factors is especially interesting and important to study because all social disorders may be thought of and studied as emotional disorders and as resulting from repeated broad changes (Nesse 1998). Finally, we can design experiments that will prompt proper cognitive treatments for such cognitive disorders, for example, enriching the environment with controlled stimuli in the case of simulated autism, so as to hinder isolation.

Mechanisms of fluid cognition: Relational integration and inhibition

Indre V. Viskontas and Keith J. Holyoak

Department of Psychology, University of California, Los Angeles, CA, 90095-1563.

indre@ucla.edu holyoak@psych.ucla.edu

Abstract: Blair argues that fluid cognition is dissociable from general intelligence. We suggest that a more complete understanding of this dissociation requires development of specific process models of the mechanisms underlying fluid cognition. Recent evidence indicates that relational integration and inhibitory control, both dependent on prefrontal cortex, are key component processes in tasks that require fluid cognition.

As Blair notes, numerous studies have shown that fluid cognitive processes can be dissociated from general intelligence in individuals with prefrontal cortex (PFC) damage (Duncan et al. 1995; Waltz et al. 1999). Furthermore, Blair also presents evidence supporting the hypothesis that the development of fluid intelligence precedes and even "paves the way for the development of crystallized intelligence" (sect. 4.1, para. 1) (Cattell 1971; Horn & Cattell 1967). Others have observed that prefrontal cortex, which appears to be critical to fluid intelligence, plays a major role in cognitive development. For example, Damasio (1985) concluded that, "It seems probable that bilateral damage to the frontal lobes in infancy or childhood produces a more devastating effect on personality and cognitive ability than the same amount of damage sustained elsewhere in the brain at any time in the course of development" (p. 351).

The conceptual separation of fluid cognition from general intelligence sets the stage for more specific hypotheses concerning the processing mechanisms that support fluid cognition. Recent work on human reasoning supports the proposal that tasks requiring fluid cognition depend on specific functions of prefrontal cortex: the representation and manipulation of explicit representations of relations, and the capacity to inhibit responses based on salient but less complex representations (Robin & Holyoak 1995). In the target article, Blair cites a study by Waltz et al. (1999) in which we observed a decline in relational processing with frontal impairment. Specifically, patients with frontal-variant Frontotemporal Lobar Degeneration (FTLD) were able to solve problems that required processing a single relation at a time (e.g., understanding a simple relation such as "Mary is taller than Sally"); however, their performance fell to chance on problems that required integrating multiple relations (e.g., using the premises "Mary is taller than Sally" and "Alice is taller than Mary" to infer by transitivity that Alice is taller Sally).

Similar but less dramatic impairment of relational integration has been observed in Alzheimer's patients who display frontal signs (Waltz et al. 2004). Our lab has also found (Morrison et al. 2004) that patients with frontal-variant FTLD are severely impaired in solving even 1-relation verbal analogies when active inhibition of a semantically related distractor is required (e.g., PLAY:GAME:GIVE:? where the analogical answer PARTY competes with the semantically-related distractor TAKE). Solving the kinds of problems associated with fluid cognition thus requires both relational integration (a core function of working memory) and inhibitory control.

We have recently extended these findings by investigating relational integration and inhibitory control in younger, middle-aged, and older adults (Viskontas et al. 2004; in press). A general decline in working memory capacity with age is well documented (Craik et al. 1990; Dobbs & Rule 1989). Most of the evidence indicates that while primary or immediate memory capabilities, such as digit span, remain relatively constant throughout life, working memory processes that involve the actions of the central executive, such as manipulating information held in memory, are vulnerable to age (Craik et al. 1990). In our reasoning tasks (including transitive inference, and versions of Raven's Matrices problems), participants had access to all of the information needed to make inferences at all times; we thus minimized demand on short-term storage systems. However, we varied the number of relations that had to be manipulated to find a solution; as more relations had to be integrated, the central executive would be increasingly taxed. In addition, we varied whether or not a superficially similar distractor item was present to compete with the correct relational response.

We found that, as people age, their ability to manipulate multiple relations declined. Moreover, the number of relevant relations interacted with the requirements for inhibitory control, such that older people were most vulnerable when high levels of relational complexity were coupled with high need for inhibition of superficially related alternatives (see Fig. 1).

