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Growth of verbal short-term memory of nonwords varying in phonotactic probability: A longitudinal study with monolingual and bilingual children

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ABSTRACT

This study investigates the hypothesis that verbal short-term memory growth in young children can be explained by increases in long-term linguistic knowledge. To this aim, we compare children's recall of nonwords varying in phonotactic probability. If our assumption holds, there should be growth in recall of high-probability nonwords, but no or less growth in recall of low-probability nonwords. Monolingual and bilingual children are compared to see if bilingual children who have less phonotactic knowledge of the target language (Dutch) show different growth patterns than their monolingual peers. Participants were 72 monolingual Dutch children and 69 bilingual Turkish-Dutch children with Dutch as their non-dominant language. Children were assessed at four, five and six years of age. At all ages, they completed serial nonword recall tasks containing Dutch-based high- and low-probability nonwords. They also performed a series of control measures, including a Dutch receptive vocabulary task. Latent Growth Modeling was used to model the data. A model with clear improvement in children's recall of high-probability nonwords, but no improvement in recall of low-probability nonwords in both groups, and equal gains of recall of high-probability nonwords in the two groups, gave good fit to the data. These results indicate that (i) verbal short-term memory growth can be explained by increases in long-term phonotactic knowledge and (ii) bilingual children with lower levels of phonotactic knowledge in the target language benefit from such knowledge to the same degree as monolingual children.

Introduction

Verbal-short term memory is not stable, but develops during childhood such that children are able to remember increasingly longer lists of nonwords or digits (Alloway, Gathercole, & Pickering, 2006; Gathercole, 1998; Gathercole, Pickering, Ambridge, & Wearing, 2004). To explain this growth, a number of factors have been proposed, including increased articulation rate enabling faster rehearsal of verbal material (Hulme, Thomson, Muir, & Lawrence, 1984), slower decay of memory traces (Cowan, Nugent, Elliott, & Saults, 2000; Gomes et al., 1999), increased memory capacity (Cowan & Alloway, 2009), or better developed executive functions (Rypma, Prabhakaran, Desmond, Glover, & Gabrieli, 1999). Another factor that has been proposed relates to the impact of long-term linguistic knowledge on verbal short-term memory performance, in particular of phonotactic knowledge, which refers to the statistical distribution of phonemes and phoneme clusters in a language (Roodenrys, Hulme, & Brown, 1993). In a series of studies, verbal short-term memory performance on nonword

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repetition and nonword recall tasks was enhanced for nonwords containing frequent phoneme combinations as compared to nonwords containing less frequent phoneme combinations, indicating that long-term knowledge about phoneme distributions (or phonotactic knowledge) supports short-term storage (Kovacs & Racsmany, 2008; Majerus, Van der Linden, Mulder, Meulemans, & Peters, 2004; Messer, Leseman, Boom, & Mayo, 2010; Thorn & Frankish, 2005).

Previous studies on the development of verbal short-term memory are typically cross-sectional rather than longitudinal (Alloway et al., 2006; Gathercole et al., 2004) and restricted to monolingual children. In this study, our aim is twofold. First, we examine growth of verbal short-term memory longitudinally in children aged four to six years. We hypothesize that growth in verbal short-term memory during this period can be explained by growing long-term language knowledge. If this is indeed the case, we expect to see growth in children's recall of high-probability nonwords, but no growth or much smaller growth in their recall of low-probability nonwords, as for the latter type of nonwords, not much support from long-term linguistic knowledge about phonotactics is available. Our second aim is to compare monolingual and (sequential) bilingual children to see if bilingual children show the same growth patterns as monolingual children. We hypothesize that sequential bilingual children have had less exposure to the target language, Dutch, and therefore have less (and less well entrenched) Dutch phonotactic knowledge. Previous work on the same sample as studied here has shown that phonotactic knowledge affects verbal short-term memory in bilingual children's non-dominant (or second) language, albeit not as strongly as in monolingual peers (Messer et al., 2010). However, it remains to be investigated how verbal short-term memory develops in these children as a function of growing phonotactic knowledge of their second language.

The current study looks at bilingual children's first years in a rich second language (preschool) environment, when their knowledge of the second language develops rapidly. As for recall of low-probability nonwords, we predict a similar growth rate in the monolingual and bilingual children, because, for both groups, there will be no or only very little support from long-term memory. For recall of high-probability nonwords, there is no clear hypothesis, so we consider three possible outcomes: (i) the bilingual children show a similar growth rate as the monolingual children, since phonotactic knowledge and the support thereof may develop at a similar pace in both groups, (ii) the bilingual children show a slower growth rate than the monolingual children due their comparatively smaller amount of exposure to the second language, and hence, slower development of phonotactic knowledge in this language, or (iii) they show faster growth than the monolinguals due to their immersion in a rich second language environment, causing a catch-up effect of their phonotactic knowledge of the second language, similar to well-observed catch-up effects in Dutch vocabulary in this group during the early school years (Extra, Aarts, van der Avoird, Broeder, & Yagmur, 2001).

Verbal short-term memory development

Cross-sectional studies have shown that verbal short-term memory capacity grows significantly during childhood (Alloway et al., 2006; Gathercole et al., 2004). Children are able to remember increasingly longer sequences of spoken digits and other words, from two to three items at the age of four to about six items when they are twelve years old (Gathercole, 1998). Studies on bilingual children and children learning a second language in a classroom setting have found rather similar growth patterns in verbal short-term memory capacity, both in children's first language (Chincotta & Underwood, 1997; Hu, 2003; Swanson, Saez, & Gerber, 2006) and in their second language (Chiappe, Siegel, & Wade-Woolley, 2002; Chincotta & Underwood, 1997; French & O'Brien, 2008; Service, 1992; Service & Kohonen, 1995; Swanson et al., 2006). Different factors have been proposed to explain this growth, these factors being derived from the different processes that are assumed to be involved in the recognition, encoding and storage of verbal material (for reviews, see Cowan & Alloway, 2009; Gathercole, 1998, 1999).

According to the commonly used working memory model of Baddeley and Hitch (1974), individuals store incoming verbal information temporarily in a phonological form in the storage component of the phonological loop, where the memory trace decays in about two seconds if not rehearsed. A sub-vocal rehearsal system refreshes information in the phonological loop, by rehearsing verbal information out loud or silently, as a strategy to prevent decay of memory traces. Traditionally, it was thought that developmental increases in memory capacity during childhood could be entirely explained by growth in articulation rate supporting the efficiency of (sub-)vocal rehearsal as a strategy to prevent decay. Specifically, since rehearsal takes place in real time, increases in articulation speed would result in a higher number of memory traces that can be refreshed in the phonological store (Hulme et al., 1984). However, there are indications that children use rehearsal strategies only from seven years of age onwards (Baddeley, Gathercole, & Papagno, 1998), making it unlikely that increases in articulation rate explain the substantial growth in memory performance observed during the first years of life.

A number of alternative mechanisms have been proposed to account for increases in short-term memory capacity during childhood. First, it has been assumed that the rate of decay of memory traces decreases as children grow older (Cowan et al., 2000; Gomes et al., 1999). Although Baddeley and Hitch's memory model assumes that the rate of decay is about two seconds in all individuals and does not change with age, behavioral and electrophysiological studies have shown a developmental change in the retention of verbal material in short-term memory (Cowan et al., 2000; Gomes et al., 1999). However, in these studies, children between six and ten years behaved similarly to each other (but differently from adults) in most respects, suggesting that developmental changes in decay rate are not a plausible explanation of verbal short-term memory growth, at least not in school-aged children. A second suggested explanation for