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Working memory, visual–spatial-intelligence and their relationship to problem-solving

Markus Bühner [a,*], Stephan Kröner [b], Matthias Ziegler [c]

[a] Department of Psychology, Ludwig-Maximilians University Munich, Germany
[b] Department of Educational Psychology, Faculty of Education, Friedrich-Alexander-University Erlangen-Nuremberg, Germany
[c] Humboldt University Berlin, Germany

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ABSTRACT

The relationship between working memory, intelligence and problem-solving is explored. Wittmann and Süß [Wittmann, W.W., & Süß, H.M. (1999). Investigating the paths between working memory, intelligence, knowledge, and complex problem-solving performances via Brunswik symmetry. In P.L. Ackerman, R.D. Roberts (Ed.), *Learning and individual differences. Process, trait content determinants* (pp. 77–104). Washington: APA.] showed that working memory shares unique variance with problem-solving beyond intelligence. We used measures of visuo-spatial intelligence (G_v) and working memory to predict performance in the simulation-based problem-solving test *MultiFlux* in a sample of N=144 undergraduate students. SEM analyses showed that while there was no unique contribution of G_v, working memory was a significant predictor of *MultiFlux* rule knowledge and rule application. This result is not in line with findings by Wittmann and Süß. It is discussed that task content (verbal, figural, numerical) might play an important role in explaining the relationship between intelligence and problem-solving.

Using dynamic computer-based simulations for assessment purposes has the potential of bridging the gap between real world problem-solving and static tasks constructed to assess problem solving for research questions. However, if such simulations are to be used, their construct validity has to be explored. Especially, the relation of performance in problem-solving scenarios with measures of "established" constructs like intelligence and working memory has to be investigated. In the following, we first review past research on problem-solving and intelligence. Then we discuss whether working memory and intelligence are distinct constructs. This is a prerequisite for differentiating between them while predicting problem-solving performance in the present study.

A strong research tradition is concerned with the relationship between working memory and intelligence (e.g., Buehner, Krumm, & Pick, 2005; Kyllonen & Christal, 1990). The same holds true for problem-solving and intelligence (Kröner, 2001; Kröner & Leutner, 2002; Kröner, Plass, & Leutner, 2005; Süß, 1996; Süß, Oberauer, Wittmann, Wilhelm, & Schulze, 2002; Wittmann & Süß, 1999). However, up to now, the network of relations between all three constructs has rarely been empirically assessed. Hence, in the present study we will investigate this network of relationships.

1. Intelligence and problem-solving

Although originally, it was thought that problem solving abilities as measured by performance in computer simulations would be independent from intelligence, correlations between these constructs have repeatedly been shown (Kröner et al., 2005; Rigas, Carling, & Brehmer, 2002; Süß, 1996).

Rigas et al. (2002) used the scenarios NEWFIRE and Kühlhaus to assess problem-solving performance. When corrected for attenuation, the correlations between problem-solving scores and intelligence (Advanced Progressive Matrices, APM, Raven, 1976) were r=.34 (NEWFIRE) and r=.43 (Kühlhaus).

Süß (1999) also found moderate to high correlations between fluid intelligence as measured by the Berlin-Intelligence-Structure test BIS-K (Jäger, Süß, & Beauducel, 1997) and an aggregated problem-solving score from the

* Corresponding author. LMU Munich, Leopoldstraße 13, 80802 Munich, Germany. Tel.: +49 89 21 80 62 57; fax: +49 89 21 80 30 00.
E-mail address: buehner@edu.uni-muenchen.de (M. Bühner).

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scenarios *PowerPlant*, *Tailorshop*, and *Learn*. He further concluded that lower correlations reported in earlier studies might have been due to low reliabilities of some problem-solving tasks. He also argued that low reliabilities of problem-solving scores might be due to uncontrolled individual differences in prior knowledge. Although statistically controlling for the influence of prior knowledge is possible to some degree, this procedure will only be successful if all relevant prior knowledge is assessed with specific knowledge tests. Otherwise, correlations of problem-solving performance with other constructs may still be biased. To avoid such pitfalls, the problem-solving scenario *MultiFlux* was constructed by Kröner (2001).

MultiFlux is a domain-independent simulation with an evaluation-free exploration phase. Therefore, no simulation-specific prior knowledge acquired under uncontrolled conditions helps or hinders task completion. Kröner et al. (2005) found correlations up to $r=.65$ between problem-solving performance on *MultiFlux* and intelligence (BIS-K). Three components of problem-solving performance were confirmed: ***rule identification, rule knowledge and rule application***. The largest correlations with intelligence were observed for rule knowledge and rule application. In other words, people who acquired more rule knowledge during simulation exploration are better in applying this knowledge at least partly because they are more intelligent. Thus, in the present study we focused on the variables of rule application and rule knowledge.

