

Effects of task-irrelevant background speech on verbal working memory tasks

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ABSTRACT

Immediate serial recall of visually presented verbal items is impaired by task-irrelevant background speech that the participants are instructed to ignore. This so-called “irrelevant speech effect” (ISE) has been attributed to interference with phonological representations, interference with representations of serial order, or attentional capture away from the focal task.

In order to learn more about the task characteristics necessary for ISE evocation, we designed 3 verbal working memory tasks that were comparable with respect to task structure, but differed in the cognitive processes involved. In each task, sequences of 7 German nouns were presented pictorially. In Task 1, participants had to reconstruct the serial order of the items. In Task 2, participants had to decide which of the 7 words represented by the pictures had no “partner” with the same initial phoneme. In Task 3, participants had to decide which of the 7 items had no “partner” with respect to semantic category. Serial order reconstruction of verbal items and phonological categorization were significantly impaired by irrelevant speech, whereas semantic categorization was unaffected. Implications for theoretical accounts of the ISE are discussed.

Keywords: Irrelevant speech effect, irrelevant sound effect, working memory, noise effects on cognitive performance

1. INTRODUCTION

Whether and to what extent task-irrelevant background sounds of moderate intensity disrupt performance in non-auditory tasks (i.e., tasks that require processing of visually presented information) depends on characteristics of the tasks and the sounds. The duplex-model proposed by Hughes et al. [1] provides a general framework for noise effects on performance. This model assumes two independent mechanisms of sound-induced disruption, i.e., “attentional capture” (involuntary diversion of attention away from the focal task after an unexpected deviation from the recent auditory past) and “interference-by-process” (specific interference between processes involved in the pre-attentive, obligatory processing of the irrelevant sound, and intentional processes involved in the focal task).

Research in this field focused on verbal short-term memory, assessed by a standard task in which participants have to recall a sequence of visually presented verbal items, e.g., digits, consonants, or words, in the correct serial order. Performance in this “immediate serial recall”-task is reliably impaired when task-irrelevant background sound is presented during item presentation, or during presentation and recall. This so-called “irrelevant sound effect” (ISE) is especially pronounced with speech sounds [2]. The ISE has been attributed to (i) interference between phonological representations in the phonological store component of the phonological loop [3], (ii) interference between serial order representations resulting from obligatory auditory perceptual organization of the speech stream and serial order representations of the list items (“changing state effect”, [4]), and (iii)

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mere attention capture due to speech [5].

In a series of experiments, we aim to elucidate the role of phonological processing, serial order retention, and attention capture in the detrimental effect of speech sounds on working memory tasks. In the experiment reported here, we assessed the effects of irrelevant speech on performance in three verbal working memory tasks that were comparable with respect to task structure, but differed in the cognitive processes involved (serial order retention, phoneme comparison, and semantic categorization).

2. Methods

2.1 Participants

Participants were 74 students and junior researchers (51 male), aged between 19 and 34 years ($M=23.5$ years; SD 2 years), with German as first language. Participants were assigned to one of 3 experimental groups. One group ($n=24$, 19 male) performed the serial order reconstruction task, one group ($n=25$; 16 male) performed the phonological processing task and one group ($n=25$, 16 male) performed the semantic processing task.

2.2 Tasks and Sounds

In each of the three tasks, 7 easy-to-name pictures representing German nouns were presented one after another in the center of the computer screen, with a presentation time of 1100 msec and a 1000 interval between stimuli. After presentation of the seventh picture, all 7 pictures were shown simultaneously in a random arrangement on the screen.

In the serial order task, participants had to reconstruct the serial order by clicking with the mouse on the pictures in the order they had been presented. For the phoneme comparison task, sequences were composed of 3 pairs of items with the same initial sound, and an “odd” item with a different initial sound. In the semantic categorization task, sequences were composed of 3 pairs of items from the same semantic category (e.g., furnitures, vehicles), and one “odd” item representing a different category. In both tasks, participants had to decide which of the 7 items is the “odd” one.

As task-irrelevant speech, we used a recording of narrative speech produced a male speaker reading a textbook in Korean language.

2.3 Procedure

Participants were tested individually in a sound-attenuated booth. After instruction, 3 practice trials were performed, followed by 24 experimental trials. In half of the trials, irrelevant speech was played through headphones at a comfortable sound level of about 60 dB. The remaining trials were performed in silence. Sound conditions (silence vs. speech) were varied quasi-randomly from trial to trial, so that at most two successive trials were performed under the same sound condition.

2.4 Results

Mean performance (proportion correct) in the control condition was significantly lower in the semantic categorization task ($M = 0.56$, $SD = 0.18$) when compared to serial order reconstruction ($M=0.78$; $SD=0.12$) and phoneme comparison ($M = 0.68$; $SD = 0.22$), with $p < .01$ and $p = .06$, respectively. Serial order reconstruction and phoneme comparison did not differ with respect to control performance ($p > .20$). Separate t-tests for paired samples revealed significant effects of irrelevant speech in the serial order reconstruction task ($p < .001$) and in the phoneme comparison task ($p < 0.05$). Semantic categorization was unaffected by irrelevant speech ($p = .65$).

3. Discussion

3.1 Mechanisms underlying the irrelevant speech effect

The current findings indicate that serial order retention is not a necessary condition for ISE evocation. The phoneme comparison task does not require serial order retention, but evoked an ISE similar to that observed in the serial order reconstruction task. Furthermore, the null effect found in the semantic categorization task contradicts the attention capture account of the ISE. If irrelevant speech impairs performance merely through diversion of attention, each of the three tasks should have been

affected. Thus, the results found here indicate that irrelevant speech evokes specific interference with phonological processing, which is involved in both serial order retention and phoneme comparison.

3.2 Limitations

Even though pilot studies were performed in order to verify comparable task difficulty, it turned out that performance in the semantic categorization task was lower when compared to the other tasks. So, the possibility that the difference in task difficulty is responsible for the differential effects of background speech cannot be ruled out. However, this seems unlikely, as performance was well above chance and below ceiling in each of the tasks, and prior findings argue against an impact of task difficulty on the ISE [6]. A further limitation is a lack of statistical power. Even though separate t-tests indicate differential effects of irrelevant speech on the three tasks, the interaction could not be verified statistically in a 2 (Sound condition) x 3 (Task) ANOVA ($p > .20$). Currently, we are performing further experiments, aiming to confirm the current findings with increased sample sizes and trials per condition, the latter aiming to increase the reliability of the performance measures.

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