Openness, fluid intelligence, and crystallized intelligence: Toward an integrative model

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ABSTRACT

Many studies are concerned with the bivariate relationships between Openness, fluid intelligence (Gf), and crystallized intelligence (Gc). Results suggest an influence of Gf and Openness on Gc. However, the overlap between Gf and Openness is rarely controlled for. Moreover, interaction effects or longitudinal influences are also often neglected. The present two studies aimed to elucidate exactly these interactions and longitudinal influences. Besides a main effect of Gf on Gc, Study 1 ($N = 180$) revealed an interaction effect between Openness and Gf. Study 2 utilized longitudinal data ($N = 172$) and identified an effect of Openness on the development of Gf. Gf and Openness predicted Gc 6 years later. A model integrating the results and providing a theoretical framework and outlook is proposed.

1. Introduction

The interface between personality and intelligence has been the focus of several studies (Ackerman & Heggestad, 1997; Ashton, Lee, Vernon, & Jang, 2000; Harris, Vernon, & Jang, 2005; Ziegler, Knogler, & Bühner, 2009). In particular, the relationship between Openness to Experience and intelligence has been the focus of much research (Ackerman & Heggestad, 1997; DeYoung, Peterson, & Higgins, 2005). However, complex models integrating intelligence and personality and the way they interact with each other have been scarce (Ackerman, 1996; Chamorro-Premuzic & Furnham, 2004; Gow et al., 2005). A prominent exception to this is the Intelligence-as-Process, Personality, Interests, and Intelligence-as-Knowledge (PPIK) model by Ackerman (1996) which includes ideas by Cattell (1943, 1987). The present studies were conducted in order to test some of the ideas brought forward hitherto and to add to this literature. To this end the relationship between fluid intelligence (Gf), crystallized intelligence (Gc), and Openness to Experience was examined. Study 1 focused on possible interactions between Openness facets and Gf concurrently predicting Gc. In Study 2, data from the Munich Longitudinal Study on the Genesis of Individual Competencies (LOGIC, see Weinert & Schneider, 1999) were reanalyzed to explore the interplay between the constructs in a longitudinal setting.

Within the following passages the bivariate relationships between Gf, Gc, and Openness are shortly reviewed to lay the ground for the more complex models including all three traits.

2. Fluid intelligence and crystallized intelligence

McGrew (2009) argued for the use of the well-established Cattell–Horn–Carroll model in intelligence research. He defined Gf as "the use of deliberate and controlled mental operations to solve novel problems that cannot be performed automatically" (p. 5) and Gc as "the knowledge of the culture that is incorporated by individuals through a process of acculturation. Gc is typically described as a person's breadth and depth of acquired knowledge of the language, information and concepts of a specific culture" (p. 5). Based on these definitions as well as on other empirical findings (Ackerman, 1996; Ackerman & Rolfhus, 1999), the crystallized and fluid intelligence test scores used in the current studies can be seen as markers for these specific constructs.

A longstanding and very influential theory about the relationship between Gf and Gc is Cattell's Investment Theory (1943, 1987). According to this theory, Gf results in a faster and broader accumulation of Gc. Ackerman (1996) built on that theory in his PPIK model. He differentiated between intelligence-as-process

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and intelligence-as-knowledge. He wrote about intelligence-as-process that "... it seems clear that the speeded aspects of intelligence...are well-encompassed within a 'process' categorization. These information-processing components include Reasoning, Memory-Span (short-term, or working memory), Perceptual Speed, and Spatial Rotation..." (p. 239). The present research focused mainly on reasoning. Regarding intelligence-as-knowledge, Ackerman wrote: "The nature of intelligence-as-knowledge matches the first description of Gc provided by Cattell in his Investment Theory..." (p. 241). Furthermore, Ackerman suggested that intelligence-as-process has a causal influence on intelligence-as-knowledge such that more knowledge will be gathered if a person has higher fluid intelligence. Clearly, these construct definitions as well as the assumed Gf influence on Gc are in line with Cattell's Investment Theory. Empirical evidence supports this bivariate model and has shown moderate relationships between Gf and Gc (e.g., Ackerman, Bowen, Beier, & Kanfer, 2001; Bühner, Krumm, Ziegler, & Plücken, 2006; Rolfhus & Ackerman, 1999).

