THE INFLUENCE OF SPEECH INTELLIGIBILITY ON THE USE OF ACCENTUATION AND GIVEN/NEW INFORMATION IN SPEECH PROCESSING

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ABSTRACT

Two experiments were carried out to investigate whether the quality of speech intelligibility influences the use of the interdependence between ('given/new') information and accentuation in speech processing. Both normal-hearing and hearing-impaired listeners were tested. The results of the two experiments showed that, as speech becomes less intelligible, listeners depend increasingly on the interdependence between information value and accentuation.

INTRODUCTION

Previous research on speech perception has shown that the distribution of ('given-new') information and accentuation over sentences is strongly connected. Terken and Nooteboom [1] found in a series of sentence verification experiments that 'new' information is usually processed faster if it is accented, while 'given' information is generally processed faster if it is de-accented

The aim of the present research is to deepen our insight into factors influencing listeners' use of information and accentuation. Do listeners' strategies shift under the influence of, for instance, speech intelligibility? It is likely that listeners make more optimal use of the information-accentuation correspondence if word processing is complicated by the fact that the quality of speech intelligibility is low. When the speech signal is degraded, supra-segmental information is usually preserved better than segmental information, and therefore prosodic cues may be used by listeners to interpret the signal. As 'new' information is usually accented, a sentence accent may be interpreted as a marker of 'new' information. The absence of an accent on a focused constituent may be interpreted as an indication of 'given' information. The interdependence also seems useful to hearing-impaired listeners who cannot distinguish all the segments, but can perceive the intonation of utterances. However, research by Vingerling [2] led to the conclusion that the hearing-impaired subjects use speech intensity, rather than intonation, as a cue to accentuation. Linguistic patterns concerning accentuation seemed of little importance to the hearing-impaired listeners.

In the study presently described, it is assumed that, when segmental information is not easily available, both hearing-impaired and normal-hearing listeners will exploit the interdependence between information value and accentuation to the fullest, by regarding accented words as 'new' and unaccented words as 'given'.

In order to make a fair comparison between normal-hearing and hearing-impaired subjects, a two-choice task was designed. Target words were embedded in sentences and provided either 'given' or new' information, they were either accented or unaccented. The subjects had to choose between two word candidates that differed in the last consonant by one phonetic feature (e.g., mat/map).

A pretest was carried out to determine the intelligibility of the sentence materials for the hearing-impaired subjects, given a certain sound level. The intention was to achieve comparable intelligibility scores for both groups of listeners. For normal-hearing subjects USASI noise was used to reduce the quality of speech. Given a signal level of about 60 dB and a signal-to-noise ratio of roughly 0 dB for normal-hearing listeners, the average intelligibility score on test words for both groups of listeners in the pretest was 41%. A S/N ratio of 0 dB was therefore employed again in the main experiment.

An on-line two-choice task results in two different types of dependent variable: response latency (in ms) and accuracy rate (in %). It was predicted that both normal-hearing (NH) and hearing-impaired (HI) listeners would make more correct decisions and have shorter latencies for accented 'new' and unaccented 'given' target words than for unaccented 'new' and accented 'given' words.

METHOD

Material

Word material. Thirty pairs of Dutch word candidates consisting of high-frequency monomorphemic nouns that differed only in the final consonant (e.g., map/mat= file/mat) were selected.

Sentence material. The target words were embedded in sentence contexts that did not bias subjects toward one of the words of a pair. The sentence materials consisted of questions and answers in pairs. When a question contained a target word, this word was considered 'given' in the answer, otherwise it was new. The target words in the answers were either accented or not. Accent patterns were only considered correct when a 'new' word was accented, and a 'given' word unaccented. There is a difference, however, between correctness of accent pattern and correctness of response. A response was considered correct when the word was chosen that was actually offered in the answer, independent of the correctness of the accent pattern. An English transliteration of word candidates, sentence materials, and correct and incorrect accent patterns is given in Table 1.

Table 1. English example of materials. Accented words are capitalized, target words in bold. Two-choice candidates are: mouth / mouse. (N=new, G=given, A=accented, U=unaccented).

Correct accent pattern:	
N+A	Did the little girl hurt her MOUTH? She accidentally hurt her **MOUSE.**
G+U	Did the little girl hurt her MOUTH? She ACCIDENTALLY hurt her **mouth.**
Incorrect accent pattern:	
N+U	Did the little girl hurt her MOUTH? She ACCIDENTALLY hurt her **mouse.**
G+A	Did the little girl hurt her MOUTH? She accidentally hurt her **MOUTH.**

Realisation. All sentences were read by a male phonetician and recorded on DAT. Sentence accents were realised as so-called 'pointed hats'. Sentences were digitized with a sampling frequency of 10 kHz.

Subjects

Fourteen subjects, between 22 and 30 years old, who had participated in the pretest were tested. Seven subjects had self-reported normal hearing. Seven subjects had a bilateral sensorineural prelingual hearing loss. According to their audiograms, average audiometric threshold at octave frequencies form 250 Hz to 2000 Hz were 65,60,69 and 68 dB HL (mean SD=20.8). The HI subjects performed the tests without hearing aids.