Our results indicated that this apparent decline in processing capacity in working memory follows a gradual pattern: younger adults reached their working memory capacity when integrating four relations, middle-aged people had some trouble integrating three relations, and older adults had trouble integrating even two relations. This pattern of results suggests that aging does not produce a catastrophic failure in processing multiple relations, as was observed for patients with extensive frontal lobe degeneration (Waltz et al. 1999). Rather, the decline in relational

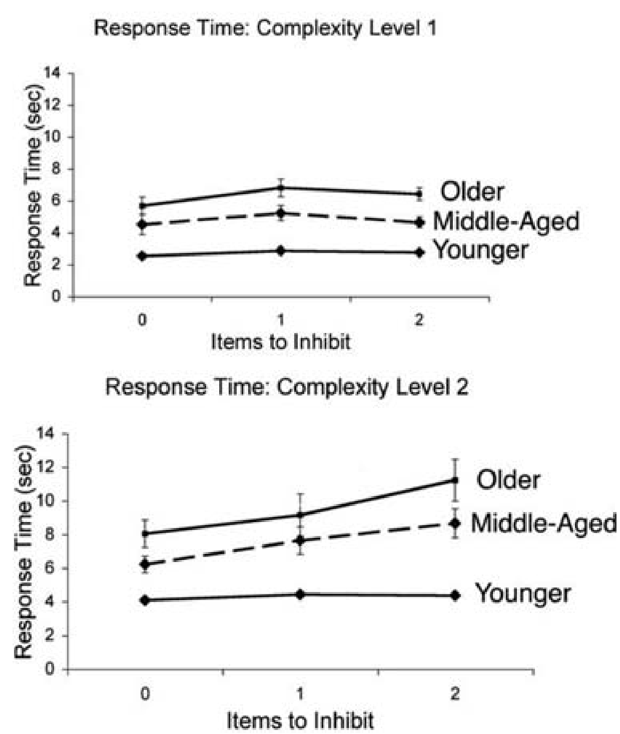

Figure 1 (Viskontas & Holyoak). Response time in the People Pieces Analogy task for three levels of inhibition at the first two levels of complexity for younger ($n = 31$), middle-aged ($n = 36$), and older ($n = 22$) groups (*error bars* depict standard error of the mean). Data from Viskontas et al. (2004).

integration follows the trajectory of the development of relational integration in reverse (Halford 1993; Richland et al. 2004). Even when memory-storage demands are minimized by the continual presence of the premises, normal aging is accompanied by declines in processing capacity that cause impairments in relational integration and inhibitory control.

We have developed a computational model of relational reasoning that has been used to simulate differences in reasoning ability attributable to changes in the neural mechanisms responsible for relational integration and inhibitory control (Hummel & Holyoak 2003; Morrison et al. 2004; Viskontas et al. 2004). By defining the processes underlying fluid cognition in specific computational terms, it should be possible to make predictions concerning which measures of general intelligence will bring age-related deficits to light, and which will fail to show any decline. We can also apply this deconstructive method to daily tasks faced by the general population. This approach may prove fruitful in assessing individual differences in cognition within large populations.

Phlogiston, fluid intelligence, and the Lynn–Flynn effect

Martin Voracek
School of Psychology, University of Vienna, A-1010 Vienna, Austria.
martin.voracek@univie.ac.at
http://mailbox.univie.ac.at/martin.voracek/

Abstract: Blair's assertion that fluid intelligence (gF) is distinct from general intelligence (*g*) is contradictory to cumulative evidence from intelligence research, including extant and novel evidence about generational IQ gains (Lynn–Flynn effect). Because of the near unity of gF and g, his hypothetical concept of gF' (gF "purged" of g variance) may well be a phlogiston theory.

In 1669, the German chemist and adventurer J. J. Becher advanced an entirely nonsensical, but regrettably influential, hypothesis regarding the nature of combustion that became later to be known as phlogiston theory. According to Becher and his followers, phlogiston – some kind of "elastic principle," without color, odor, taste, or weight – is present in all flammable ("phlogisticated") materials. During combustion ("dephlogistication"), this hypothetical matter was thought to be given off. Phlogiston theory was strongly supported throughout most of the eighteenth century, until the French chemist A. L. Lavoisier, now rightly recognized as the father of modern chemistry, discovered the true nature of combustion (namely, the role of oxygen therein, along with the law of conservation of mass). I confess that several key points in Blair's target article sound phlogiston-like to me.

Blair considers the relation of fluid intelligence (gF; his term is "fluid cognitive functioning") to general intelligence (*g*), asserting that gF is distinct from *g*. This is in stark contrast to the cumulative empirical record from intelligence research. There is now broad consensus that the loading of gF on the highest-order factor (*g*) is essentially unity; that is, that the two are effectively identical (Carroll 1993; Gustafsson 1984). Although some debate about this view appears to be still going on (Carroll 2003; Johnson & Bouchard 2005), even impressively cautious and critical commentators like Mackintosh (1998, pp. 227, 297) agree with the consensus view about this aspect of the hierarchical structure of human intelligence.

