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Phonological short-term memory impairment and the word length effect in children with intellectual disabilities

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ABSTRACT

There is mounting evidence that children and adolescents with intellectual disabilities (ID) of nonspecific aetiology perform poorer on phonological short-term memory tasks than children matched for mental age indicating a structural deficit in a process contributing to short-term recall of verbal material. One explanation is that children with ID of nonspecific aetiology do not activate subvocal rehearsal to refresh degrading memory traces. However, existing research concerning this explanation is inconclusive since studies focussing on the word length effect (WLE) as indicator of rehearsal have revealed inconsistent results for samples with ID and because in several existing studies, it is unclear whether the WLE was caused by rehearsal or merely appeared during output of the responses.

We assumed that in children with ID only output delays produce a small WLE while in typically developing 6- to 8-year-olds rehearsal and output contribute to the WLE. From this assumption we derived several predictions that were tested in an experiment including 34 children with mild or borderline ID and 34 typically developing children matched for mental age (MA). As predicted, results revealed a small but significant WLE for children with ID that was significantly smaller than the WLE in the control group. Additionally, for children with ID, a WLE was not found for the first word of each trial but the effect emerged only in later serial positions. The findings corroborate the notion that in children with ID subvocal rehearsal does not develop in line with their mental age and provide a potential explanation for the inconsistent results on the WLE in children with ID.

1. Introduction

Many studies that examined working memory impairments in children and adolescents with intellectual disabilities (ID) drew on Baddeley's multicomponent model (Baddeley, 1986, 2007). In this model a central executive provides the attentional control of the working memory system and focuses, switches and divides the limited attentional resources. The phonological loop is concerned with storing and maintaining sound and speech-based information, while the visuo–spatial sketchpad is engaged in storing and maintaining visual and spatial material. The episodic buffer was added as a fourth component; it provides storage of information in a multimodal code and is capable of binding information from the other storage components and from long-term memory (Baddeley, 2000). Various studies comparing children with and without ID

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of the same chronological age have consistently found deficits in all four components that increased with the severity of the intellectual disability (Henry, 2001, 2010; Maehler & Schuchardt, 2009; Schuchardt, Gebhardt, & Maehler, 2010; van der Molen, van Luit, Jongmans, & van der Molen, 2009). In the tradition of the developmental–difference controversy (Zigler & Balla, 1982), research additionally focussed on the question whether these deficits in working memory do reflect a developmental lag and children with ID have the same cognitive structures as younger children matched for mental age (MA), or whether performance differences with MA matched children point to a structural difference or a qualitative deviation from typical development.

Because various studies reported that children with ID of nonspecific aetiology performed more poorly than MA children on some or on all phonological short-term memory (PSTM) tasks (Bayliss, Jarrold, Baddeley, & Leigh, 2005; Henry & MacLean, 2002; Henry & Winfield, 2010; Hulme & Mackenzie, 1992; Russell, Jarrold, & Henry, 1996; Schuchardt et al., 2010; Schuchardt, Maehler, & Hasselhorn, 2011; van der Molen, van Luit, Jongmans, & van der Molen, 2007), it is likely that there is a structural difference in the development of the phonological loop.

According to Baddeley's (1986, 2007) model, the phonological loop comprises a phonological store and a subvocal articulatory rehearsal mechanism. To counteract the rapid decay of verbal memory traces in the phonological store, traces can be refreshed by rehearsing the items through covert or silent articulation and then be fed back into the phonological store. The most commonly suggested explanation for the aforementioned difficulties with PSTM tasks is that subvocal rehearsal is impaired in individuals with ID. Studies addressing this hypothesis used the word length paradigm to examine whether a word length effect (WLE) with superior recall of short compared to long words occurred in groups of individuals with ID. Some studies found a significant word length $\times$ group interaction with no WLE for the group with ID, but a significant WLE as rehearsal indicator for the MA control group (Hasselhorn & Mähler, 2007; Hulme & Mackenzie, 1992; Rosenquist, Conners, & Roskos Ewoldsen, 2003). Additionally, articulation speed correlated with word span in the samples of MA matched children but not in the samples of individuals with ID. Therefore, these studies suggested that subvocal rehearsal is impaired in individuals with ID and not developed according to their mental age. However, other studies (Schuchardt et al., 2011; van der Molen et al., 2007) reported no word length $\times$ group interaction and found significant WLEs for children and adolescents with ID as well as for children of the MA control group indicating equal reliance on subvocal rehearsal.

The interpretation of these inconsistent results is further complicated by the fact that a WLE as well as a relationship between articulation speed and memory span not only could have been caused by subvocal rehearsal but also by output delays throughout responding. During full serial recall of lists of long words, more time elapses until the words in later serial positions can be said than during recall of lists of short words. Because of the longer output delay, there is more time for the memory traces to decay in lists of long words. This notion that verbal output delays produce WLEs is supported by several findings: the WLE grew larger across serial positions in verbal serial recall (Cowan et al., 1992; experiment 1); in mixed lists containing short words followed by long words or vice versa, recall for long words in the later serial position was superior to recall for short words which were preceded by long words allowing for more decay (Cowan et al., 1992; experiments 2 and 3). In verbal serial recall and to a lesser extent in probed recall (i.e. a memory task type in which not all words have to be reproduced, but one of the to-be-remembered words is probed per trial, e.g. it is required to name the first or third word when the first or third probe is presented) a WLE was also present under articulatory suppression when participants were required to rapidly say words like "the" to prevent subvocal rehearsal (Avons, Wright, & Pammer, 1994; experiments 1 and 2). Even though these experiments stress the role of output in producing a WLE, it is unlikely that output delays are the only source of the WLE because reduced but reliable WLEs were also found in experiments with serial recognition tasks that eliminated the output differences of verbal serial recall (Baddeley, Chincotta, Stafford, & Turk, 2002).

Most studies examining the WLE in children and adolescents with ID only tested word spans with verbal serial recall tasks so that it is not possible to decide whether the WLE found in the control group and sometimes in the experimental group indicated rehearsal or was only caused during output. Two studies were exceptional in this regard (Jarrold, Baddeley, & Hewes, 2000; Russell et al., 1996), focusing on the PSTM of children with autism or children with Down syndrome and including control groups of children with ID of nonspecific aetiology. Russell et al. (1996) reported inconclusive results on the question whether children with ID differ in rehearsal from typically developing children with a mean mental age of 6 years. While the WLE did not differ significantly between groups, the correlation between articulation speed and memory span was only significant in the MA control group, but not in the group with ID. In their samples with mental ages of about four to five years, Jarrold et al. (2000) found WLEs only in a verbal serial recall task but not in a probed recall task. They therefore concluded that neither the individuals with ID nor the typically developing children engaged in spontaneous subvocal rehearsal. Likewise, experiments by Henry (1991) showed that in typically developing 5-year-olds, there was no WLE in probed recall tasks with no full verbal output requirements and suggested that the WLE in verbal serial recall tasks was caused by verbal output only. In 7-year-olds, however, a WLE could be found with probed recall tasks indicating that subvocal rehearsal starts to develop between the ages of 5 and 7 years.

Because there is a lack of studies that examine the WLE in children with ID focusing on a mental age of 6–8 years, and that take effects of verbal output on the WLE into consideration, we planned such a study. Since some previous studies reported a WLE for children with ID and a mental age of roughly seven years but others did not (whilst for the control groups the WLE was consistently found), we suppose that the WLE in verbal serial recall is smaller in children with ID and only caused by output delays, whereas output delays and subvocal rehearsal both contribute to the larger WLE in typically developing children matched for mental age.