as an important information-storage device, and the role of posterior brain regions in that kind of storage. Relevant cognitive and imaging studies are discussed.

This target article provides an impressive review of research indicating that fluid cognition is separate from general intelligence and is highly susceptible to environmental, emotional, and specific neurological influences. Fluid cognition is defined as "all-purpose cognitive processing not necessarily associated with any specific content domain and as involving the active or effortful maintenance of information" (sect. 2.1). The term *fluid cognitive functioning* is "used interchangeably to some extent with the terms working memory and executive function" (sect. 2.1) and is said to be associated strongly with frontal-lobe functioning. However, this characterization leaves behind an important part of fluid cognition, involving the use of attention to store information.

In a long-standing model of working memory, Baddeley (1986) described a system in which the storage of information occurred in phonological and visuospatial passive buffers. Executive functions were said to use the stored information to carry out tasks, but did not themselves store information. The phonological store was limited in the duration of the sequence that could be retained, and the visuospatial store supposedly had a similar limit. Both were assumed to hold information automatically, without an investment of effort, for a short time. However, this model did not consider all information in working memory. Stored information actually could include semantic elements, as well as links between elements of different types (e.g., in a group conversation, information about who just said what). It might have to be held in the focus of attention. That type of storage has been taken into account in more recent models (e.g., Baddeley 2000; Case 1995; Cowan 1988; 1995; 1999). An attention limit can account for situations in which the number of elements or chunks that can be held concurrently is severely limited (Cowan et al. 2004; 2005; Garavan 1998; Oberauer 2002).

It does not appear that information in the focus of attention is actually held in the frontal lobes. Although frontal regions are key to the manipulation of information, the storage of information actually appears to take place in posterior regions. Thus, although the frontal regions are more sensitive to the task requirement to manipulate information, posterior regions are more sensitive to the memory load of a task (e.g., see Postle et al. 1999; 2003). Some have proposed that, although the frontal lobes are heavily involved in the control of attention, more posterior, largely parietal areas make up the more important part of the seat or focus of attention, with the retention of attended information (Cowan 1995; Posner & Peterson 1990). For example, Schacter (1989) pointed out that disorders of awareness, such as lateral neglect (inattention to one half of space or one half of each object) and anosognosia (ignorance that one is disabled), are more likely to result from parietal, rather than frontal, lesions.

If the focus of attention is closely associated with activity posterior in the brain and the storage of information also takes place in posterior regions, can we infer that storage itself is attention-demanding? Perhaps. We have examined this question with respect to a visual working memory task in which a haphazard array of small, diversely colored patches is to be compared to a second array that is the same or differs only in the color of one patch (Luck & Vogel 1997). In a well-controlled version of the task, one item in the second array is encircled and the participant has been informed that, if any item in the array changed, it was that one. This task results in excellent performance for arrays of four or fewer patches, and increasingly poorer performance with increasing array sizes. A formula for capacity in the task is based on the assumption that, for items in working memory, the participant correctly indicates whether the cued item has changed or not. If the item is not in working memory, the participant guesses (Cowan 2001). The formula indicates that adults typically keep three or four items in working memory. Neuroimaging and event-related potential studies with this task indicate that neural activity dependent on the set size and the subject's capacity takes place not in the frontal regions, but in certain posterior regions of the brain (Todd & Marois 2004; Vogel & Machizawa 2004). Moreover, recent evidence indicates that performance in this task is attention-demanding. Overt recitation of a random six- or seven-digit list impairs performance on the visual-array task, especially on trials in which the digit list is recited incorrectly. As controls for other factors, silently retaining a digit list during the retention interval of the visual-array task does not impair performance unless the demands of both tasks are rather large, and neither does the overt recital of a two-digit list or a known telephone number (Morey & Cowan 2004; 2005). Thus, silent verbal maintenance can occur automatically, as can the act of articulation; but recitation of a memory load requires effortful retrieval, and performance on the visual-array task suffers from the consequent drain on attention. Even retrieval of a response in a tone-identification task has this effect on visual-array comparisons (Stevanovski & Jolicoeur 2003).

