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# Fluid/spatial and crystallized intelligence in relation to domain-specific working memory: A latent-variable approach

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**Abstract**

Fluid/spatial intelligence, crystallized intelligence and their relationships to verbal and visuospatial working memory (WM) were studied. A total of 120 Finnish Air Force recruits participated in this study. Fluid/spatial intelligence was assessed using four different tasks, while crystallized intelligence was defined with the help of test scores of Finnish upper secondary school National Matriculation Tests in three different academic subjects and one additional Verbal Relations task. Complex WM span tasks were used to measure visuospatial and verbal WM capacities. Structural equation modeling indicated that verbal WM was related to crystallized intelligence when both WM tasks were included in the model, whereas performance on the visuospatial WM task was related to fluid/spatial intelligence, but not to crystallized intelligence. Verbal WM was not related to fluid intelligence when used as a single WM predictor. The results indicate that verbal WM might be related to verbal ability and learning at school, while visuospatial WM is relatively strongly related to nonverbal reasoning and spatial visualization. The current results further suggest that WM capacity is not a unitary system.


*Keywords:* Intelligence; Working memory; Complex span task

## 1. Introduction

In modern psychology, the constructs of intelligence and working memory (WM) have advanced along separate paradigms. Psychometric intelligence research began already in the late 19th and early 20th centuries. No less than 70 years after its birth, Baddeley and Hitch (1974) introduced the theory of

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WM in modern cognitive psychology. Despite their paradigmatic distance from each other, intelligence and WM are both crucial constructs that are used to predict performance on various complex cognitive tasks (e.g., Just & Carpenter, 1992; Kyllonen & Christal, 1990; Ree & Carretta, 1996; Ree & Earles, 1996). However, only relatively recent studies have revealed a connection between intelligence and WM (e.g., Ackerman, Beier, & Boyle, 2002; Colom, Flores-Mendoza, & Rebollo, 2003; Colom, Rebollo, Palacios, Juan-Espinosa, & Kyllonen, 2004; Engle, Tuholski, Laughlin, & Conway, 1999; Kyllonen & Christal, 1990; Nečka, 1992; Schweizer & Koch, 2002; Stankov, 2000; Verguts & De Boeck, 2002). Thus far, the number of these studies is rather small. Therefore, the main goal of the present study was to provide further evidence about how specified intelligence factors are separately related to visuospatial and verbal WM tasks.

In Spearman's (1927) terms, *general intelligence* (*g*) is considered to be an abstract, statistically defined construct that indicates that all cognitive tasks and intelligence tests tend to correlate positively with each other. Based on factor analyses, some tests are more strongly *g* loaded than others. Most of the highly *g*-loaded tests are nonverbal and many of them demand reasoning of spatial relations. In applied settings, *g*-loaded extensive test batteries have been the best predictors of job performance, training, and academic success (see Jensen, 1998; Ree & Carretta, 1996; Ree & Earles, 1996; Rolfhus & Ackerman, 1999; Snow & Yalow, 1982).

Since the early years of the 20th century, several intelligence factors have been defined (see Sternberg, 1982). For instance, Cattell and Horn (Cattell, 1963, 1971, 1987; Horn, 1968; Horn & Cattell, 1966, 1967) found in their empirical work that the single *g* factor is not sufficient to explain all variance of intelligence tests. Their widely confirmed theory claims that intelligence consists of two higher order factors, fluid and crystallized intelligence. However, some researchers (Undheim & Gustafsson, 1987) have suggested that fluid intelligence and general intelligence may be equivalent concepts. Fluid intelligence is defined as the ability to reason under novel conditions and crystallized intelligence is related to performance based on already learned knowledge and experiences. More specifically, fluid intelligence is said to reflect an ability to induce abstract relations (Carpenter, Just, & Shell, 1990), whereas crystallized intelligence is said to reflect scholastic achievement and cultural knowledge (Cattell, 1971). High fluid intelligence tends to predict high crystallized intelligence if educational opportunities are available (Cattell, 1971). In younger age groups, fluid and crystallized intelligence are more closely related than in older age groups, because school curriculum tends to standardize students' knowledge base (Schweizer & Koch, 2002). In adulthood, the acquisition of specialized knowledge in different professions decreases the relationship between fluid and crystallized intelligence (Schweizer & Koch, 2002).

The second essential concept for the present study is WM. Two different main traditions in WM research have prevailed. In Europe, Baddeley and Hitch (1974) introduced the WM model with two slave systems, a phonological loop and a visuospatial sketchpad, and one coordinating system, the central executive (see Baddeley, 1986). The phonological loop is responsible for temporary storing and rehearsing of the verbally coded information, while the visuospatial sketchpad maintains visual and spatial material. Recently, additional slave systems have been suggested, for example, for music (Berz, 1995) and episodic memory (Baddeley, 2000). The central executive coordinates the slave systems by controlling encoding and retrieval, switching attention between the tasks, and controlling the mental manipulation of domain-specific material (Baddeley, 1996).

In contrast to the modular conception adopted in Europe, North American research has suggested that WM is a unitary system or capacity. This approach has focused on individual differences, and within it,