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# On the special relationship between fluid and general intelligence: New evidence obtained by considering the position effect

Karl Schweizer [a,*], Stefan J. Troche [b], Thomas H. Rammsayer [b]

[a] Department of Psychology, Johann Wolfgang Goethe University, Frankfurt, Germany
[b] Department of Psychology, University of Bern, Bern, Switzerland

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ABSTRACT

We investigated the influence of the position effect on the relationship between fluid intelligence and general intelligence. The position effect reflects the dependency of responses to items on the position of the items and, therefore, is a possible bias in measurement. A special confirmatory factor model enables the subdivision of the true component of a fluid intelligence measure into ability-specific and position-specific parts. Both parts of the measure of fluid intelligence are related to general intelligence in the framework of a hierarchical model. In a sample of 203 participants the ability-specific part that may be considered as purified fluid intelligence showed an almost perfect relationship to general intelligence. Although the position-specific part also correlated with general intelligence, this correlation was remarkably smaller than the correlation for purified fluid intelligence.



## 1. Introduction

Proceeding from Spearman's (1904) pioneering work, general intelligence is considered a very basic ability related to a broad variety of cognitive and biological processes (Jensen, 1998). It is this property that complicates the search for the source of general intelligence. In contrast, fluid intelligence, as proposed by Cattell (1963), is less general and assumed to primarily contribute to higher mental activities such as reasoning, problem solving, and abstract thinking.

Hierarchical models of cognitive ability (e.g., Alfonso, Flanagan, & Radwan, 2005; Carroll, 1993; McGrew, 2005, 2009), which are currently very popular, widely agree that human ability can be described as a hierarchy with general intelligence at the top of this hierarchy. In Carroll's (1993) Three-stratum Model of Cognitive Ability, fluid intelligence is conceptualized as second-order ability and, thus, as a member of the same stratum as crystallized intelligence, visual perception (or visual ability) and other second-stratum factors.

Visual ability, which is another ability of interest for our considerations, shows a substructure including visualization, mental rotation, and closure. It corresponds to Carroll's (1993) visual-perception factor as broad second-stratum ability. Visual ability is clearly separable from fluid intelligence (Schweizer, Goldhammer, Rauch, & Moosbrugger, 2007) but both abilities show substantial loadings on general intelligence (Ullstadius, Carlstedt, & Gustafsson, 2004).

Although fluid intelligence and visual ability are both second-order abilities within the Three-stratum Model, they refer to different aspects of cognitive information processing. Fluid intelligence is assumed to be involved in rather abstract cognitive operations whereas visual ability is necessary for matching external stimuli and cognitive concepts. Investigating general ability in combination with these second-order abilities is especially challenging. An implicit assumption of hierarchical models is that upper-level abilities cause the association between different lower-level abilities. This assumption is indicated by the direction of the arrows in Panel A of Fig. 1 relating general intelligence to fluid intelligence and visual ability as two distinct lower-level abilities. Specificities of lower-level abilities are actually independent of each other. Therefore, correlations between such lower-level abilities must arise from the influence of the common upper-level ability.

Within this conceptual framework, evidence for a close relationship between general and fluid intelligence has been achieved by means of conventional methods, such as correlational analyses and exploratory factor analyses (e.g., Carroll, 1993). In contrast, applying more advanced methods such as confirmatory factor analysis (CFA) led to the competing notion of virtual parity of general and fluid intelligence (Gustafsson, 1984; Kvist & Gustafsson, 2008). Similarly, Marshalek, Lohman, and Snow (1983) obtained corresponding results by applying radex and hierarchical models that took the complexity of the models of cognitive ability into account.

* Corresponding author. Address: Department of Psychology, Goethe University Frankfurt, Mertonstr. 17, 60054 Frankfurt a. M., Germany. Tel.: +49 69 798 22081; fax: +49 69 798 23847.
E-mail address: K.Schweizer@psych.uni-frankfurt.de (K. Schweizer).

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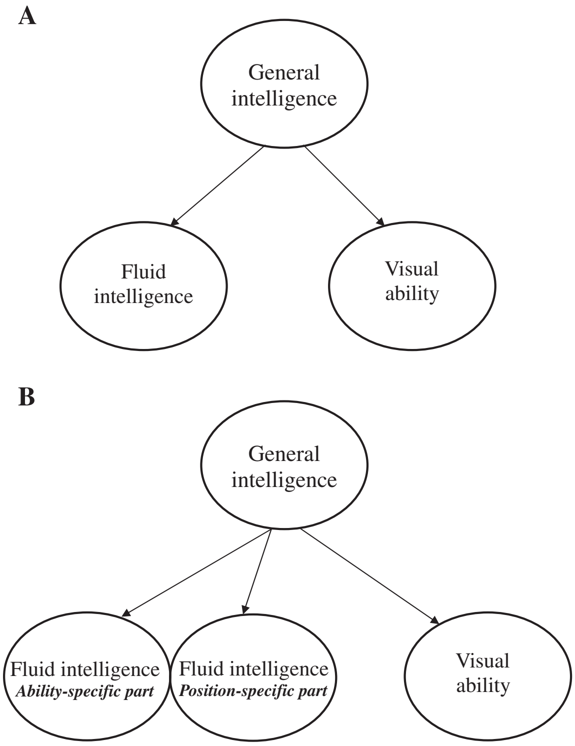


**Fig. 1.** Two-levels ability structure with general intelligence as second-order latent variable and fluid intelligence and visual ability (Panel A) or the ability-specific and position-specific parts of fluid intelligence and visual ability (B) as first-order latent variables.