As a consequence of the near unity of gF and g, there appears to be no room left for Blair's hypothetical concept of gF′ (i.e., gF "purged" of *g* variance, to be studied independently from *g*). Importantly, Blair's outline of gF′ lacks any data-analytic examples. Should these be undertaken, I anticipate that it will be recognized that gF′ consists merely of a hodgepodge of method variance, measurement error, and, possibly so, residues of visuospatial ability facets (gV) contaminating our best vehicle of gF (i.e., Raven-type matrices tests of abstract reasoning).

Blair sets out various lines of evidence allegedly supportive for his assertion of a gF–*g* dissociation. Among others, the so-called Lynn–Flynn effect (for the name, see Rushton [1999, p. 382]; for reviews, see Neisser [1998] and Fernández-Ballesteros et al. [2001]) – that is, the secular increase in IQ and related measures of achievement – is also called on. Specifically, Blair asserts that there is evidence for a gF–*g* dissociation in regard to the rising mean IQ of populations over time (target article, sect. 3.1). According to Blair, IQ gains have almost entirely occurred on measures of gF and not on measures of crystallized intelligence (gC).

A more principal objection is waived here: it is perhaps not the best idea to try to prove or support one highly debatable matter (i.e., a supposed gF–*g* dissociation, along with the meaningfulness of the gF′ concept) with another matter that is itself far from being well understood (i.e., the Lynn–Flynn effect). Rather, the focus will be on Blair's claim regarding the Lynn–Flynn effect. I opine that his presentation is based on an incomplete narrative review of the pertinent literature, with selective referencing. Elsewhere (Blair et al. 2005a), he has argued that educational changes have largely been responsible for the Lynn–Flynn effect. This stance appears to be lopsided, overlooking the fact that generational IQ gains have been ascertained even in preschoolers, which makes nutritional factors a very likely explanation (Colom et al. 2005; Lynn 1990). Further, this stance discounts the real eventuality that the IQ gains are not necessarily solely environmental, but rather are also compatible with demographic (i.e., genetically based phenotypic) changes over time (Mingroni 2004).

The international pattern regarding the Lynn–Flynn effect is erratic: the highest IQ gains have been observed in the Netherlands and further in France, Japan, and Israel (Flynn 1987; 1998b), whereas below-average gains have been reported for countries such as Great Britain, Ireland, New Zealand, and Australia (Flynn 1987). IQ gains may have already ceased or even reversed in Norway and Sweden (Flynn 1998a; Sundet et al. 2004) and actually have recently reversed in Denmark (Teasdale & Owen, in press). Similarly, there are enigmatic cross-national differences in the gF:gC gain ratios: whereas gF gains have been larger than gC gains within the Anglo-American sphere, there have been noticeable gains on vocabulary tests (gC) in Germany and in the German-speaking countries Austria and Switzerland (Flynn 1987; 1998a; 1999; Schallberger 1987; Schubert & Berlach 1982), approaching the gains seen there on gF measures.

Adding to this evidence, here I bring forward new data (Voracek 2002). Based on a sample of 5,445 consecutively referred psychiatric patients (Vienna, 1978–1994) and using Flynn's (1998b, p. 551) methodology, the estimated (IQ (i.e., the amount of IQ change per decade; Jensen 1998, p. 319) on a gC measure (the multiple-choice vocabulary test MWT; Lehrl et al. 1995) was 1.98, whereas IQ was 2.47 on a gF measure (a 30-item Rasch-scaled version of Raven's Standard Progressive Matrices; Wytek et al. 1984). It is not only intriguing to see that the Lynn–Flynn effect appears to generalize to subpopulations such as psychiatric patients, too, but also that – contrary to Blair's general claim – there certainly is no "dissociation" of gC and gF gains in this study (the gC:gF gain ratio being a modest 1:1.25).

Further, a novel research approach was pursued in the same work (Voracek 2002): I wondered whether a Lynn–Flynn effect could be ascertained from mean group scores on the widely used MWT, as incidentally reported in research from German-speaking countries, taking into account publication year. Of course, each mean MWT score from a small sample of research subjects is unrepresentative for the general population – but what would be the aggregate evidence, based on a great many of such samples? By means of a cited-reference

https://doi.org/10.1017/S0140525X06379034 Published online by Cambridge University Press