with factual knowledge would contribute to both fluid and crystallized intelligence, but such tests would not contribute to perceptual ability. The structure of ability follows the verbal-perceptual outline rather than the fluid-crystallized outline (Johnson & Bouchard 2005; in press), rendering the controversy surrounding the question of the equivalence of fluid and general intelligence moot.

Psychometric models of the structure of intellectual ability offer objective and rigorous frameworks for studying genetic (Gottesman 1997; Plomin & Craig, in press) and epigenetically mediated neurobiological endophenotypes and processes (Gottesman & Gould 2003; Weaver et al. 2004), as well as insight into the relative accuracy of the measurement tools we use to assess the ability of individuals and to predict their success in educational and occupational domains. The research Blair describes highlights the limitations of the fluid-crystallized model in addressing these purposes. Paper-and-pencil tests of ability are blunt measurement tools. Performance on any task always reflects learned behavior to at least some degree. People also likely differ in their prior exposure to any task as much as they do in innate ability to address any truly novel task. Consequently, it is never possible to measure innate ability per se, and there is always variance in the degree to which innate ability is reflected in individual test scores. In addition, most problems can be solved using multiple strategies, making it difficult to be sure that any specific task measures any specific ability. Nevertheless, it is clear that the variance common to even a relatively small battery of such tests taps a general intellectual ability with substantial relevance to a wide variety of life outcomes (Gottfredson 1997; Jensen 1998; Lubinski 2004). Blair raises important questions related to the biological development of this general ability in the context of emotional regulation and environmental stress, but we will be able to address these questions more fruitfully by separating the process of development from the structures developed.

Jensen (1998, p. 95) nicely distinguished between processes and structures in their implications for understanding intellectual performance. We may be able to use fluid-crystallized theory to understand how intellectual performance emerges in the individual, but understanding the structural manifestation of general intelligence and other more specific abilities requires comparison across individuals in a systems biology context (Grant 2003). Fluid-crystallized theory has little to offer in this regard. It may even delay the resolution of important issues involving the distinction of pervasive learning disabilities (low general intelligence) from specific, content-related disabilities that impede the development of particular skills. These specific disabilities also tend to follow Vernon's (1965) hierarchical structure of general intelligence supplemented with specific verbal and perceptual abilities, further supplemented with image-rotation ability.

Some considerations concerning neurological development and psychometric assessment

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Abstract: Blair makes a strong case that fluid cognition and psychometric g are not identical constructs. However, he fails to mention the development of the prefrontal cortex, which likely makes the Gf–g distinction different in children than in adults.[1] He also incorrectly states that current IQ tests do not measure Gf; we discuss several recent instruments that measure Gf quite well.

Blair's target article makes a strong case that fluid cognition and psychometric *g* are not identical constructs. Indeed, these constructs are clearly dissimilar for adults, a notion supported for years by a wealth of aging research generated by Horn and Cattell's (1966) constructs of fluid (Gf)[1] and crystallized (Gc) intelligence. Dramatically different growth curves have been demonstrated for Gf and Gc across the adult life span for numerous adult tests (e.g., Kaufman 2001). Blair includes aging research on the Horn-Cattell constructs as one piece of evidence for the distinctiveness of Gf and *g*, and we agree that this one argument, per se, is stronger than any factor-analytically based psychometric argument that Gf and *g* are virtual identities.

Blair's evidence for the distinctions between Gf and *g* for children, though strongly reasoned and diverse in its breadth, is less compelling than the evidence for adults. Blair appropriately discusses the key role played by the prefrontal cortex (PFC) in fluid cognitive functions, but fails to mention or consider the development of these functions in children. As Golden (1981) indicates, it is not until about ages 11–12, on average, that "the prefrontal areas of the brain that serve as the tertiary level of the output/planning unit develop" (p. 292). This level corresponds to the onset of Piaget's stage of formal operations (Inhelder & Piaget 1958) and the emergence of Luria's (1970) Block 3 planning abilities.

The identification of Gf factors in groups of normal children also has a distinct developmental component. These factors do not emerge as separate constructs until about age 6 or 7 (Elliott 1990; Kaufman & Kaufman 2004). Therefore, the relationship between Gf and *g* in children is likely to be a different phenomenon for children below age 6, for those between 7 and 11, and for adolescents. As multifaceted in scope as Blair's analysis was, his conclusions for children should be treated as tentative pending more thorough developmental analyses.

One other area of Blair's review that was relatively weak was his apparent lack of awareness of the contemporary psychometric scene regarding the assessment of fluid cognition, especially in children. He cited a 15-year-old source (Woodcock 1990) and an 8-year-old source (McGrew 1997) to document "the limited assessment of gF currently available in many widely used intelligence tests" (sect. 4.1, para. 3) and to state that these tests "disproportionately assess crystallized skills and domains of intelligence associated with opportunity for learning" (sect. 7.1, para. 2).

Those claims are simply not true. Tests that deemphasized *g* and provided measurement of fluid cognition began to be published shortly after Woodcock's (1990) article went to press, and have proliferated since McGrew's (1997) chapter was published. The latest versions of the Wechsler and Binet tests are joined by many other well-normed, psychometrically sound, cognitive ability tests that minimize the importance of *g*, emphasize the assessment of multiple abilities and measure fluid cognition. Listed chronologically, the following tests all provide excellent measurement of fluid cognition:

1. *Differential Ability Scales* (DAS [Elliott 1990]), $2\frac{1}{2}$–17 years; includes three scales for school-age children, one of which is a Nonverbal Reasoning Scale that measures Gf (Keith 2005).
2. *Kaufman Adolescent and Adult Intelligence Test* (KAIT [Kaufman & Kaufman 1993]), 11–85+ years; includes two scales named Crystallized Intelligence and Fluid Intelligence; two subtests (Mystery Codes and Logical Steps) are considered excellent measures of Gf (Flanagan & Ortiz 2001).
3. *Wechsler Adult Intelligence Scale*, 3rd edition (WAIS-III [Wechsler 1997]), 16–89 years; added a measure of Gf (Matrix Reasoning) to the Performance Scale, a measure of working memory (Letter–Number Sequencing), and a separate Working Memory Index.
4. *Cognitive Assessment System* (CAS [Naglieri & Das 1997]), 5–17 years; includes four scales derived from Luria's theory, one

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

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