Procedure

Subjects had to listen to sequences of questions and answers and simultaneously look at a computer screen. The questions were first shown orthographically and then presented auditorily. The answers were presented auditorily only. During the answers, two similar words appeared on the screen immediately after the target words (e.g., mouth-mouse). Subjects had to decide as fast as possible which of the two words they had just heard in the answer, and push a corresponding button. Reaction times were

measured from the offsets of the target words. The sessions took approximately 20 minutes.

Design

Fixed factors were Information ('given/-new'), Accent (plus/minus), and Listener group (HI/NH); random factors were Item and Subject (nested within Listener group). The percentages and latencies were subjected to separate analyses of variance, with subjects (F_1) and items (F_2) as random factors respectively.

RESULTS AND DISCUSSION

Both NH and HI subjects failed to respond on approximately 2% of the trials offered. Of the remaining responses, the HI subjects had 67% correct, and the NH subjects 85%. This response accuracy was high as compared to the pretest (41%) and probably due to the fact that a forced binary choice was employed in the main experiment, whereas free report was used in the pretest. Figure 1 gives the percentages as a function of Accent, Information and Listener group.

The effects of Accent and Listener group were significant in the analyses (at p<.001). The two-way interaction between Accent and Listener group was also significant in subject and item analyses (p<.05). The three-way interaction between Accent, Information and Listener group reached significance as well (p<.05).

NH and HI listeners followed different strategies in making their choices. Only 'accent' played a role in the decisions of NH subjects, it had a highly significant effect in a separate analysis on the NH group of listeners (p<.001). There was no interaction between Information and Accent. In the analyses on the HI group of listeners, both Accent and the two-way interaction between Accent and Information reached significance (p<.05). The latencies revealed similar response patterns, but also showed an effect of Information. Both HI and NH listeners responded faster to 'new' than to 'given' words. There was an effect of Listener group since the response times of NH and HI subjects differed 200 ms on average.

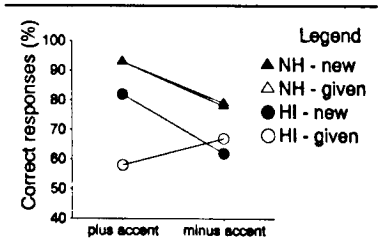

Fig.1. Correct responses (in %).

On the basis of response accuracy and latency results, the experimental predictions appear correct only for HI listeners. The question arises whether this might be due to a higher intelligibility of speech for the NH subjects. Both percentages of correct responses and latencies indicate that the noise level determined in the pretest was not optimal for comparing the two listener groups in the main experiment. In order to find out whether NH subjects would behave like HI subjects when the intelligibility of speech was more severely reduced, a second experiment was carried out.

EXPERIMENT II

In this experiment, a different group of seven NH subjects was tested with the same stimulus material and a reduced S/N ratio (of approximately -9dB).

Results

In the replication experiment, NH subjects failed to respond on 2% of the trials. Only 70% of the remaining answers was correct. This percentage closely approximated that of the HI subjects earlier. Figure 2 gives the average percentages as a function of Accent and Information. Apart from a significant main effect of Accent (p<.001), a significant interaction between Information and Accent was found in the analyses (p<.05). The latencies for NH subjects in this experiment were longer (+100ms on average) than in the previous experiment and revealed similar significancies. The outcome shows that NH listeners also use the information-accentuation interdependence when the segmental quality of speech is severely reduced.

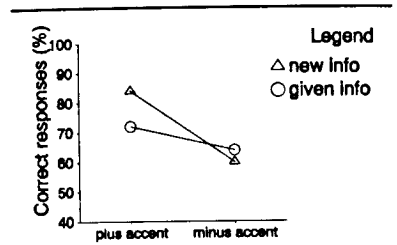

Fig.2. Correct responses NH (in %).

GENERAL DISCUSSION

A first conlusion from this study is that normal-hearing listeners make better use of the interdependence between information and accentuation when the segmental quality of speech is more reduced. This interdependence showed an asymmetry, however. Listeners did benefit from the presence of sentence accents on 'new' words, but the importance of de-accentuation for 'given' information was less clear. This asymmetry may have been induced by the experimental set-up and materials, but the phenomenon was also witnessed in experiments by others (e.g., [3]). A recent study [4] showed that de-accentuation seems less important in processing identically repeated 'given' information than in processing more implicit 'given' information.

A second conclusion is that the prelingual hearing-impaired subjects in this experiments effectively used the interdependence between information value and accentuation. From a comparison between the hearing-impaired subjects in the first experiment and the normal-hearing in the second experiment, it can be concluded that these listeners do not intrinsically differ in their use of the interdependence.

The findings in these experiments were also interpreted in terms of a temporal perspective on speech processing [4]. If listeners cannot identify word forms on the basis of segmental information only, word form identification is delayed. Incoming perceptual information on accents (e.g., intonation) and higher order knowledge on the distribution of information and accentuation are then employed to select a word candidate.

ACKNOWLEDGEMENT

This research was carried out at the Institute for Language and Speech of Utrecht University, The Netherlands. The author wishes to thank Jurgen Lentz for his help in carrying out the experiments and Sieb Nooteboom for his useful discussion of the results.

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