



Distraction in verbal short-term memory: Insights from developmental differences [☆]



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ABSTRACT

The contribution of two mechanisms of auditory distraction in verbal serial short-term memory—interference with the serial rehearsal processes used to support short-term recall and general attentional diversion—was investigated by exploiting differences in auditory distraction in children and adults. Experiment 1 showed that serial rehearsal plays a role in children's as well as adults' distractibility: Auditory distraction from irrelevant speech was greater for both children and adults as the burden on rehearsal increased. This pattern was particularly pronounced in children, suggesting that underdeveloped rehearsal skill in this population may increase their distractibility. Experiment 2 showed that both groups were more susceptible to changing- than steady-state speech when the task involved serial rehearsal—indicating that both groups suffer interference-by-process—but that children, but not adults, were also susceptible to any sort of sound (steady or changing) in a task thought to be devoid of serial rehearsal. The overall pattern of results suggests that children's increased susceptibility to auditory distraction during verbal short-term memory performance is due to a greater susceptibility to attentional diversion; in this view, under-developed rehearsal-skill increases children's distractibility by exacerbating their under-developed attentional control rather than by increasing interference-by-process.

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Introduction

The ability to maintain verbal information in order over a short time period is an important cognitive skill, underpinning many fundamental higher-order functions

including language comprehension, language learning, and verbally-mediated problem-solving (e.g., [Baddeley, 2007](#)). Common to numerous theoretical accounts is the notion that a key process in verbal serial short-term memory is rehearsal, in which the vocal system is used either as a means of offsetting the decay of phonological representations in a labile short-term store (e.g., [Baddeley, 2007](#); [Camos, Lagner, & Barrouillet, 2009](#); but see [Lewandowsky & Oberauer, 2015](#); [Oberauer & Lewandowsky, 2008](#)) or, according to other theories, of constructively binding a grammatically and semantically unconstrained sequence into a coherent motor-plan for action (e.g., [Hughes, Marsh, & Jones, 2009](#); [Jones, Hughes, & Macken, 2006](#)).

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However, there is evidence that such active rehearsal processes are peculiarly vulnerable to disruption by passively processed irrelevant auditory stimuli, whether speech or non-speech (e.g., tones), even when the memory task is presented visually (e.g., Beaman & Jones, 1997; Colle & Welsh, 1976; Jones & Macken, 1993; Jones, Macken, & Nicholls, 2004; Salamé & Baddeley, 1982). The study of this *irrelevant sound effect (ISE)*, particularly across development, is instructive for theories of short-term memory and selective attention as it provides a vehicle for understanding the ability to maintain and reproduce aspects of one's environment in the service of complex cognition, the role of attentional control in such maintenance, and how such processes emerge over time. The current research examines the ISE in both children and adults with the aim of establishing the extent to which verbal short-term memory is susceptible to distraction due to the vulnerability of serial rehearsal and/or to poor general attentional control. Additionally, we examine whether these two factors play different roles at different points of cognitive development.

