Differential effects of irrelevant speech and environmental sounds on short-term memory in children and adults

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ABSTRACT

Short-term memory for visually presented material is impaired by task-irrelevant speech that the participants are instructed to ignore. This so-called Irrelevant Speech Effect (ISE) has been attributed to attentional capture and to specific interference between preattentive, automatic sound processing and deliberate processes involved in retention of the serial order of items in the memory lists.

Aiming to explore the roles of attention control and specific interference in the ISE, we analyzed the effects of background speech and nonspeech environmental sounds on short-term memory in third-grade children and adults. If the environmental sounds evoke attentional capture, children should be more affected than adults due to immature attention control.

Irrelevant speech evoked a reliable impairment, which did not differ between age groups. However, only the children were affected by environmental sounds. These findings indicate different mechanisms underlying the effects of background speech and environmental sounds. Theoretical implications and practical consequences for the acoustical design of learning environments are discussed.

1. Introduction

Whether it is the rain pelting the window, the car that drives by, or the radio constantly playing in the background - in almost every situation of our lives, we are exposed to various noises from our environment. Given the everyday noises, it is worth considering whether exposure to certain ambient noises may cause long-term deficits in children's cognitive development. One place where children are exposed to environmental sounds for several hours a day is the classroom. Even in homeschooling, which is more common in times of the COVID-19 pandemic, children are exposed to a lot of environmental noises everyday as they learn. Generally, the topic of acoustics of the learning environment has attracted much attention in recent decades. Some studies found that children's listening ability is severely affected by noise and reverberation under classroom-like conditions [12, 23]. Noise and reverberation impair children's speech perception and listening comprehension much more than it does in adults [12, 24]. Moreover, noise also impairs nonauditory functions such as verbal short-term memory (for a review, see [14]). Language and literacy acquisition, as well as second-language learning, rely heavily on verbal short-term memory. Therefore, for young children, constant exposure to background speech and noise affects language development and literacy acquisition.

Over 40 years of research have shown that task-irrelevant background sounds disrupt short-term memory performance [5, 20]. This so-called “Irrelevant Sound Effect” (ISE) refers to the detrimental effect on immediate serial recall of verbal items, such as digits or letters, presented visually when task irrelevant speech or sound is played in the background. This impairment occurs even though participants are instructed to ignore the task-irrelevant sounds. Since its first discovery in the early 1980s, the ISE has been replicated several times with a variety of materials, designs, and experimental procedures. Since then, it has been found that the performance impairment occurs independently of both the volume of task accompanying speech or sound [4, 21] and the semantic content [20]. It has also been shown that memory tasks that do not require serial recall are not affected or are affected only to a smaller extent, e.g., the missing item task [2, 17] or the free recall task [16, 22]. In addition, the ISE has also been studied with background noise without speech. Non-speech sounds such as tones [6], music, both vocal and instrumental [11], and environmental sounds [3] cause a decrease in performance compared to silence.

Several theories have been proposed to explain the detrimental effects of task irrelevant background sounds. One hypothesis states that performance deficiency is related to the automatic entry of the to-be-remembered material during rehearsal into the phonological store [1]. Another theory suggests that the sequence information of the material to be remembered interferes with the changing-state of the background noise [10]. Both theories predict that children have less impairment from auditory distractors compared to adults, because their rehearsal mechanism is not yet fully developed [1]. What is missing in these theories is the influence of attention, as it is also known that attentional resources change over time. Children who have fewer attentional resources are expected to have greater impairment (e.g., [7]).

More recently, these previous assumptions have been combined in the Duplex-Mechanism Account of sound-induced disruption. According to Hughes and colleagues [9], there are two mechanisms that may be responsible for the noise effects on performance: attentional capture

and interference-by-process. In the context of developmental change, the question is whether children are more or less affected by background noise compared to adults.

If children are assumed to have poorer attention abilities than adults, the distinction between children and adults becomes especially important. Moreover, the results on the impact of irrelevant sounds on serial short-term memory changes with age are inconsistent. To date, it is not clear whether children are more affected by background noise than adults (e.g., [7]) and whether the memory impairment is equivalent across age groups (e.g., [13]).