In the working-memory tasks usually used to show high correlations with intellectual aptitude, storage and processing are combined. However, various types of evidence suggest that, within such tasks, what is important for correlations with aptitude is simply that the processing task prevents rehearsal of the information in storage (see Lépine et al. 2005). Rehearsal may ease the demand for attention. Tasks correlating well with aptitudes also include those that do not have a separate processing component, but that nevertheless preclude rehearsal of the stored information (e.g., the aforementioned visual-array task). A simple digit-span task also correlates with aptitudes in children too young to rehearse the digits (Cowan et al. 2005). All of this suggests that storage, as well as processing, can fall within the camp of *fluid cognition* when attention must be used for storage.

Sometimes, the distinction between storage and processing is unclear. Blair states that "Individuals with prefrontal damage exhibit no deficits on problems whose solution requires holding in mind no relations or only one relation, but exhibit a near inability to solve problems involving two or more relations (Waltz et al. 1999)" (sect. 3.2, para. 1). In this phenomenon (see also Halford et al. 2005), it may take storage to facilitate processing, and it is an open question whether individual differences lie in storage, processing, or both. Fluid cognition is not necessarily all frontal processing.

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Dissecting *g*

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Abstract: Two studies substantiating Blair's main postulates are summarized. The first study showed that fluid cognition, reasoning, and perceived competence about reasoning are separate and equipotent partners in g. The second study showed that reasoning, understanding of emotions, and perceived competence about reasoning and emotions partake in the formation of g, substantiating Blair's claim that cognition and emotion are linked in the brain.

Blair's main arguments are quite simple. Psychometric *g* and fluid cognition are not identical, and fluid cognition is connected to emotion. I fully endorse both arguments. Psychometric *g* is an intensive construct reflecting whatever is common between all kinds of tasks included in psychometric tests. Most tasks in most tests of intelligence require, in varying proportions, inferential and reasoning processes, problem-solving and self-management skills, domain-specific knowledge, and interest and motivation

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to succeed on the test, and, of course, fluid cognition (Demetriou 2004). Fluid cognition sets the frame for the construction and functioning of the other processes but is not identical with them. Emotions regulate how efficiently fluid cognition can be used for the sake of the other processes. Thus, general intelligence is, necessarily, a hyper-construct where all of these processes interact dynamically. In this commentary, I summarize two studies substantiating these postulates.

The first study specifies the relative contribution of fluid cognition, reasoning, and self-awareness in *g* (Demetriou & Kazi, submitted). This study involved 83 participants sampled among 11-, 13-, and 15-year-old adolescents. Three aspects of fluid cognition were examined: speed of processing (e.g., reading color words written in the same ink color), control of processing (e.g., recognizing the ink color of color words where meaning and ink color were incompatible), and working memory (i.e., phonological and visual storage and executive processes). The reasoning tasks addressed four domains: verbal (i.e., verbal analogies and propositional syllogisms), quantitative (i.e., numerical analogies and simple algebraic equations), and spatial reasoning (i.e., mental rotation and the water-level task), and drawing (i.e., draw a scene involving various components). Finally, an inventory probed self-representation in regard to these four domains (e.g., "I immediately solve everyday problems involving numbers").