3. Openness and crystallized intelligence

Costa and McCrae (1992) reasoned that some of the adjectives used to measure Openness have an intellectual connotation, which led other researchers to call the factor Intellect (Saucier, 1994). A person open to experience is curious, imaginative, willing to deal with new themes, and eager to learn. Based on this simple description, it could be argued that such a person spends more time trying to figure out new problems or learning new things. Moreover, a person high in Openness to Experience might be more likely to encounter new situations and receive new information. This could lead to more learning opportunities. The idea of specific personality traits positively influencing the development of cognitive abilities through providing more learning opportunities has already been suggested by Cattell (1987, p. 449). Even though Cattell did not use the term Openness (the Big 5 were suggested later), he included a general factor S_e as a variable influencing Gc. S_e consists of time invested into learning, interests, and memory. Surely, Openness goes hand in hand with more time spent on learning. Thus, it should not be surprising that Gc is positively influenced by Openness. Openness is also a vital part in Ackerman's PPIK model in which it is regarded as a major variable influencing the development of knowledge.

Exactly this influence of Openness on Gc has been investigated in an extensive study by Ashton et al. (2000). Those authors demonstrated that the Openness facet Understanding revealed the largest correlation with knowledge tests. According to Ashton et al., this is because "... many Understanding items describe preferences for artistic, literary, and scientific activities, and such interests would naturally be expected to correlate with the general knowledge that is assessed by the crystallized intelligence subtests" (p. 205). This argumentation is in line with the reasoning stated above; that is, Openness to Experience leads to learning opportunities, and thus increases Gc.

The importance of differentiating between different Openness facets when investigating the Openness–Gc relationship has been demonstrated also in a recent study by Zimprich, Allemand, and Dellenbach (2009). Those authors reported positive and moderate correlations between different Openness facets (Aesthetic Interests, Intellectual Interests, and Unconventionality) and Gc. Moreover, a suppressor effect was observed for Aesthetic Interests when Gf and Gc were regressed on the Openness facets. Based on the NEO model, DeYoung et al. (2005) investigated the relationship between Openness facets and Gc. They found that significant and small to moderate correlations emerged between Gc and the Openness facets Fantasy, Aesthetics, Ideas, and Values.

In sum, theoretical ideas regarding the influence of personality on Gc have already been brought forward by Cattell and can also be found in Ackerman's PPIK model. Recent theoretical developments designated Openness to Experience as an important individual difference variable influencing Gc. Empirical results have documented a substantial relationship between Openness and Gc. Additionally, literature has acknowledged the necessity of differentiating between Openness facets.

4. Openness and fluid intelligence

Theoretical models seldom include a link between Openness and Gf. Ackerman's PPIK model for example does not speak to this bivariate relationship. Oftentimes it is argued that the correlation between measures of Openness and Gf are too small to speak of a substantial relationship. Ackerman and Heggestad (1997) reported meta-analytical results that showed significant yet small correlations between Openness and so-called general intelligence. General intelligence in this analysis encompassed two broad factors: intelligence-as-process and intelligence-as-knowledge. Thus, it can be interpreted as a blend of both Gf and Gc, and therefore allows for no clear conclusions regarding the relationship between Openness and Gf. Studies which employed measures that can more directly be regarded as Gf measures yielded more precise findings. Results from the LOGIC study showed that there was a moderate and significant correlation ($r = .32$) between Openness at ages 4–6 and Gf at age 9 (Asendorpf & van Aken, 2003b). Moutafi, Furnham, and Crump (2003) reported that Openness to Experience was a good predictor of Gf. Moreover, they identified Openness to Ideas as the facet with the strongest relationship to Gf. Other studies suggested small yet significant correlations, typically between .10 and .25 (e.g., Ackerman et al., 2001; Ashton et al., 2000). The robustness of these findings across different age groups has recently been reported (Soubelet & Salthouse, 2011; Zimprich et al., 2009). Once again, it seems relevant to highlight the importance of content when looking at the relationship between Openness and Gf. Whereas Ashton et al. administered Gf tasks which included only figural and numerical content in their study, the LOGIC project, which revealed a more substantial Openness–Gf relationship, used verbal Gf tests. The study by DeYoung et al. (2005) mentioned above also yielded small to moderate and significant correlations between Gf and the Openness facets Ideas and Values using a broad range of tests.

In sum, even though earlier theoretical models did not include a relationship between Openness and Gf, empirical studies have yielded substantial correlations between Openness and Gf. However, it seems important to investigate these relationships on the facet level. Consequently, in Study 1, we used different Openness facets.

5. Process models

As mentioned above, besides looking at the bivariate relationships, Ackerman also formulated a complex model in which the interplay between Gf, Gc, and Openness is a crucial part. In this PPIK model, Ackerman (1996) considered the role of personality traits and interests in the accumulation of intelligence-as-knowledge. He argued that intelligence-as-knowledge contains specific knowledge structures (e.g., the physical or social sciences). A personality factor that Ackerman described as closely related to intelligence-as-knowledge was Openness to Experience. He further stated that people open to experience have greater verbal crystallized abilities and knowledge in the fields of arts and humanities. In his model, he elaborated that Openness and interests interact and influence time and effort spent acquiring knowledge. It was