There is some evidence that psychometric tests for the measurement of fluid intelligence are prone to the so-called position effect (e.g., Kubinger, Formann, & Farkas, 1991; Schweizer, Schreiner, & Gold, 2009). This effect refers to the dependency of the response to a given item on the responses to previously processed items. To date, however, it remains unclear whether the position effect is related directly to fluid intelligence or whether it just dilutes the measurement of fluid intelligence.

Knowles (1988) reported an increase in item reliability as a function of the serial position of the item; the last items within a series of items were considerably more reliable than the first items. Thus, true variance increases with increasing distance from the beginning of the series of items. The position effect was originally observed in experimental settings (e.g., Hamilton & Shuminsky, 1990; Knowles, 1988; Knowles & Byers, 1996). But recent developments in CFA (Hartig, Hölzel, & Moosbrugger, 2007; Schweizer et al., 2009) allow for a representation of the position effect as a part of a confirmatory factor model as well as for the statistical decomposition of variance due to fluid intelligence from variance due to the position effect. Because the position effect has been predominantly observed in sets of similar items, learning processes such as implicit learning or priming mechanisms may represent a major candidate to account for the position effect.

In most ability scales items are arranged in an order of increasing difficulty so that a participant does not get stuck before having completed all items below his/her individual performance level. This arrangement may lead to a confounding of the position effect and the effect of item difficulty. Although this confounding effect cannot be avoided in such scales, results of experimental studies suggest that the position effect may be independent of the effect of item content (e.g., Knowles, 1988). In these studies the size of the position effect varied as a function of the positions of the item. So it was the manipulation of the position that was instrumental in stimulating the effect.

To date, the major focus of psychometric research on the position effect has been on scales assessing fluid intelligence; probably because such scales are rather homogeneous with a large number of highly similar items. The position effect was observed in Raven's Standard Progressive Matrices by applying methods of item response theory (Kubinger et al., 1991) and also in Raven's Advanced Progressive Matrices by specific models of CFA (Schweizer et al., 2009). Furthermore, position effects could be established for a scale assessing numerical reasoning (Schweizer, 2009).

The separation of ability- and position-specific components of measurement (Schweizer et al., 2009) proceeds from the assumption that both components constitute two independent latent variables. This assumption implies that the ability-specific part of measurement can be considered as the purified representation of the corresponding ability, whereas the position-specific part reflects the result of repeatedly processing similar items. These two latent variables can replace the latent variable representing fluid intelligence (see Panel B of Fig. 1). It is only the ability-specific part of the measurement of fluid intelligence that should be related to visual ability due to the influence of general intelligence. Although the position-specific part of the measure of fluid intelligence may also be related to visual ability, general intelligence cannot be the source. Thus, Fig. 1 illustrates that the representation of the position effect helps to gain new insight into the relationship between general and fluid intelligence when the measure of fluid intelligence is controlled for the influence of a possible bias due to item position.

The main goal of the present study was to further elucidate the relationship between general intelligence and fluid intelligence by using confirmatory factor models that enable the separation of ability- and position-specific components of a measure of fluid intelligence. For this purpose, fluid intelligence was measured with a numerical reasoning task. The representation of general intelligence was conceptualized as a second-order factor based on measures of fluid intelligence and visual ability. To avoid that performances on visual ability and fluid intelligence overlap due to the type of stimuli to be processed, the items of the visual ability tasks required processing of figural stimuli, while the items to assess fluid intelligence required numerical processing. Within this novel approach, we investigated whether the ability- or the position-specific component of fluid intelligence is more closely related to general intelligence. To achieve this goal, a confirmatory factor model for representing the position effect was transformed into a hierarchical confirmatory factor model by adding a second-order latent variable. Proceeding from this model, it was investigated whether the relation between general intelligence and fluid intelligence originates from the position effect inherent in most ability measures, or whether fluid intelligence is more closely related to general intelligence independent of a bias produced by the position effect.

## 2. Method

### 2.1. Participants

Participants were 83 male and 120 female university students with a mean age of 24.2 years (SD = 2.69). They were either paid or received course credit for participating in this study. Estimated on the basis of the reasoning measure, their corresponding IQ scores varied between 97 and 130.

### 2.2. Psychometric measures

#### 2.2.1. Numerical Reasoning Scale (Horn, 1983)

This scale was selected to measure fluid intelligence. It comprised 40 items arranged in a column. Each item consisted of a sequence of nine stimuli (numbers, letters, or pairs of letters).