Figure 1 shows the best-fitting model to the mean scores representing performance on the various tasks. Specifically, the mean score representing speed and the mean score representing control of processing are related to one factor that stands for processing efficiency. The scores representing phonological, visuo-spatial, and executive memory are related to another factor that stands for working memory. Each pair of scores representing performance in or self-representation about a domain of reasoning is related to a separate factor. Therefore, there are four factors standing for performance and four factors standing for perceived competence in each domain. These first-order factors are regressed on three second-order factors. Specifically, the processing efficiency and the working memory factors are regressed on one factor that stands for fluid cognition (**gF**). The four factors representing performance in the four domains are regressed on another factor, which stands for general reasoning and inferential processes ($\mathbf{g_r}$). Psychometric *g* is very close to this factor. The four self-representation factors are regressed on another factor that stands for general perceived competence ($\mathbf{g_{pc}}$). Finally, the three second-order factors are regressed on a third-order factor, the "grand *g*" ($\mathbf{G_{grand}}$). Attention is drawn to the relations between the three second-order factors and $\mathbf{G_{grand}}$. They are all very high (all > 0.86), clearly suggesting that fluid cognition, inference and problem solving, and self-awareness are distinct, equipotent, and complementary dimensions of general intelligence.

The second study explores the relative contribution of reasoning, understanding and regulation of emotions, and self-representation about these processes to the formation of *g* (Demetriou & Andreou, in preparation). Therefore, this study is related to Blair's claim that intelligence and emotions are interrelated because of corticolimbic connections linking the rational brain (i.e., the prefrontal cortex) with the emotional brain (i.e., the limbic system). This study involved 247 participants, drawn among 10-, 12-, 14-, 16-, and 20-year-olds, who were examined by four batteries: The reasoning battery addressed quantitative (algebraic equations and numerical analogies), causal (isolation of variables and combinatorial reasoning), spatial (mental rotation and coordination of the spatial systems of reference), and social reasoning (understanding the motives and intentions of others). The understanding-of-emotions battery asked participants to construct stories integrating different emotions with relevant events (e.g., "Write a story about an event that makes Michael sad and disappointed and Chris happy and optimistic"). The self-representation battery involved items addressed to the four reasoning domains mentioned above. Finally, the emotions battery addressed emotional self-knowledge (e.g., "I know my emotions very well") and self-regulation (e.g., "I control my emotions"), understanding and regulation of the social aspects of emotions as related to the self (e.g., "I am aware of the non-verbal messages I send to others") and the other (e.g., "I know what others feel by simply looking at them"), a constructive approach to emotionally

