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Research paper

The pupil response reveals increased listening effort when it is difficult to focus attention

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ABSTRACT

Recent studies have shown that prior knowledge about where, when, and who is going to talk improves speech intelligibility. How related attentional processes affect cognitive processing load has not been investigated yet. In the current study, three experiments investigentenS2v87.2(the)-297.pupilhe d(aitpriov)16.ne
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available cues to facilitate target-masker segregation processes. For effective early fi

SNR. After removal of the trials with too many blinks and/or eye moments, the number of trials that remained available for the analyses with SNR as additional independent factor was relatively small. We did not collect sufficient data for each participant to make a single analysis (i.e. with independent factors: task, condition, and SRN) feasible. Such an analysis would likely have been more sensitive to the effects of interest. Therefore, we proceeded with two separate ANOVAs: in one, we averaged pupil data over the tasks and conditions, and in the other, we averaged over SNRs. Note that by averaging the data across factor levels that may have influenced the data, we increase the variance that is unaccounted for in the ANOVAs, which made our analyses relatively conservative. First, to assess whether the current data replicated the effect of SNR on the mean pupil dilation observed by Koelewijn et al. (2014), we performed an ANOVA with SNR as independent factor, and pupil response (averaged over tasks and conditions) as dependent factor. The outcomes showed a significant effect of SNR ($F_{[2,46]} = 19.60$, $p < 0.001$). More negative SNRs resulted in a larger mean pupil dilation response, which is consistent with our previous results. Second, to examine the effect for each condition and task, we

3.1. Methods

Sixteen young adults (age between 19 and 33 years, mean age 26.3 years) recruited at the VU University Medical Center were included. All participants had normal hearing, normal or corrected-to-normal vision, no history of neurological diseases, and were native Dutch speakers. All provided written informed consent.

In the single-target task, the target sentence was always uttered by the same female talker and always presented to the left ear against a background of fluctuating noise. The distractor sentence (in noise) was always uttered by the same male talker and presented to the right ear. The onset times of the target and distractor sentences were manipulated. In the onset-fixed condition, within a block, both sentences began 4 s after the onset of the fluctuating noise. In the onset-random condition, the two sentences were still simultaneously presented, but started randomly at 2, 4, or 6 s after the noise onset. The rationale for this approach was that participants would implicitly know the onset in the onset-fixed condition, but not in the onset-random condition. To make sure that the speech onset in the 6-s trials was unpredictable despite the fact that after 4 s, participants could exclude the possibility of onsets at 2 or 4 s, in 25% of the trials no sentences were presented and the participants heard only noise. To make sure that the only thing changing between blocks was onset uncertainty and not the probability of a sentence occurring, 25% of the trials in the fixed-onset condition also contained no sentences. Each block contained 12 trials for each SNR and 12 trials in which no sentences were presented, for a total 48 trials. The order of the trials was randomized within each block, and the order of the blocks was balanced over participants. All other procedures and equipment were identical to those used in Experiment 1. The whole experiment took approximately 1 h per participant.

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plotted in Fig. 2B. Paired-samples t-tests were performed comparing the *mean pupil dilation* ($p = 0.13$), *peak pupil dilation* ($p = 0.19$), *peak latency* ($p = 0.77$), and *baseline* ($p = 0.46$) for the fixed and random conditions. There were no significant effects.

3.2.3. Subjective data

There was no significant difference in subjective effort between the fixed and random conditions.

3.3. Discussion

Uncertainty in the onset time of the target speech did not affect performance or the pupil dilation response. Additionally, subjective scores were similar for onset-fixed and onset-random conditions. These results differ from previously observed effects of target timing uncertainty on performance (Kitterick et al., 2010). This difference might be explained by less onset uncertainty in the current study compared to the study of Kitterick and colleagues.

4. Experiment 3: talker uncertainty

Vocal characteristics, including pitch, timing, and timbre, differ across talkers (Brungart, 2001; Kraus and Chandrasekaran, 2010). These differences can be used to orient one's attentional focus onto target speech and filter out (ignore) the voices of other distracting talkers. Several studies suggest that talker/voice uncertainty affects the ability to understand a target talker amidst other talkers (Brungart et al., 2001; Brungart and Simpson, 2004; Kitterick et al., 2010). To date, however, very little is known about how this factor affects listening effort.

In Experiment 3, we determined the effect of target talker uncertainty on the pupillary response and task performance while a distractor sentence was eitherresponse pm50 tasks, independent samples of fluctuating noise were presented to both ears. Although the structure and content of the sentences were similar to those used in Experiments 1 and 2, this time the sentences were gathered from the other two out of the four sets described by Versfeld et al. (2000). Each set contains the same sentences uttered by four different talkers: two male (coded as AM and RB) and two female (coded as HB and MS). From each set, the same 384 sentences were selected, based on intelligibility, articulation, and whether every talker uttered all words in the correct order. The audio files of these uttered sentences differed in length. The mean duration was 1.9 s for talker AM (range = 1.4−2.9 s, SD = 0.2), 1.8 s for talker HB (range = 1.3−2.6 s, SD = 0.2), 1.8 s for talker MS (range = 1.3−3.0 s, SD = 0.2), and 2.0 s for talker RB (range = 1.3−3.1 s, SD = 0.3). To equate the amount of energetic masking of all four talkers by the fluctuating noise, the power spectrum for each talker was adjusted to match the mean power spectrum. Additionally, the power spectrum of the fluctuating noise was adjusted to have this power spectrum.

The target sentence was always presented to the left ear and was tested here, potentially enabling them to observe significant effects where we did not.

5. General discussion