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Working memory studies among individuals with intellectual disability: An integrative research review

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ABSTRACT

Background: Integrative research review infers generalizations about a substantive subject, summarizes the accumulated knowledge that research has left unresolved and generates a new framework on these issues. Due to methodological issues emerging from working memory (WM) studies in the population with non-specific intellectual disability (NSID) (N = 64) between 1990–2014, it is difficult to conclude on WM performance in this population.
Aim: This integrative research review aimed to resolve literature conflicts on WM performance among individuals with NSID and to identify the conditions/moderators that govern their WM performance compared to controls with Typical development.
Method/procedure: We used the six stages of integrative research review: problem formulation, data collection, evaluation, data analysis, results, interpretation and discussion.
Outcomes and results: The findings indicate two types of moderators that determine WM performance in the population with NSID: Participants' moderators (criteria for matching the ID and TD groups, CA and MA), and **task** moderators [the three WM components of Baddeley and Hitch's (1974) model and task load]. Only an interaction between the two moderators determines WM performance in this population. The findings indicate a hierarchy (from more to less preserved) in WM performance of individuals with NSID: The visuospatial tasks, then some of the executive functions tasks, and the phonological loop tasks being less preserved. Furthermore, at a low level of control, the performance of participants with NSID was preserved beyond the modality and vice versa.
Conclusions and implications: Modality and MA/intelligence determine WM performance of individuals with ID. Educators should prepare intervention programs take the impact of the two moderators into account.

1. Introduction

"Working memory refers to a broad framework of interacting processes that involve the temporary storage and manipulation of information in the service of performing complex cognitive activities" (Baddeley, Allen, & Hitch, 2011, p. 1393).

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It evolved from the earlier concept of short-term memory (STM), from which it differs by emphasizing the functional importance of the system and by replacing a unitary store with a multicomponent system (Baddeley & Hitch, 1974).

Scientists are in disagreement on whether WM per se explains fluid intelligence (Garlick & Sejnowski, 2006) and whether the working memory (WM) capacity is associated with fluid intelligence (*g*) (Conway et al., 2005; Garlick & Sejnowski, 2006; Kane & Engle 2002). Baddeley (2000) (and in Baddeley et al., 2011) claimed that "Attention and temporary storage, are themselves unchanged by learning, other than indirectly via the crystallized systems". Kane and Engle (2002) stated that the "Executive attention, is the psychological core of the statistical construct of general fluid intelligence, or psychometric Gf (page 638)".

It has been documented that WM is associated with cognitive skills such as problem solving, reasoning and academic achievements (Bayliss, Jarrold, Baddeley, & Leigh, 2005; Hitch & McAuley, 1991) as well as with everyday life skills such as reading, writing, arithmetic, and language (Gathercole, Alloway, Willis, & Adams, 2004; Numminen, Service, & Ruoppila, 2002) which enable an independent life. Thus, the importance of WM in the population with intellectual disability) is thus self-evident (Van der Molen, Luit, Van de Molen, & Jengmans, 2011).

The most widely recognized model of WM is that of Baddeley and Hitch (1974) and Baddeley (2003, 2008). This model assumes a limited capacity controller, the central executive, supported by two temporary slave systems, the phonological loop and the visuospatial sketchpad. *The phonological loop* involves the temporary storage of phonological auditory information and is comprised of two sub-systems: The phonological store and the sub-vocal rehearsal process (Schuchardt, Maehler, & Hasselhorn, 2011). The *visuospatial sketchpad* is assumed to be capable of holding and manipulating visual and spatial information. The use of spatial imagery in immediate recall is disrupted by tasks such as tracking a moving object (Baddeley, Thomson, & Buchanan, 1975), while memory for pattern and shape is disrupted by the passive processing of line drawings, or even colour patches (Logie & Pearson, 1997; Logie, 1986). *The central executive* is involved in conditions of high level processing, including a set of high level attentional cognitive abilities such as planning, attention, inhibition and shifting (Baddeley et al., 2011; Camos & Barrouillet, 2014). A neutral modality storage, the episodic buffer, has recently been proposed (Baddeley et al., 2011), which is assumed to be a temporary multidimensional store that forms an interface between the subsystems of WM, long-term memory (LTM) and the central executive. Its major function is to bind different sources of information into integrated chunks (Baddeley et al., 2011). The phonological loop, the visuospatial sketchpad and the central executive were examined broadly in the population with ID, whereas the episodic buffer was examined in only one study (Henry, 2010), and will therefore not be included in the present review.

Cornoldi, Rigoni, Venneri, and Vecchi (2000) argued that Baddeley's model cannot by itself explain WM performance patterns of individuals with ID. Cornoldi and Vecchi (2003) suggested a double '*Horizontal and vertical continuum*' model. The *horizontal continuum* relates to the above-mentioned components of Baddeley et al.'s (2011) model. The *vertical continuum* reflects the required degree of control which is defined by the amount of active processing necessary for manipulating the information maintained in a temporary memory system ranging from passive to active tasks (Cornoldi & Vecchi, 2003), i.e. the cognitive load inherent in the task. Some tasks that measure the articulatory loop or visuospatial sketchpad simply require remembering the material as it was presented, and involve a low level of control, while other tasks require a high level of control. The concept of cognitive load raised by Cornoldi and Vecchi (2003) parallels the concept of attention and cognitive load suggested by Camos and Barrouillet (2014). They define cognitive load as the duration of attentional capture divided by the total time of performing the task.

Scientists are interested in the question of whether WM is domain-specific or domain-general (Baddeley & Logie, 1999). In their time-based resource-sharing model, Camos and Barrouillet (2014) argue that domain-general resources are responsible for processing and storage and that attention is involved in both. They claim two systems that are involved in the maintenance of verbal information: the phonologica loop and the executive loop. The phonological loop is less attention-demanding (primary memory according to Unsworth & Engel, 2007) and involves the recalling of simple verbal tasks (i.e., digit span forward). The executive loop involves manipulation of the task in addition to just recalling, and demands a higher level of attention according to the tasks (inhibition, selecting, etc.).

Use of the phonological loop makes recall sensitive to the phonological characteristics of the material to be maintained, whereas the phonological nature of the memory items does not affect recall performance under the use of the executive loop. This does not imply that the executive loop is a "better" system of maintenance that should always be favored for verbal information. Because attentional refreshing is more attention-demanding than sub-vocal rehearsal, the former is very sensitive to the availability of attention and the presence of concurrent attention-demanding tasks. Attention is involved in both the retention of information and in processing activities. The capacity of the focus of attention appears clearly when verbal rehearsal is prevented, suggesting that maintenance of verbal information through attentional focusing and verbal rehearsal must be distinguished. Brain imaging studies reported distinct neural structures supporting the separation of these two loops.

As far as we know, only one study tapped the effect of cognitive load on WM performance among individuals with Down syndrome versus peers with typical development (TD) with the same mental age (MA) (Lanfranchi, Cornoldi, & Vianello, 2004). It was found that in tasks requiring a low level of control, children with Down syndrome showed impairment of verbal but not visuospatial WM tasks. As the requirement for control increased, they showed greater impairment on both tasks. The above study implies the need to examine the effect of cognitive load in WM tasks among individuals with non-specific