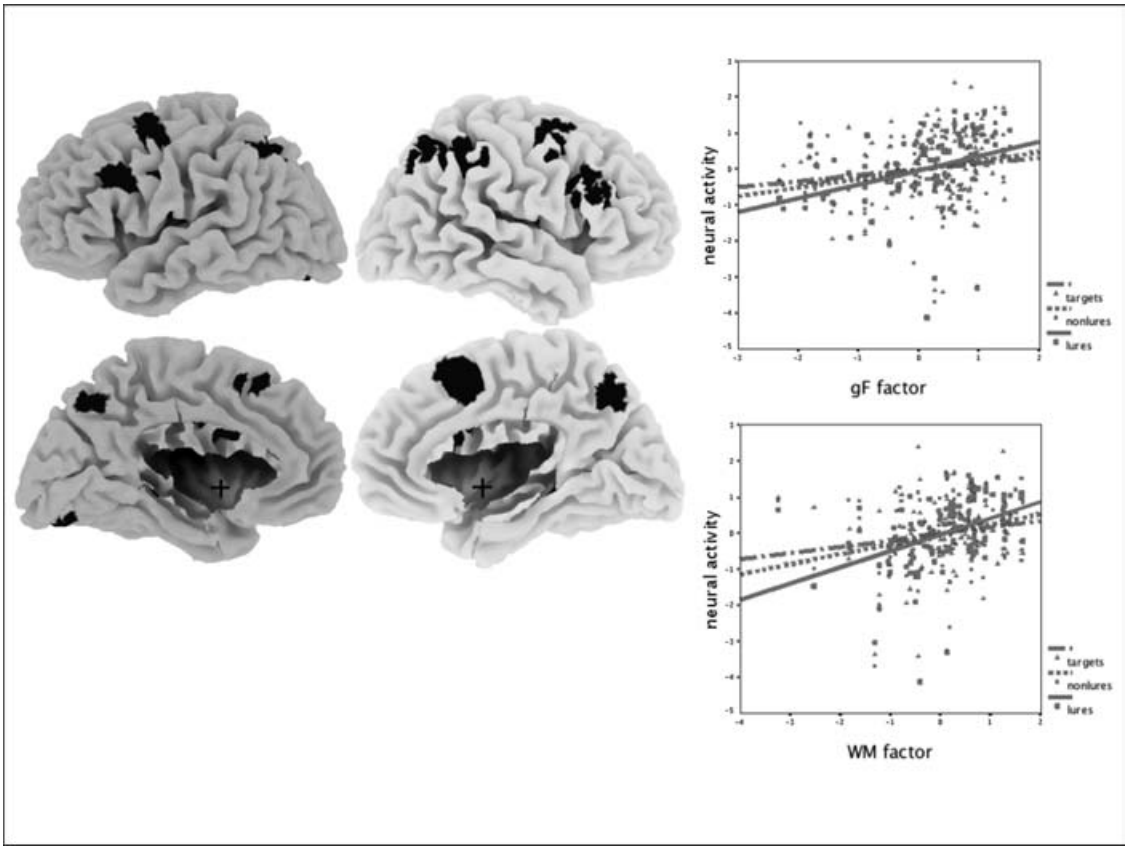


Figure 2 (Burgess et al.). Correlations between neural activity in executive function (EF)–related brain regions and fluid intelligence (gF) and working memory (WM) span. By experimentally manipulating the presence of interference across trial types, we could index the relationships between gF (or WM span) and more specific processes. Lure activity (*solid lines*) correlates strongly with gF (top pane) and WM span (bottom pane), while correlations with nonlure (*narrow dashes*) and target (*wide dashes*) activity are considerably smaller.

arousal and the stress response, may impact fluid cognitive functioning and its apparent similarity to general intelligence" (sect. 2.3, last para.). In the 48 participants from the first study, we tested whether individual differences in affective personality dimensions might impact brain activity in lateral PFC and ACC during 3-back performance in a similar manner as gF (Gray et al., in press). We found that BAS (behavioral activation sensitivity; Carver & White 1994) and extraversion were correlated with activity in lateral PFC and ACC, as predicted by Blair's account. However, the picture was more complex than this. First, in contrast to gF, the correlations were present across all three trial types, not just lures. Second, the correlations were negative (high BAS/extraversion = less activity), as opposed to the positive correlations with gF. Third, the gF and personality correlations were independent, in that both variables explained lateral PFC activity, even after controlling for the other. Thus, the results suggest that affective individual differences modulate activity in brain regions related to EF, but in a manner distinct from the effects of gF.

Both studies make clear the point that there are relationships among gF, WM, and EF, but that the constructs are not isomorphic. Nevertheless, these results highlight the promise of a combined correlational–experimental approach for more precisely determining the relationships among individual difference constructs. It is our belief that this approach could be extended further to examine other questions raised by Blair, such as the relationship between gF and psychometric *g*, the relationship of gF to distinct EF processes (e.g., conflict detection), affect–cognition interactions, and the mechanisms that relate gF versus psychometric *g* to real-world outcomes (e.g., academic success). Critically, the effects of compensatory training or interventions could be more meaningfully evaluated by determining how performance changes relate to changes in underlying brain activity, and whether such changes are linked to variation in gF versus other individual difference constructs, such as psychometric *g*. Such an approach might elucidate the real goal of Blair's analysis, which is to develop and implement optimal intervention programs for young children facing adversity in order to improve their real-world outcomes. This is a goal that we wholeheartedly support.

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Within fluid cognition: Fluid processing and fluid storage?

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Abstract: Blair describes fluid cognition as highly related to working memory and executive processes, and dependent on the integrity of frontal-lobe functioning. However, the literature review appears to neglect potential contributions to fluid cognition of the focus of attention

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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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