of which is called Planning Ability that measures the planning functions of the PFC.

5. *NEPSY: A Developmental Neuropsychological Assessment* (Korkman et al. 1998), 3–12 years; developed from Luria's theory and includes five domains, including Attention/Executive functions.

6. *Woodcock-Johnson*, 3rd edition (WJ III [Woodcock et al. 2001]), 2–95+ years; developed from Cattell-Horn-Carroll (CHC) theory; measures seven cognitive factors, including Fluid Reasoning.

7. *Wechsler Preschool and Primary Scale of intelligence*, 3rd edition (WPPSI-III [Wechsler 2002]), $2\frac{1}{2}$–7 years; added three measures of fluid reasoning – Matrix Reasoning, Word Reasoning, and Picture Concepts.

8. *Stanford-Binet Intelligence Scales*, 5th edition (SB5 [Roid 2003]), 2–85+ years; developed from CHC theory and includes five scales, including Fluid Reasoning.

9. *Wechsler Intelligence Scale for Children*, 4th edition (WISC-IV [Wechsler 2003]), 6–16 years; added three measures of fluid reasoning – Matrix Reasoning, Word Reasoning, and Picture Concepts – and one measure of working memory (Letter–Number Sequencing); eliminated verbal and performance IQs in favor of four indexes.

10. *Kaufman Assessment Battery for Children*, 2nd edition (KABC-II [Kaufman & Kaufman 2004]), 3–18 years; developed from a blend of CHC and Luria theories; includes five scales, including one labeled Planning/Gf intended to measure the PFC Block 3 functions from Luria's theory and fluid reasoning ability from CHC theory.

Consequently, Blair's following statement is false: "As measures of crystallized skills, currently available assessment batteries will provide a limited perspective on the cognitive abilities of children ... [They] will not really be able to address [fluid aspects of cognition]" (sect. 7.1, para. 3).

In fact, excellent measures of children's fluid cognition are readily available. The newer breed of intelligence test decidedly does *not* overemphasize crystallized abilities. Instead, the focus has shifted to fluid reasoning, planning ability, the ability to learn new material, and working memory. As Blair urges, much research needs to be done. We agree. But it is important to note that appropriate tests of fluid cognition are ready and waiting.

In addition, there is psychometric evidence with recent tests that suggests strong overlap between measures of fluid ability and *g*. Keith (2005) applied the technique of hierarchical confirmatory factor analysis (CFA) to several data sets. For the DAS, the fluid factor correlated .98 with *g* in one study and 1.0 in another. Kaufman and Kaufman (2004) applied Keith's CFA approach to the KABC-II and observed 1.0 correlations between fluid cognition and *g*.

These psychometric findings do not mean that fluid cognition and psychometric *g* are identical constructs. Blair has cogently argued that a wealth of other data needs to be integrated with the psychometric results to reach any reasonable conclusions about this relationship. However, we believe that more research needs to be done with samples of children (not adults) before reaching the firm conclusion that the two constructs are distinct.

NOTE

1. Whereas Blair used the abbreviation "gF" to denote fluid cognition, we have opted to use "Gf," which is the abbreviation used by Cattell-Horn-Carroll (CHC) theorists and researchers.

Difficulties differentiating dissociations

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Abstract: We welcome Blair's argument that the relationship between fluid cognition and other aspects of intelligence should be an important focus of research, but are less convinced by his arguments that fluid intelligence is dissociable from general intelligence. This is due to confusions between (a) crystallized skills and g, and (b) universal and differential constructs.

Blair's review provides a thorough account of how Gf[1] is grounded in fluid cognition (defined as the maintenance of information, inhibition and sustained attention), working memory and the prefrontal cortex. One of his aims is to establish that fluid cognition is dissociable from general intelligence, and that Gf can therefore be dissociated from *g*. Having established these dissociations, Blair then wants to encourage the development of tests of fluid cognition, or Gf, in children. Such tests would provide the potential to examine important questions, such as the relationship between fluid and crystallized intelligence in development. There is no question that investigations of fluid skills in typical and atypical development will provide valuable insights into both theoretical and applied issues in intelligence testing. However, it does not seem necessary to us to establish that fluid cognition can be dissociable from general intelligence in order to make this point.

