception. The degree of improvement in speech recognition suggests the importance of the language proficiency plays an important role in speech perception under realistic listening environments. From this data it is clear that speech perception in bilinguals is different, during rehabilitation care should be taken in selection of language.

There is an increase in the number of CI users worldwide. This type of objective measurement of listening effort will provide clinicians an index of cognitive capacities of patient. The dual task paradigm is a natural approach where speech perception will be assessed during multi task which can be used routinely. It provides an account of the individual's cognitive capacities which can be recorded

objectively. Objective measurement of listening effort can be used as an assessment tool, as an outcome measure to differentiate listeners, to select the candidates for rehabilitation (Humes and Humes, 2004; Sarampalis *et al*. 2009).

CONCLUSIONS

The components of the auditory test battery should be appropriate to assess the auditory communication performance. Usually in auditory test battery importance is given to speech perception, but the tests for signal recognition, sound quality, spatial hearing, listening comfort, listening effort, and an adequate processing of daily sounds are ignored. The dual-Task paradigm which is used in the present study measures listening effort in bilinguals. It gives an additional performance index over how much effort is needed for speech perception under different listening conditions beyond traditional word recognition scores for each language in bilinguals.

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Measuring speech-in-speech intelligibility with target location uncertainty

NIELS SØGAARD JENSEN, RENÉ BURMAND JOHANNESSON, SØREN LAUGESEN, AND RENSKJE K. HIETKAMP

Eriksholm Research Centre, Oticon A/S, Kongevejen 243, DK-3070 Snekkersten, Denmark

The most common speech-intelligibility tests do only to a limited extent reflect the situations where hearing-impaired people typically experience speech-intelligibility problems in their everyday life. One major problem is that the resulting speech reception threshold (SRT) typically is unrealistically low. In an attempt to increase the ecological validity of the Danish Dantale II speech-intelligibility test, a modified version of the test was developed. The new version includes speech masking and target location uncertainty as ways to increase the resemblance to real-life situations. In the present study, test results were obtained from 16 hearing-impaired listeners and comparison was made to results obtained in three other test conditions, all having a fixed target position but including different types of masking signals. The results showed that the introduction of speech masking as well as target location uncertainty contributed to an increase in SRT.

INTRODUCTION

A common problem experienced by hearing-impaired people is poor speech intelligibility when in a group of people where different talkers of interest frequently take turns and where other people are talking simultaneously. This problem is not reflected in the most common standardized speech-intelligibility tests, which typically are based on presentation of speech from a fixed position in front of the listener in a background of steady-state noise (e.g., the Danish Dantale II test, Wagener *et al.* 2003). The result in this type of test is often a speech reception threshold (SRT), which is very low compared to the signal-to-noise ratios where real-life problems typically are experienced. Previous research has shown that the introduction of target location uncertainty (e.g., Brungart and Simpson 2007, Kidd *et al.* 2005, and Singh *et al.* 2008) and speech masking (e.g., Francart *et al.* 2011 and Helfer and Freyman 2008) affects performance in such tests in the direction of a higher and thus more realistic SRT.

A modified version of the Dantale II test was developed, including target location uncertainty as well as speech masking. The first goal was to increase the ecological validity of the test by increasing the resemblance to everyday life (including an increase in SRT). The second (and ultimate) goal was to be able to reveal effects of

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