1. Commentary on Clancy Blair target article

2. Word counts:

Abstract	62
Main text	1,066
References	487 (435 excluding 2 references already in the target article)
Total	1,615 (1,563 excluding 2 references already in the target article)

3. Title: Within Fluid Cognition: Fluid Processing and Fluid Storage?

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Abstract

Blair described 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 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.

Main Text

This is 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 was defined as "all-purpose cognitive processing not necessarily associated with any specific content domain and as involving the active or effortful maintenance of information." It was "used interchangeably to some extent with the terms working memory and executive function" (Section 2.2) and was 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 itself 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, Chen, & Rouder, 2004; Cowan et al., in press; Garavan, 1998; Oberaeur, 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., Postle, Berger, & D'Esposito, 1999; Postle, Druzgal, & D'Esposito, 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 (Posner & Peterson, 1990; Cowan, 1995). 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 3 or 4 items in working memory. Neuroimaging and event-related potential studies with this task indicate that neural activity dependent on the set size and 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 6- or 7-digit list impairs performance on the visual array task, especially on trials in which the digit list was 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 2-digit list or a know telephone number (Morey & Cowan, 2004, in press). 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, Barrouillet, & Camos, in press). 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 visual array task described above). A simple digit span task also correlates with aptitudes in children too young to rehearse the digits (Cowan et al., in press). 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 (Section 3.2) 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)." In this phenomenon (see also Halford, Baker, McCredden, & Bain, 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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