Nor, indeed, does it seem to us that Blair has established in his review that fluid cognition is dissociable from general intelligence. In the five sections in which he reviews evidence for this apparent dissociation, it is quite clear that the evidence cited does no more than document a dissociation between fluid cognition and crystallized cognition (Gc). Essentially, all the studies that are said to show discrepancies between scores on different tests have used tests of fluid cognition and tests of crystallized intelligence. It comes as little surprise that Gf is dissociable from Gc: no one has disputed this. What is surprising is that Blair appears to consider Gc to be identical with *g* (see, e.g., sect. 3 of the target article). This impression is given, in part, by the slippage throughout this part of the review between the terms crystallized skills or intelligence and general intelligence or *g*; at one moment, he asserts that such and such evidence shows that Gf and Gc are dissociable; in the next sentence or paragraph, this evidence is said to show that Gf is dissociable from *g*.

This latter dissociation is not helped by Blair's attempt to argue for a residual Gf', an argument that would be disputed by Gustafsson (1984; 1988), who has claimed that Gf and *g* are essentially identical. Carroll (2003), a firm believer in *g*, has established that hierarchical factor analysis of a large test battery will show both a general factor *g* as well as a number of orthogonal factors, namely, Gf, Gc, Gv, etc. It is notable that, in two separate data sets, this residual Gf was either the smallest or second smallest factor, accounting for no more than a quarter of the variance accounted for by residual Gc. So, residual Gf is not very important – and, if these residual factors are orthogonal, one will not explain any of the variation in another.

But the slippage between terms introduces another flaw. Blair uses the term "general intelligence" as a synonym for "*g*" or "the *g* factor" throughout his article, and regularly substitutes "Gf" with "fluid cognition." This is unfortunate and misleading. General intelligence and fluid cognition are universal constructs that provide causal explanations of universal processes, and thus can be applied to a single individual; *g* and Gf, on the other hand, are differential constructs, being latent variables that are used in causal explanations of individual differences. To see the importance of this distinction, consider the main topic of the article: dissociation. In cognitive psychology, dissociation between A and B is assumed when (a) in experimental conditions, A does not interfere with B (or vice versa), or (b) in clinical studies, the injury of one part of the brain results in the malfunctioning of A while B remains intact (or vice versa). However, a

https://doi.org/10.1017/S0140525X06349035 Published online by Cambridge University Press

dissociation of two processes in this sense tells us nothing about the correlation between them. For example, measures of the strength of people's left hand will most probably correlate with those of the right hand, and this is not affected by the fact that (a) people can do things with their hands in parallel or (b) that people can lose their arms separately in accidents. Let us assume that a measure of the strength of the right hand shows a very high correlation with measures of the strength of the left hand. It is right to conclude that they measure the same *thing*, if by a "thing" we mean a latent causal variable that explains the covariation – in this case, perhaps general muscular make-up. But it would be foolish to conclude that they measure the same *thing* in the universal sense, since it would mean that we are born with only one hand. But we are born with two, and we can lose them one by one. In short, they can be dissociated, independently of the correlation.

The architecture of cognition does not determine the structure of correlations between performance on various tasks, and the latent variable structure of between-subject differences does not determine the architecture of cognition. Hence, the correlation matrix, or the factor (latent variable) structure of different tasks, tells us nothing about whether they can be dissociated in the cognitive psychologist's sense, or vice versa.

This leads back to the difference between the theoretical status of variables like *g* and Gf, or general intelligence and fluid cognition. Fluid cognition and general intelligence are universal constructs that give causal explanations at the level of the individual, whereas *g* and Gf are differential constructs that account for the common variance between various tests or tasks. Nevertheless, to be able to choose between different factorial solutions, differential constructs (such as Gf) must be grounded in universal ones (such as fluid cognition). But the methodological differences and the different scope of explanation must be kept in mind. If we pay attention to the difference between the (universal) constructs of general intelligence and fluid cognition, on the one hand, and the (differential) constructs of *g* and Gf, on the other, we will be in a better position to consider whether any of the two pairs can be dissociated.

NOTE

1. We prefer to use the "Gf" abbreviation used by Cattell and Horn to signify fluid intelligence; Blair's use of "gF" is unusual.

