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Working memory and intelligence are highly related constructs, but why?

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Abstract

Working memory and the general factor of intelligence (*g*) are highly related constructs. However, we still don't know why. Some models support the central role of simple short-term storage, whereas others appeal to executive functions like the control of attention. Nevertheless, the available empirical evidence does not suffice to get an answer, presumably because relevant measures are frequently considered in isolation. To overcome this problem, here we consider concurrently simple short-term storage, mental speed, updating, and the control of attention along with working memory and intelligence measures, across three separate studies. Several diverse measures are administered to a total of 661 participants. The findings are consistent with the view that simple short-term storage largely accounts for the relationship between working memory and intelligence. Mental speed, updating, and the control of attention are not consistently related to working memory, and they are not genuinely associated with intelligence once the short-term storage component is removed.

Keywords: Working memory; Intelligence; Short-term storage; Mental speed; Executive functioning; Updating; Controlled attention

There are several studies reporting strong relationships, at the latent variable level, between working memory and intelligence (Ackerman, Beier, & Boyle, 2002, 2005; Colom, Rebollo, Palacios, Juan-Espinosa, & Kyllonen, 2004; Colom, Abad, Rebollo, & Shih, 2005; Colom & Shih, 2004; Conway, Cowan, Bunting, Therriault, & Minkoff, 2002; Kane, Hambrick, Tuholski, Wilhelm, Payne, & Engle, 2004; Kyllonen & Christal, 1990; Miyake, Friedman, Rettinger, Shah, & Hegarty, 2001; Stauffer, Ree, & Carreta, 1996; Engle, Tuholski, Laughlin, & Conway, 1999). However, the components underlying their strong relationship remain mysterious, despite the research efforts made to date.

We think this is because published reports do not comprise a comprehensive and concurrent assessment of the constructs of interest. There are some studies considering verbal and quantitative tasks only (Conway et al., 2002; Engle, Tuholski, et al., 1999), whereas others analyze spatial tasks only (Miyake et al., 2001). There are some studies measuring working memory and short-term memory (Colom, Abad, et al., 2005; Colom, Flores-

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Mendoza, Quiroga, & Privado, 2005; Engle, Tuholski, et al., 1999; Kane et al., 2004), whereas others measure working memory and mental speed (Fry & Hale, 1996). Therefore, researchers undertake hard inferences about the components presumably underlying the relationship between working memory and intelligence. Is mental speed a key component? Is short-term storage capacity? Is the control of attention? Is executive functioning? Still we don't know.

1. Overview of the present studies

Working memory tasks comprise short-term storage plus some sort of processing requirements (Conway, Kane, Bunting, Hambrick, Wilhelm, & Engle, 2005; Engle, Kane, & Tuholski, 1999; Miyake & Shah, 1999) so their correlation with intelligence could be attributed to storage, processing, or both.

The present studies address the contribution of these storage and processing components. It must be emphasized from the outset that the tasks modelled for measuring the constructs of interest follow the mainstream. This underscoring implicates that here we are not concerned with the question of whether or not executive tasks, for instance, measure what they intend to. The tasks are modelled in ways routinely employed in the literature to tap the considered constructs. Their relationships regarding the working memory–intelligence network are explored concurrently.

Therefore, short-term storage is operationalized by simple memory span tasks, whereas working memory is defined by complex memory span tasks (Colom, Rebollo, Abad, & Shih, 2006). Engle, Tuholski et al. (1999) declare that "tasks thought to be good short-term memory tasks (…) can be performed with relative removal of attention from the representation of the list items", whereas "working memory tasks are characterized as dual tasks in that attention must be shifted back and forth between the representation of the list items and the so-called processing component of the task" (p. 314). Miyake et al. (2001) state: "for simplicity (and to follow the convention in the field) we hereinafter refer to simple storage-oriented span tasks with no explicit concurrent processing as short-term memory span tasks and to complex span tasks that involve not only a storage requirement but also an explicit concurrent processing requirement as working memory span tasks. According to this classification, traditional verbal span measures such digit and word spans are considered short-term span tasks, whereas more complex span measures such as reading or operation spans are considered working memory span tasks" (p. 622).

Here we measure short-term memory by tasks requiring the temporary maintenance of verbal, quantitative, or spatial simple items for latter recall, whereas working memory is measured by tasks requiring processing + storage verbal, quantitative, or spatial information. Conway et al. (2005) discuss the problem of scoring procedures for working memory tasks, suggesting that they should exhaust the information collected with a task. Therefore, participants' scores were obtained as the number of correct answers in both the processing and storage sub-tasks.

Because the processing component is multi-faceted, we measure mental speed (study 1), mental speed and executive functioning (study 2), and mental speed, executive functioning, and controlled attention (study 3) along with measures of short-term storage, working memory, and intelligence.

Mental speed is measured by simple verbal, quantitative, and spatial verification tasks. Participants are requested to verify, as quickly and accurately as possible, if a given test stimulus is presented within a small sized memory set. Note we are tapping the construct of mental speed as a property of the working memory system (i.e. short-term recognition speed). The design expressly avoids tapping constructs such as perceptual speed.

We can make this latter argument fully clear by comparing our approach with the study reported by Conway et al. (2002). According to our view, these researchers measured speed by tasks that do not tap directly the construct of interest. Firstly, they used psychometric speed tests (pattern comparison, letter comparison, and digit copying) widely known as measures of perceptual speed (Carroll, 1993). Mental speed may or may not correlate to perceptual speed, but mental speed, as a component of the working memory construct, should implicate at least minimal temporary storage requirements. Secondly, Conway et al.'s (2002) dependent measure was not speed per se, but the total number of correct responses. Thirdly, it is difficult to understand the high correlation between short-term memory and perceptual speed (.40), but the very low correlation between perceptual speed and working memory (−.06) in their study. Finally, the correlation between the perceptual speed factor and intelligence was surprisingly low (.07). For these reasons, we are inclined to suggest that, although interesting, Conway et al.'s (2002) operationalization of the speed component of the working memory construct should be seen with reservations.

Executive functioning is usually defined by the control and regulation of mental processes. Miyake, Friedman, Emerson, Witzki, and Howerter (2000) as well as Friedman et al. (2006) analyzed factors representing three executive functions: inhibition, shifting, and updating. Inhibition