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Short Communication

# Does processing speed exert an influence on the special relationship of fluid and general intelligence?

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

[a] Goethe University Frankfurt, Germany
[b] University of Witten/Herdecke, Germany
[c] Department of Psychology, University of Bern, Bern, Switzerland

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ABSTRACT

The paper investigates why the virtual correspondence of the ability component of fluid reasoning scores and general intelligence observed by Schweizer, Troche, and Rammsayer (2011) was not replicated by Lozano (2015). It is shown that the time limit of the scale used in the former study caused a speed effect that strengthened the relationship, whereas the scale used by Lozano (2015) that was considered as unspeeded did not cause such an effect. Modifying the statistical model to eliminate this effect resulted in similar estimates of the relationship between the ability component of fluid reasoning and general intelligence.

## 1. Introduction

Studies demonstrated that fluid reasoning is closely related to general intelligence (Gustafsson, 1984; Marshalek, Lohman, & Snow, 1983). This observation found its way into Carroll's (1993) model of human cognitive abilities with fluid reasoning showing the closest link of all second stratum abilities to general intelligence at the third stratum. More recent evidence of this special relationship was provided by Schweizer et al. (2011) using a hierarchical structural equation model. An attempt of a partial replication of this finding by Lozano (2015) confirmed the appropriateness of the model but failed to yield regression weights corroborating the assumption of a very close relationship between fluid reasoning and general intelligence. Because of the consequences for the construct definition of general intelligence, clarification regarding the closeness of this relationship is an important topic. The present paper investigates a possible reason for the divergence of the results by Schweizer et al. (2011) and Lozano (2015). It is argued that processing speed plays a crucial role in this relationship and, thus, needs to be controlled for in order to yield similar results.

Since contradictory results can originate from various differences between Schweizer et al.'s (2011) and Lozano's (2015) research, the search for the reason starts with a comparison of the two studies. In both studies, the variance of fluid reasoning scores was decomposed into ability-specific variance and variance due to the item position by means of a fixed-links model (Schweizer, 2008). This measurement model was integrated into the hierarchical structural equation model. The latent variables of the fluid reasoning scores were related to the latent variable representing general intelligence.

The two studies used different broad abilities, besides fluid reasoning, to extract general intelligence with mental rotation and visualization abilities in the study by Schweizer et al. (2011) and abilities reflecting working memory and perceptual speed in the study by Lozano (2015). Therefore, the representations of general intelligence could not be considered completely equivalent. However, in both studies quite different broad abilities have been measured so that the communality of these abilities reflects general intelligence to a considerable degree.

Furthermore, the studies differed in the scales used to assess fluid intelligence. While Schweizer et al. (2011) deployed the Numeric Reasoning Scale (NRS; Horn, 1983), Lozano (2015) used the Advanced Progressive Matrices (APM; Raven, Raven, & Court, 1997). Each item of NRS consists of a sequence of nine stimuli (numbers or letters). The order of stimuli follows an underlying rule with one exception. Participants are requested to identify the stimulus that does not fit into the sequence. The scale contains 40 items to be solved within 8 min. Raven's APM, on the other hand, assesses figural reasoning. An item consists of an arrangement of 3 × 3 squares, eight of them filled with simple geometric forms and one empty square, and a set of eight response options for completing the empty square. Participants are required to select the correct response option to complete the empty square. A total of 36 items has to be completed within 40 min.

Decomposing performance on the reasoning scale into ability-specific and item-position specific latent components, Schweizer et al.'s (2011) study yielded a virtually perfect relationship between the ability-specific and general intelligence latent variables as well as a significant, but less strong

* Corresponding author at: Department of Psychology, Goethe University Frankfurt, Theodor-W.-Adorno-Platz 6, 60323 Frankfurt a. M., Germany.
*E-mail address:* K.Schweizer@psych.uni-frankfurt.de (K. Schweizer).

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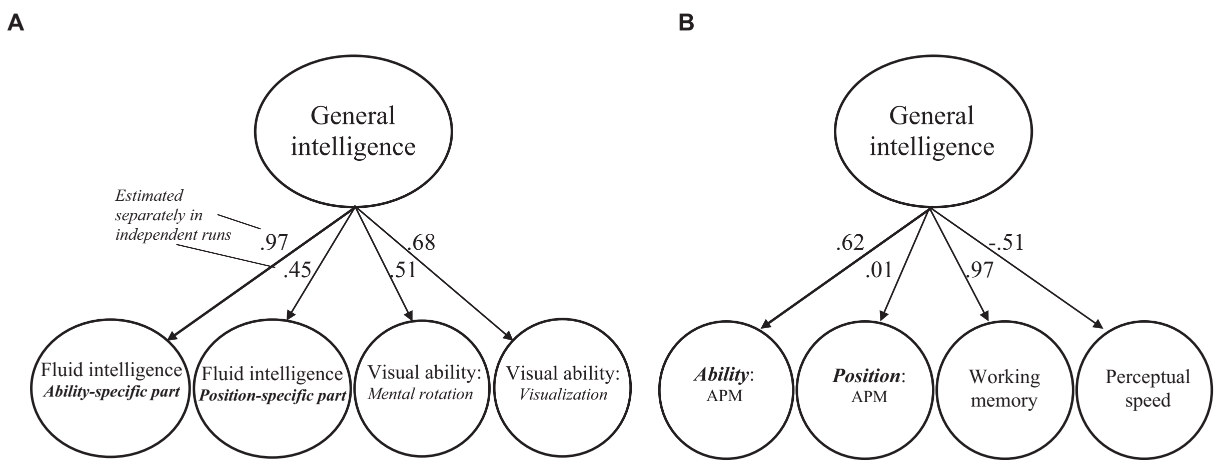