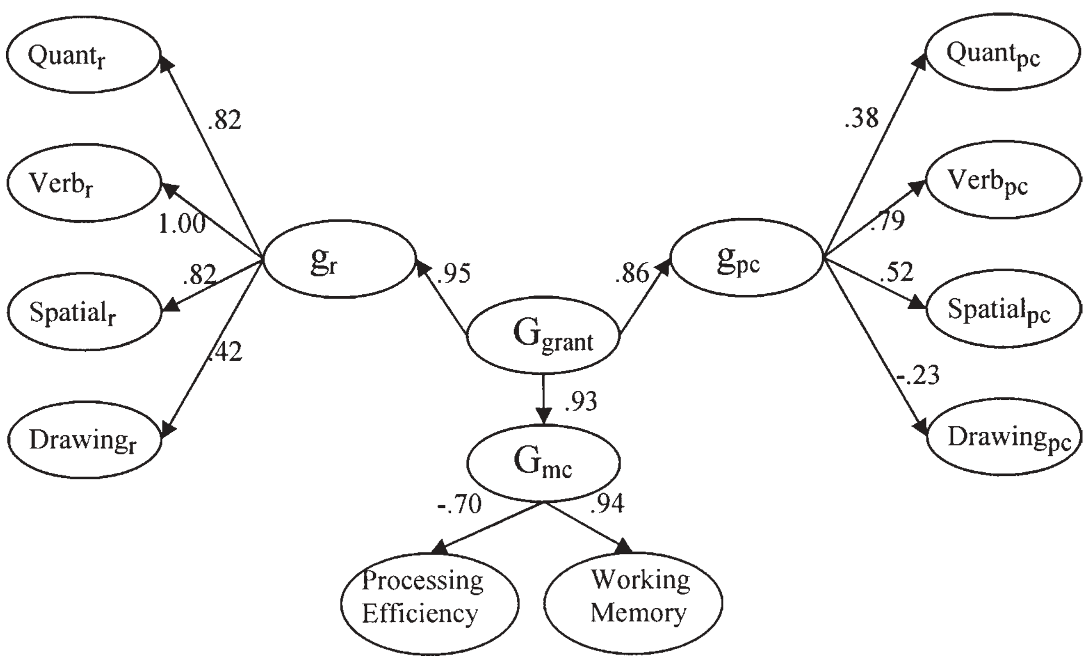

Figure 1 (Demetriou). The best-fitting model to the performance and self-representation attained at the batteries of the first study. *Note 1:* χ^2 (175) = 197.236, CFI = .956, p = .120, RMSEA = .039, and 90% confidence interval = .000 − .065. *Note 2:* All loadings are significant. [Glossary: G and *g* stand for general; grand stands for processing underlying general domains of ability; r stands for reasoning; pc stands for perceived competence; mc stands for mental capacity; Quant, Verb, Spatial, Drawing stand for ability in quantitative, verbal, spatial reasoning and drawing.]

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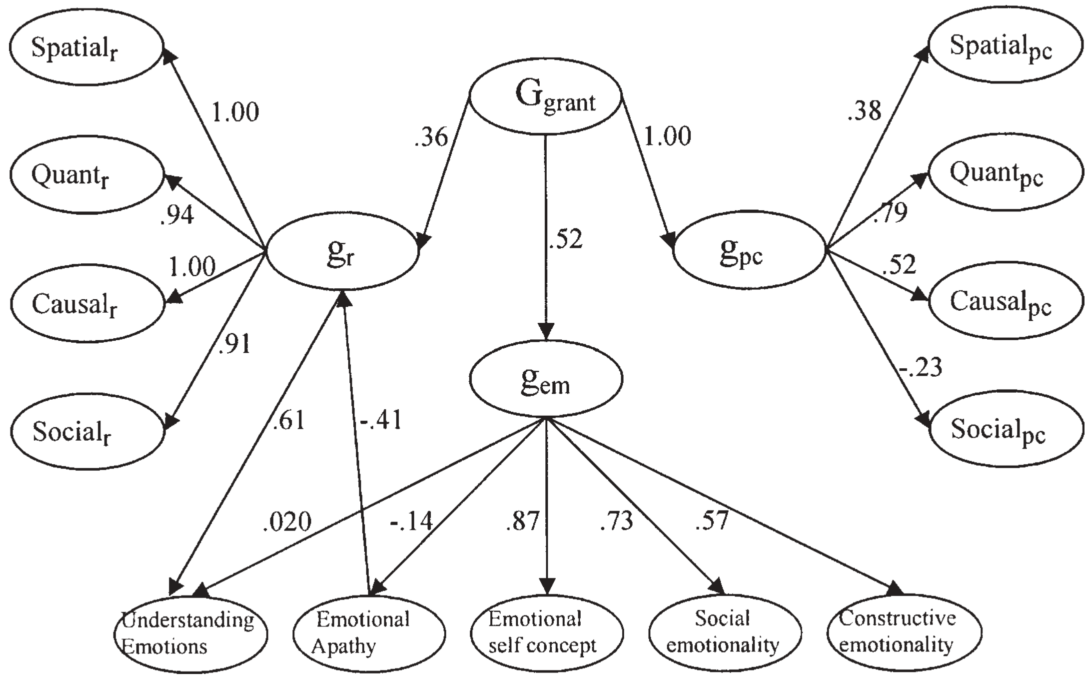

Figure 2 (Demetriou). The best-fitting model to the performance and self-representation attained at the batteries of the second study. *Note 1:* χ^2 (305) = 486.824, CFI = .918, $p < .001$, RMSEA = .049, and 90% confidence interval = .041 − .057 *Note 2:* All but the $\mathbf{g_{em}}$ – *Understanding emotions* relations are significant.
[Glossary: **em** stands for emotional; for the other symbols, see Fig. 1 caption.]

laden situations (e.g., "When unfairly scolded, I prefer to talk with others and show them that they are wrong"), and emotional apathy (e.g., "I am indifferent to praise").