There is evidence that young children may be especially affected by irrelevant sound as compared to college students and older adults, who do not differ in their susceptibility to such distraction (Beaman, 2005; Elliott, 2002; Elliott, Bhagat, & Lynn, 2007; Elliott & Briganti, 2012; Rouleau & Belleville, 1996; cf. Klatt, Lachmann, Schlittmeier, & Hellbruck, 2010). In the typical irrelevant sound experiment, participants are presented visually with a series of around 5 to 9 verbal items (digits or words) at the rate of about 1 item per second. Following the last item, or following a short retention interval, the items must be recalled in serial order. The ISE refers to the robust finding that the presentation of sound that is not necessarily loud [e.g., 55–65 dB(A)], is irrelevant to the task, and that participants are therefore told to ignore, disrupts serial recall appreciably (e.g., Beaman & Jones, 1997; Colle & Welsh, 1976; Jones, Madden, & Miles, 1992; Salamé & Baddeley, 1982). A prominent account of the ISE in adults posits that it is due to a conflict of two concurrent processes of seriation (e.g., Hughes, 2014; Hughes & Jones, 2001). A key line of evidence for this *interference-by-process* account is the changing-state effect: While some degree of disruption from 'steady-state' sound (e.g., "K K K K K...") compared to quiet has sometimes been observed (e.g., Hughes, Tremblay, & Jones, 2005), a plethora of studies has shown that changing-state sound (e.g., "K P R L N...")—that forms a series of auditory stimuli—is particularly disruptive of serial recall (e.g., Elliott, 2002; Hughes, Vachon, & Jones, 2005; Jones & Macken, 1993; Jones et al., 1992). In addition, a demand for seriation in the focal task—in the form of serial rehearsal—plays a role in the disruption: On the interference-by-process account, engagement in serial rehearsal is vulnerable to interference from the pre-attentively seriated auditory information (Beaman & Jones, 1997). Similarly, in tasks that are typically thought to be supported by serial rehearsal, impeding the capacity for rehearsal through articulatory suppression diminishes or eliminates the disruption from changing-state sound (Jones et al., 2004).

Given the important role ascribed to serial rehearsal in the ISE in adults, one of the chief questions we address in the present study is whether the inchoate state of children's rehearsal skill plays a role in their increased susceptibility to the effect (Tam, Jarrold, Baddeley, & Sabatos-DeVito, 2010). The efficiency of rehearsal processes is thought to increase with development during childhood (e.g., Flavell, Beach, & Chinsky, 1966; Tam et al., 2010; but see also Jarrold & Citroën, 2013). Recent evidence suggests that relatively young children's (age 8) rehearsal processes are less practiced and continue to change from a single-item repetition style of rehearsal to a more cumulative style as they approach later childhood (e.g., age 10; Lehmann & Hasselhorn, 2012). Furthermore, there is evidence that younger children use greater levels of processing resources when rehearsing, relative to older children. For example, Gutentag (1984) used a dual-task approach to quantify the mental cost incurred by rehearsal in three groups of children, ranging in age from approximately 7 to 12 years. Using a free recall task, he found that a cumulative rehearsal strategy demanded greater mental effort in younger children as evidenced by a greater cost of a secondary finger-tapping task.

In adults, it is argued that the more skilled or fluent the rehearsal process—based either on the nature of the to-be-remembered material or individual differences in speech-planning and production—the less vulnerable they will be to the ISE. That is, disruption by the seriation cues yielded by changing-state sound is assumed to be a negative function of the extent to which the to-be-remembered items can be fluently co-articulated during serial rehearsal (e.g., Jones, Beaman, & Macken, 1996). It follows, therefore, that it is the less efficient rehearsal abilities of children that renders them more vulnerable to disruption by changing-state sound. Another possibility, however, is that if children gain less from using rehearsal—due to its underdevelopment—they stand to lose less in the presence of a factor assumed to further reduce the efficiency of that rehearsal process. However, at least within the interference-by-process framework, this would predict a smaller ISE in children (that are beginning to rehearse) compared to adults which, to our knowledge, has never been observed.

Our reasoning so far has been that underdeveloped rehearsal skill could leave children compared to adults particularly susceptible to interference-by-process (e.g., Jones & Tremblay, 2000): The less fluent the transition from one to-be-remembered item to the next during serial rehearsal the more opportunity there would be for seriation cues yielded obligatorily by changing-state sound to intrude into that rehearsal process and thereby impair recall performance (see, e.g., Jones et al., 1996; Macken, Mosdell, & Jones, 1999). An alternative possibility, however, is that the underdeveloped nature of rehearsal in children could impose a general attentional or executive-processing load. To elaborate, in addition to the quantitative and qualitative changes in rehearsal, evidence suggests that children have a smaller working memory capacity (Cowan et al., 2005) and hence a more limited ability to filter out irrelevant stimuli, especially when placed under conditions of high focal-task demand (Cowan, Morey, AuBuchon, Zwilling, & Gilchrist,

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