Developmental delays in phonological recoding among children and adolescents with Down syndrome and Williams syndrome

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ABSTRACT

This study examined the development of phonological recoding in short-term memory (STM) span tasks among two clinical groups with contrasting STM and language profiles: those with Down syndrome (DS) and Williams syndrome (WS). Phonological recoding was assessed by comparing: (1) performance on phonologically similar and dissimilar items (phonological similarity effects, PSE); and (2) items with short and long names (word length effects, WLE). Participant groups included children and adolescents with DS ($n = 29$), WS ($n = 25$) and typical development ($n = 51$), all with average mental ages around 6 years. The group with WS, contrary to predictions based on their relatively strong verbal STM and language abilities, showed no evidence for phonological recoding. Those in the group with DS, with weaker verbal STM and language abilities, showed positive evidence for phonological recoding (PSE), but to a lesser degree than the typical group (who showed PSE and WLE). These findings provide new information about the memory systems of these groups of children and adolescents, and suggest that STM processes involving phonological recoding do not fit with the usual expectations of the abilities of children and adolescents with WS and DS.

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What this paper adds

Children and adolescents with Down syndrome show some evidence of using phonological recoding. Children and adolescents with Williams syndrome show no evidence of using phonological recoding. Development of phonological recoding is related to both language and cognitive abilities.

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1. Introduction

Vygotsky (1987) believed that a fundamental aspect of the development of thinking involves a progression from private speech to inner speech; or from non-communicative speech, which often 'helps' problem-solving when children talk to themselves about possible actions, to verbally based internal thought processes that are not spoken aloud. This progression plays a crucial role in the development of cognition. More specifically, Vygotsky suggested that inner speech provides a new code for higher level thinking and that much of adult thinking occurs with inner speech. More recently, Winsler and Naglieri (2003) provided evidence for this progression by showing that children's inner speech strategies progressed from overt, to partially covert, to fully covert forms with age. However, Alderson-Day and Fernyhough (2015, p. 931), in their recent review, have argued that the study of inner speech is 'diffuse and largely unintegrated', indicating a need to investigate fundamental processes. One of these is the ability to form a phonological code when processing information about visual material.

The purpose of the current study was to examine the development of an indicator of inner speech, namely phonological recoding in short-term memory (STM). We looked at this process in two clinical groups with contrasting STM and language profiles: those with Down syndrome (DS) and Williams syndrome (WS). *Phonological recoding* refers, in the current study, to the process of recoding *non-verbal* stimuli into a phonological form, for example, remembering the names of a series of pictured objects rather than remembering their visual images. This is not to be confused with the former label for 'decoding' in reading, which was also called phonological recoding (and involved the conversion of printed visual stimuli into phonological forms).

The mechanisms underlying phonological recoding can be understood with reference to the working memory model, which was used to provide the theoretical underpinning for the current study (Baddeley & Hitch, 1974; Baddeley, 1986, 2000). One of the components of this model is the 'phonological loop', a temporary (1–2 s duration) passive storage system for speech-based information, usually regarded as the mechanism underlying verbal short-term memory. The phonological loop includes a passive 'phonological store', and also contains the facility to rehearse the contents of the phonological store and keep them activated, via the 'articulatory rehearsal mechanism'. This can be seen as a recycling mechanism that constantly enters and re-enters the phonological information into the phonological store to prevent decay. A further function of the articulatory rehearsal mechanism is to carry out phonological recoding, the means by which *non-verbal* information can be recoded into a verbal form and subsequently stored in the phonological store. This form of inner speech can enhance the short-term recall of visually presented materials for which verbal labels are available. For auditorily presented speech items, there is no need for phonological recoding, because auditory items have direct access to the phonological store as phonological codes are created by the vocal input (e.g., Penney, 1989). On the other hand, visually presented items such as nameable pictures can only enter the phonological store indirectly, after a phonological code has been created.

Phonological recoding provides a strong indicator of children's potential to use inner speech, which is especially relevant to the attainment of higher level thinking in the two clinical groups considered here. Not only is phonological recoding linked to the use of inner speech, but weaknesses in phonological recoding have also been linked to delayed development of reading abilities (Palmer, 2000b), a key ability for educational progress. Furthermore, the two clinical groups' uneven cognitive profiles allow interpretation of the relative importance of cognition and language for inner speech development. We will first review the language and cognitive profiles for individuals with DS and WS, before considering how to assess phonological coding in these groups. Finally, we review previous studies on phonological recoding in individuals with DS and WS.

DS is characterised at the genetic level by a triplicate copy of chromosome 21 (trisomy 21) as well as phenotypical characteristics such as mild to severe intellectual disabilities (Chapman & Hesketh, 2000; Pennington, Moon, Edgin, Stedron, & Nadel, 2003), precocious aging and high risk of dementia (Numminen, Service, Ahonene, & Ruoppila, 2001). It is by far the most commonly observed genetic disorder, occurring in approximately 1 in every 691 live births (Parker et al., 2010). Individuals with DS display broad weaknesses in language, including expressive vocabulary and grammar (Næss, Lyster, Hulme, & Melby-Lervåg, 2011), and phonological awareness (Næss, Melby-Lervåg, Hulme, & Lyster, 2012; Roch & Jarrold, 2008), although receptive vocabulary appears to be in line with non-verbal mental age (Laws & Bishop, 2004; Næss et al., 2011). In terms of short-term memory (STM), individuals with DS usually show relative weaknesses in verbal STM (see a range of studies including: Carney et al., 2013; Jarrold & Baddeley, 1997; Laws & Bishop, 2003; Smith & Jarrold, 2014b; Vicari, Marotta & Carlesimo, 2004; Wang & Bellugi, 1994), combined with relative strengths in visuospatial STM (e.g., Carretti & Lanfranchi, 2010; Yang, Conners, & Merrill, 2014). Importantly, these relative strengths in visuospatial STM occur in comparison to verbal STM, not in comparisons to mental age, as some visuospatial abilities are mental age appropriate and others are slightly below mental age expectations (Yang et al., 2014).

WS is a rare genetic disorder which occurs in approximately 1 in every 7500 individuals (Strømme, Bjørnstad, & Ramstad, 2002). The psychological phenotype of WS is primarily characterised by mild to moderate intellectual disabilities with a mean IQ of around 55 (e.g., Martens, Wilson, & Reutens, 2008), relatively strong verbal abilities (Howlin, Davies, & Udwin, 1998; Udwin, Yule, & Martin, 1987) and weaker non-verbal abilities such as spatial cognition and visuospatial construction (Martens et al., 2008). Often, those with WS have an outgoing, loquacious and distinctly 'hypersociable' personality type (Jones et al., 2000; Porter, Coltheart, & Langdon, 2007), which has been referred to as "cocktail party syndrome" (Bellugi, Birhle, Neville, Jernigan, & Doherty, 1992; Udwin & Yule, 1990). Individuals with WS are usually described as having relatively strong language abilities, but language is still delayed in relation to chronological age (Martens et al., 2008). There is agreement that WS involves an uneven profile of language abilities from neuroconstructivists (e.g., Karmiloff-Smith, Brown, Grice, &