The aim of this study is to explore the developmental dimensions of the ISE by disentangling the roles of attentional capture and automatic interference-by-process as suggested by Hughes et al. [9] in their duplex-mechanism approach. To achieve this goal, we investigated the impact of task-irrelevant environmental sounds and foreign speech on a serial order reconstruction task of verbal items in children (8 to 10 years) and young adults (19 to 26 years).

2. Methods

2.1 Participants

All participants were German native speakers. A total of 32 adults (*M* = 22.4, 21 males) between 19 and 26 and 39 children between 8 and 10 years of age (*M* = 8.78, 17 males) participated in the experiment. For details see Leist, Lachmann, Klatte (in preperation).

2.2 Material

Participants performed a serial order reconstruction task. In this task, easy-to-name pictures representing German nouns are presented one after the other in the center of the screen. After the presentation of the last picture, all pictures from this trial are simultaneously shown on the screen in random order. The task was to reconstruct the serial order of the previously seen pictures by clicking on the pictures with the computer mouse.

The adult participants saw eight pictures per trial while the children saw only five. For children the number of pictures was adjusted from eight to five pictures to ensure comparable task difficulty between the groups. Task performance was measured in three sound conditions: i) silence, ii) foreign speech (Danish), and iii) environmental sounds, i.e., telephone ringing, dog barking, etc. The sound conditions were counterbalanced and randomly selected for each trial. The same sound condition was presented in a maximum of two consecutive trials. Participants were instructed to ignore the background sounds.

2.3 Procedure

Adults were tested in groups of up to four in a soundproof booth. Children were tested individually in a quiet classroom. After instruction, participants were presented with the pictures and sounds. Participants then completed three practice trials (one trial for each sound condition), followed by 48 experimental trials (16 trials for each sound condition) for adults and 24 experimental trials (8 trials for each sound condition) for children. If a picture was clicked at the correct position in the sequence, the answer was scored as correct (e.g., Hughes, Vachon, & Jones, 2007).

2.4 Results

Performance in the serial reconstruction task was significantly reduced by foreign speech in both age groups. However, there was no significant difference in the degree of sound-induced disruption between children and adults (see Table 1). Interestingly, the environmental sounds had a significant impact on children's but not adults' performance in the serial reconstruction task. For details concerning the statistical analyses, see Leist, Lachmann, Klatte (in preparation).

Table 1: Percentage drop in performance relative to quiet

Sound condition	**Age group**	**Percentage drop**	**SD**
Environmental sounds	Adults	2 %	9 %
	Children	8 %	13 %
Foreign speech	Adults	8 %	11 %
	Children	11 %	19 %

3. Discussion

The aim of the present study was to identify the impact of irrelevant background sounds in a serial order reconstruction task presenting pictures in children and adults. Previous experiments have largely focused on the impact on adult performance, due to the empirically robust observation that task-irrelevant background sounds, such as speech and music, reliably affect performance on serial memory tasks. Only a limited number of studies on the impact of irrelevant background sounds in children have been conducted to date. Our findings show that irrelevant speech has an equivalent impact on children and adults, but environmental sounds only affect the cognitive performance of children. The extent of impairment by irrelevant speech did not depend on age. Compared to adults, children are especially susceptible to noise-induced impairments due to the capture of attention. A possible explanation for the observed results could be that children are more susceptible to auditory distraction due to poorer attentional control rather than underdeveloped rehearsal processes. Our results are in line with previous studies (e.g., [13]).Future studies are currently planned to investigate the attentional diversion in a serial reconstruction task presenting spatial items visually (dot task), a task without verbal information. We already know from previous experiments with the dot task that memory performance is not affected by irrelevant background sounds in adults and children [15, 18]. We hypothesize that attention-diverting environmental sounds distract children but not adults. This would support our assumption of developmental changes in attention capture [19]. The current findings underscore the importance of noise-free learning environments for children.

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