Fluid intelligence as cognitive decoupling

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Abstract: The dissociation of fluid cognitive functions from *g* is implicit in the Cattell-Horn-Carroll gF-gC theory. Nevertheless, Blair is right that fluid functions are extremely important. I suggest that the key mental operation assessed by measures of gF is the ability to sustain mental simulation while keeping the relevant representations decoupled from the actual world – an ability that underlies all hypothetical thinking.

Blair displays immense scholarship in marshalling a broad array of evidence in neurobiology, psychometrics, and developmental science relevant to understanding the role of fluid cognition in cognitive theory. His main thesis appears early in the target article: "[D]issociation of fluid cognitive functions from other indicators of mental abilities through which *g* is manifest suggests that some reconceptualization of human cognitive competence is needed and may indicate instances in which *g* has reached or exceeded the limits of its explanatory power" (sect. 1.1, para. 3). Although I largely agree with this thesis, I think that most of the work driving the field toward it has already been done in the form of the modern synthesis of intelligence research represented by the Cattell-Horn-Carroll (CHC) gF-gC theory (Carroll 1993; Cattell 1963; 1998; Geary 2005; Horn & Cattell 1967; Horn & Noll 1997; McGrew & Woodcock 2001).

The reason I make this somewhat deflationary comment is that many of the dissociations Blair discusses are easily handled by invoking the CHC theory. In many of the examples discussed in the target article, fluid intelligence dissociates somewhat from general intelligence because the latter is estimated from an amalgam of gF and gC tasks, and the particular effect discussed has differential impact on gF and gC. The result will be gF somewhat dissociated from *g* (but not as much as it dissociates from gC). This is certainly the case when we examine the secular rise in IQ known as the Flynn effect. Measured in standard units, the rise in gF is larger than the rise in *g* because general IQ measures contain components of crystallized intelligence which has not risen at all. Fluid intelligence dissociates from *g* in the Flynn effect because the secular rise is differential across gF and gC.

It is likewise with Duncan's demonstrations of the effects of damage to the dorsolateral prefrontal cortex (Duncan et al. 1995; 1996). One could say that these demonstrate that gF dissociates from *g*, but it is more parsimonious to simply say that the Duncan demonstrations show what CHC theory predicts: that, in certain cognitive domains, gF will dissociate from gC.

Nevertheless, I am in complete agreement with Blair that fluid functions are extremely important and that they are environmentally sensitive. I believe that research is homing in on the critical underlying operation(s) that makes fluid intelligence so critical to mental life. I have argued (Stanovich 2004) that the mental operation is one that accounts for a uniquely human aspect of our cognition – the ability to sustain an internal cognitive critique via metarepresentation. That extremely important mental operation is the decoupling of cognitive representations.

Cognitive decoupling supports one of our most important mental tasks: hypothetical thinking. To reason hypothetically, a person must be able to represent a belief as separate from the world it is representing. Numerous cognitive scientists have discussed the mental ability to mark a belief as a hypothetical state of the world rather than a real one (e.g., Carruthers 2002; Cosmides & Tooby 2000; Dienes & Perner 1999; Evans & Over 2004; Jackendoff 1996; Leslie 1987; Nichols & Stich 2003). Decoupling skills prevent our representations of the real world from becoming confused with representations of imaginary situations that we create on a temporary basis in order to predict the effects of future actions or to think about causal models of the world that are different from those we currently hold. Decoupling skills vary in their recursiveness and complexity. At a certain level of development, decoupling becomes used for so-called metarepresentation – thinking about thinking itself. Metarepresentation is what enables the self-critical stances that are a unique aspect of human cognition (Dennett 1984; 1996; Povinelli & Giambrone 2001; Sperber 2000; Stanovich 2004; Tomasello 1999). We form beliefs about how well we are forming beliefs, just as we have desires about our desires and possess the ability to desire to desire differently.

Sustaining cognitive decoupling is effortful, and the ability to run mental simulations while keeping the relevant representations decoupled is likely one aspect of the brain's computational power that is being assessed by measures of gF. Evidence that the key operation underlying gF is the ability to maintain decoupling among representations while carrying out mental simulation derives from work on executive function (e.g., Baddeley et al. 2001; Gray et al. 2003; Salthouse et al. 2003) and working memory (Colom et al. 2004; Conway et al. 2003; Kane & Engle 2003). First, there is a startling degree of overlap in individual differences on working memory tasks and individual differences in measures of fluid intelligence. Secondly, it is becoming clear that working memory tasks are only