**Fig. 1.** Illustration of the latent structure of the models investigated by Schweizer et al. (2011) (see Panel A) and by Lozano (2015) (see Panel B) with standardized regression weights.

relationship between the position-specific and general intelligence latent variables (Fig. 1, Panel A). Lozano's (2015) study confirmed the appropriateness of the decomposition by the hierarchical structural equation model. Although his model resulted in a good model fit and the regression weights showed the same relationship among each other (see Fig. 1, Panel B), the regression weights were considerably smaller than those reported by Schweizer et al. (2011).

The regression weights dropped from 0.97 to 0.62 and from 0.45 to 0.01 for the ability-general intelligence and position–general intelligence links, respectively. While the former link was still significant in Lozano's (2015) study, the link between the position-effect and general intelligence latent variables was no longer substantial.

A possible reason for the contradictory regression weights are the different time limits for completing the items. The effect of a time limit is due to the coaction of the time limit and processing speed. It varies as a function of participants' characteristics and other influences such as the proportion of easy items included in the scale (Oshima, 1994). Low processing speed may prevent some participants from reaching their highest possible score on the reasoning scale, whereas other participants with high processing speed may reach their maximum score. This means that the observed rank-order of participants regarding the assessed mental ability under a time-limit condition may not reflect the rank-order that would have been observed otherwise. It also means that the validity of measurement is impaired (cf. Chuderski, 2013; Lu & Sireci, 2007; Ren, Wang, Sun, Deng, & Schweizer, 2017).

In a previous study, Schweizer and Ren (2013) investigated NRS by means of a statistical model that decomposed the fluid reasoning score into ability-specific, position-specific, and speed-specific components. The first component reflected a source equally contributing to all items, while the second component included a source linearly increasing from the first to the last item. The source reflected by the third component showed a strongly increasing effect on the last few items (primarily items with omissions). The observed substantial improvement in model fit due to the consideration of the speed-specific component indicated that NRS was indeed prone to the effect due to a time limit if the recommended time span was selected. To date, however, the consequences for the relationship between the ability-specific latent variable and the latent variable representing general intelligence have not been investigated, yet.

Therefore, the main aim of the present re-analysis was to investigate whether the contradictory findings regarding the relationship between fluid reasoning and general intelligence reported by Lozano (2015) and Schweizer et al. (2011) can be explained by the effect of a more restricted time limit in NRS than in APM. For this purpose, Schweizer et al.'s (2011) data, which are suspected to comprise the effect of a time limit, were re-analyzed and the revised estimates of the relationship between fluid reasoning and general intelligence were compared with the estimates reported by Lozano (2015).

## 2. Method

The sample included 203 participants (83 males, 120 females) with a mean age of 24.2 years (SD = 2.69). All participants were university students who were paid or received course credit.

For this re-analysis, a revised statistical model was required. In the original study by Schweizer et al. (2011), the separation of the ability-specific and position-specific components of NRS was accomplished by means of a measurement model that included two latent variables. The factor loadings on the first latent variable were adapted from the essentially tau-equivalent model of measurement. The factor loadings on the second latent variable were constrained according to pre-selected values showing a linear increase that is faded out in the last items. The fade-out is due to the exclusive effect of processing speed as omission that increasingly prevents the other sources of responding from contributing. The ability-specific and position-specific latent variables were assumed to be uncorrelated.

For re-analyzing the data, the representation of the speed effect required the integration of another component into the measurement model for NRS. Since this measurement model served the separation of three different sources of systematic responding, it was also necessary to constrain the factor loadings on the third latent variable included in this model. The values used for the fixation of the factor loadings were adapted from the study by Schweizer and Ren (2013) that also used NRS data. In their study, the values were obtained by means of the logistic function. This function assured that only the factor loadings of the items that were not reached by all participants showed large sizes. Fig. 2 provides graphical representations of the factor loadings on all

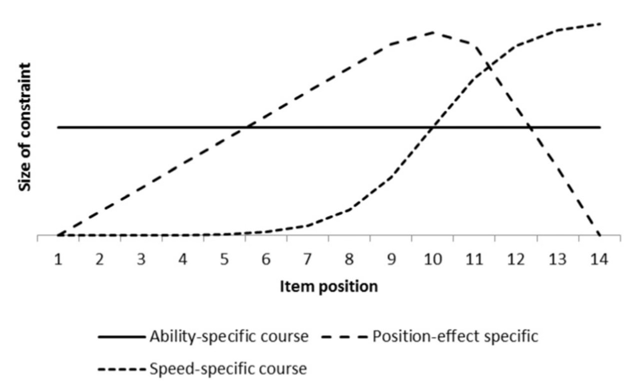


**Fig. 2.** Curves illustrating the courses of factor loadings before conducting the link transformation.