Figure 2 shows the best-fitting model to the scores generated by these batteries. There was a first-order factor for each domain of reasoning, a first-order factor for self-representation about these domains, and a first-order factor about the various emotional understanding and self-representation factors. Each set of these three types of factors was regressed on a second-order factor, standing for general reasoning ($\mathbf{g_r}$), general perceived competence ($\mathbf{g_{pc}}$), and emotional processes ($\mathbf{g_{em}}$). Finally, these three second-order factors were regressed on $\mathbf{G_{grand}}$.

Attention is drawn to the relations between the second-order factors and G$_{\mathbf{grand}}$. They are .36, 1.0, and .52 for the $\mathbf{g_r}$, $\mathbf{g_{pc}}$, and $\mathbf{g_{em}}$, respectively. Obviously, this factor, due to the dominance of self-representation items, is highly loaded by self-awareness. It is noteworthy that its relation with $\mathbf{g_r}$ and $\mathbf{g_{em}}$ is significant and in the same range, indicating that self-awareness is a powerful dimension of general intelligence that operates as a liaison between its inferential and its dynamic dimensions. Attention is also drawn to two interesting relations. On the one hand, understanding emotions was strongly connected to $\mathbf{g_r}$ (.61) but negligibly to $\mathbf{g_{em}}$ (.02). On the other hand, emotional apathy was substantially and negatively related with $\mathbf{g_r}$ (−.41). Therefore, the processing of emotions involves a strong inferential component, but, at the same time, inferential processes require emotional involvement to function.

Both models were retested after partialling out the effect of age and found to still fit well. Therefore, the architecture they revealed is genuine to the organization of the various processes rather than the result of possible developmental differences between tasks. This architecture substantiates Blair's claims that psychometric *g* and fluid cognition are not identical and that there are close relations between cognitive and emotional processes. Self-awareness is crucial in sustaining these relations. Therefore, the functional architecture of cognitive and emotional processes uncovered by structural modelling concurs with their organization as suggested by modern research in neuroscience.

Towards a theory of intelligence beyond *g*

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Abstract: Brain physiology and IQ gains over time both show that various cognitive skills, such as on-the-spot problem solving and arithmetic reasoning, are functionally independent, despite being bundled up in the correlational matrix called *g*. We need a theory of intelligence that treats the physiology and sociology of intelligence as having integrity equal to the psychology of individual differences.

Take the ability to solve problems on the spot without a previously learned method as tested by Raven's or Similarities. When normal people are ranked against one another at a given place and time, those who do better than average on this kind of problem-solving tend to do better on a wide range of cognitive tasks. Thus, this cognitive skill is positively correlated with cognitive tasks, predicts performance on them, and earns the label gF (fluid general factor). However, when society sets helter-skelter priorities over time – say, emphasizes on-the-spot problem solving and neglects arithmetic reasoning (taxpayers are too silly to pay for good math teachers) – the correlation between this kind of problem solving and other cognitive tasks simply unravels (Flynn 2003). Its predictive potency fades away and, since that is the essence of gF, it should have a new name. I suggest Fpsa (fluid problem-solving ability).

The only thing that could prevent society from unraveling the correlational matrix would be brain physiology: a human brain so structured that no single cognitive ability could be enhanced without enhancing all of them. As Blair triumphantly shows, the brain is not like that. When we turn to abnormal brains – those affected by trauma, phenylketonuria, or unusual stress – we find the following: Just as society can pick and choose which mental abilities it wishes to improve, so the brain is sufficiently decentralized that it can pick and choose. Its damaged areas can veto a normal level of Fpsa while, at the same time,