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

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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

search strategy, I located 288 primary studies, published in 1973–2002, which reported mean MWT scores for 527 groups of German, Austrian, and Swiss study participants (healthy adults as well as patient samples), totaling nearly 29,000 subjects. This large-scale meta-analysis of unrepresentative samples yielded an ΔIQ estimate of 2.61 for the gC measure MWT. This figure is comparable with the finding from the Austrian psychiatric patient sample and further nicely dovetails with extant evidence from population-based studies. Flynn (1984) originally arrived at a ΔIQ estimate of about 3 (USA, 1932–1978), which was later updated to about 2.5 (USA, 1972–1995 [Flynn 1998c]). A reanalysis of the extant international evidence by Storfer (1990, p. 439) suggests that ΔIQ was about 3.75 during the first quarter of the twentieth century, about 2.5 for the subsequent decades until about the mid-1960s, and probably less since then.

To summarize, Blair's claim of a gF–gC dissociation supposedly seen in the Lynn–Flynn effect (in order to support his gF" concept) is neither supported by the empirical record in this area nor by the new findings presented here. We are all well advised not to devote ourselves to phlogiston theories of human intelligence.

How relevant are fluid cognition and general intelligence? A developmental neuroscientist's perspective on a new model

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Abstract: Blair boldly proposes a model integrating different aspects of intelligence. Its real-life value can be put to the test by using programs designed to develop children's abilities in areas predicted to be crucial for minimizing adverse outcome. Until support from such programs is available, the model is an interesting hypothesis, albeit with remarkable possible repercussions. As such, it seems worthy of further development.

In his target article, Blair provides a comprehensive model for identifying and describing different aspects of intelligence (broadly defined), including the neurobiological underpinnings. As with many models proposed, a developmental neuroscientist is tempted to ask: So what? Numerous models are out there, aiming to describe and explain the multitude of observations regarding "intelligence" both in impaired and unimpaired subjects. What makes this work stand out is the direct applicability of the concept and, even better, the fact that we are liable to put it to the test both clinically and in neuroscience research. Clinically, those working with children from disadvantaged backgrounds or with children showing mental retardation can direct their attention towards developing programs aiming to influence the specific aspects of fluid cognition that Blair hypothesizes to be central in determining later outcome, as measured by as yet inappropriate tests. For neuroscience research, a number of directions seem to suggest themselves as to how the pertained distinction of fluid and general intelligence could be disentangled, for example, by using modern neuroimaging methods. As it is, the target article describes a bold new concept, thoroughly doing away with the monolithic idea of *g*-and-nothing-else. As such, it is likely to draw criticism from "proponents of the old order," and probably rightly so. However, programs designed to test the concept can (and, hopefully, will) be developed that enable supporting the concept with not only theoretical neuroscience data (such as functional magnetic resonance imaging [fMRI]) but, ideally, with the very practical and highly important result of children simply doing better in life. If this were the case, Blair must be commended for boldly going down this road. If not, then it will be just another model, with not much relevance for clinicians' daily work.

There are drawbacks, of course. What about the role of the thalamus and the cerebellum, both of which have been considered cornerstones for the cognitive impairment seen not only in schizophrenia (Clinton & Meador-Woodruff 2004; Rapoport et al. 2000; Schultz & Andreasen 1999)? Considering that the thalamus was classically used to define prefrontal cortex as the projection area of the mediodorsal thalamic nucleus, should it not be expected to play some kind of role, as a gatekeeper or in some other form, hitherto unknown? In our study on gray matter correlations with a broad measure of intelligence, the thalamus was implicated in these correlations in a connectivity analysis, as was the medial temporal lobe (Wilke et al. 2003). Interestingly, the correlation of global gray matter and IQ (as assessed by the Wechsler batteries and thus reflecting mainly general intelligence) only develops during childhood, perhaps lending support to the notion of fluid skills playing a larger role in early childhood. Also, if there is a dissociation of fluid skills and general intelligence in adults in a way that only fluid skills are affected, should there not also be a model for an isolated decrease in general intelligence which could shed additional light on the issues? Finally, could the differential effects of prefrontal cortex lesions in the neonatal period and in adulthood not also be seen as simply being an indication of the generally larger cortical plasticity in children? I am sure others will come up with more, and more serious, issues this model has to accommodate, and this process will be interesting to follow.

Still, it also seems interesting to complement this work with two timely studies published recently. In one fMRI study, Breitenstein et al. (2005) distinguished good learners from bad learners by the amount of hippocampal activation. This is all the more interesting as all subjects were healthy adults, indicating that, employing the right kind of paradigm and using performance data as a guide, it may be possible even in healthy subjects to tease out the different aspects of cognition described by Blair. Even more interesting and lending strong support for one of the main theses of the target article is the study by Heinz et al. (2005). Here, subjects with three genetically defined variants of a serotonin-transporter system were investigated by using fMRI and applying the concept of functional connectivity. This serotonin transporter is believed to play a crucial role in a subject's liability to develop major depression. It could be demonstrated that the strength of the coupling between the amygdala and the ventromedial prefrontal cortex is a function of the genetic variant of the subject. Therefore, a genetic influence on behavior via the pathway that plays a crucial role in Blair's model of cognition-emotion reciprocity is suggested. This adds evidence for a genetic contribution to or modulation of the putative environmental influence that Blair hypothesizes, which (by virtue of lending support to the mechanism in itself) further strengthens the point made about this link.

Overall, I believe this to be a very interesting model which accommodates a number of observations and lends itself to rigorous testing. As it is, however, its virtues, beyond explaining the observed, can be assessed only in years to come, following extensive discussions of the pros and cons. It is as yet too early to decide, but for the sake of children possibly profiting from a more targeted approach to support, I wish the model well.

Can fluid and general intelligence be differentiated in an older adult population?

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