Most of the studies on computer-simulated problem solving cited above use g_f or g as operationalizations of intelligence ignoring the content of the problem solving task(s). This might lead to biased correlations with problem solving performance in simulations based on technical problems or spatial material. In the present study, the simulation *MultiFlux* was used. Although being related to g as well (Kröner et al., 2005) this simulation can be expected to especially require spatial ability due to the graphical user interface with controls and instruments (cf. Fig. 1). Thus, when selecting intelligence tests as predictors for problem-solving, we focused on spatial tasks with high loadings on G_v.

According to Ackermann and Lohman (2006, p. 141) G_v is "the ability to generate, retain, retrieve, and transform well-structured visual images". General spatial ability (G_v) shows substantial overlap with fluid intelligence (g_f) (Colom, Contreras, Botella, & Santacreu, 2002; Lohman, 2000). From the few studies on the predictive validity of intelligence including G_v, there is some evidence that G_v has a high predictive validity for complex tasks with visuo-spatial demands like airplane piloting (cited according to Johnson & Bouchard, 2005). Therefore, we expect measures of G_v to be related to *MultiFlux* problem-solving performance. However, as the focus of the present study is not on aspects of intelligence but rather on the relation between problem-solving and working memory, this issue will be portrayed next in more detail.

2. Intelligence and working memory

Are working memory and intelligence distinct at least to some degree? There are many studies on this issue (e.g.

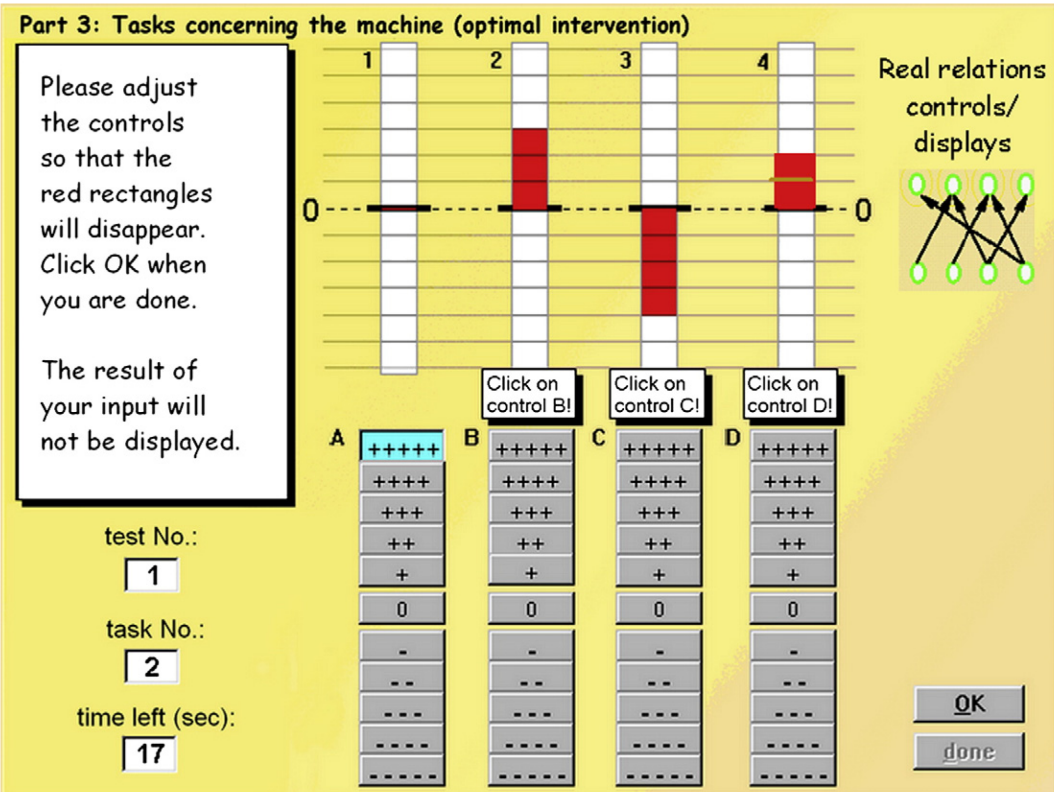

Fig. 1. The *MultiFlux* machine (screenshot from a rule application item).