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Cognitive and Personality Predictors of School Performance From Preschool to Secondary School: An Overarching Model

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In this article, existing research investigating how school performance relates to cognitive, self-awareness, language, and personality processes is reviewed. We outline the architecture of the mind, involving a general factor, *g*, that underlies distinct mental processes (i.e., executive, reasoning, language, cognizance, and personality processes). From preschool to adolescence, *g* shifts from executive to reasoning and cognizance processes; personality also changes, consolidating in adolescence. There are three major trends in the existing literature: (a) All processes are highly predictive of school achievement if measured alone, each accounting for ∼20% of its variance; (b) when measured together, cognitive processes (executive functions and representational awareness in preschool and fluid intelligence after late primary school) dominate as predictors (over ∼50%), drastically absorbing self-concepts and personality dispositions that drop to ∼3%–5%; and (c) predictive power changes according to the processes forming *g* at successive levels: attention control and representational awareness in preschool (∼85%); fluid intelligence, language, and working memory in primary school (∼53%); fluid intelligence, language, self-evaluation, and school-specific self-concepts in secondary school (∼70%). Stability and plasticity of personality emerge as predictors in secondary school. A theory of educational priorities is proposed, arguing that (a) executive and awareness processes; (b) information management; and (c) reasoning, self-evaluation, and flexibility in knowledge building must dominate in preschool, primary, and secondary school, respectively.

Keywords: cognitive development, intelligence, personality, awareness, school performance

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This review is based on five studies already published (see citations in the article). New analyses, explained in the article, were applied on the data of each study to ensure similarity of models across studies. Special thanks are due to Elena Kazali (Study 1), Demetris Tachmatzides (Study 2), Smaragda Kazi (Studies 1 and 3), and Maria Andreou (Study 5) for their contribution to the various studies.

These studies were not preregistered. The correlation tables and statistics needed for modeling are presented in Supplemental Material. The code and full models (and related figures) are also presented in Supplemental Material. Further information for each study may be obtained from the respective published articles. Raw data files may be obtained from Andreas Demetriou.

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General Postulates About Mental Architecture and Development

How does school performance relate to cognition, self-awareness, language, and personality? The present study defines "cognition" as executive functions (e.g., attention control and working memory), "reasoning" (e.g., inductive, analogical, and deductive reasoning), and problem-solving skills across domains such as mathematics and science, including spatial relation. "Awareness" involves mental states and processes, and their self-concepts, while "language" includes vocabulary, syntax, and semantics. Finally, "personality" involves dispositions in relating to the world, including sociability, self-management, emotional sensitivity, and dealing with novelty. We ground this article in three principles, originating from the psychology of individual differences, cognitive science, and developmental psychology.

A key principle assumed by individual differences is that general intelligence, or *g*, is empirically powerful and relates to all cognitive processes (Carroll, 1993; Jensen, 1998; Spearman, 1927), as well as important life outcomes, such as school learning and occupational success (Gottfredson, 2002). The principle derived from cognitive science assumes that *g* involves several cognitive processes that serve specialized needs in understanding, learning, and problem-solving. *g* reflects (a) efficiency in using cognitive processes; (b) their interdependence, implying a common core (Haier, 2017; Jensen, 1998, 2006) or orchestrated interactions between them for the purpose of understanding and problem-solving (Kovacs & Conway, 2019; van der Maas et al., 2006, 2017); and (c) systematic differences between individuals and their use of cognitive processes. The term *cognitive ability* is often used interchangeably with *g* to indicate where individuals stand relative to one another concerning points (a) and (b). The principle derived from developmental psychology assumes that *g* is not fixed; its nature changes with development. Extensive recent research shows that, at different age periods, *g* is differentially related to individual cognitive processes such as attention, working memory, and reasoning (Demetriou et al., 2013, 2017, 2021, 2022; Demetriou, Makris, et al., 2019). Changes in *g* with development explain why the standing of many individuals relative to their agemates changes throughout the years (Deary, 2014; Yu et al., 2018).

Therefore, the central message of this article should interest educators: with development, cognitive and personality processes improve for all persons, and it may also improve the possibilities of individuals relative to the accomplishments of others. Here, we show how the profile of cognitive and personality processes predicting school performance changes with age, implying that school learning draws on different combinations of processes at different phases. We also highlight cognitive and personality profiles that are more likely than other profiles to enable individuals to improve their standing relative to others as they develop. Education and family must systematically support age-appropriate priorities in cognitive and personality development, which are conducive to the attainment of learning goals for each school year and better prepare for the years following. It is important to remove developmental drawbacks when meeting these priorities in a timely way, to avoid a buildup of developmental lags that may hinder later learning.

Cognitive and personality processes relate to school performance. Psychometric *g* factor accounts for the majority, although the amount of school performance variance accounted for varies extensively across studies, ranging between ~20% and 50% (Gustafsson & Balke, 1993; Kaufman et al., 2012; Roth et al., 2015). Aspects of self-awareness, such as self-evaluation (Mabe & West, 1982) and self-concept, are also related (e.g., Guay et al., 2003; Johannesson, 2017; Orth & Robins, 2022). However, the strength of these relations also varies enormously across studies (correlations varying from $r = 0$ to .8). Self-efficacy beliefs (Bandura, 1997) that reflect one's stance on capability and motivation to succeed (Zimmerman, 2000) were found to account for ~15% of the variance (Multon et al., 1991). Finally, aspects of personality, such as being goal-oriented and organized (i.e., conscientious), or open and flexible in dealing with new experiences, were found to account for ~5% of academic performance variance, but again results vary across studies (Poropat, 2009).

Although useful, existing findings are limited in several respects. First, cognitive measures differ across studies. Many studies extract *g* from reasoning processes used in different problem-solving domains, such as inductive, analogical, mathematical, and spatial reasoning, but they do not include measures of processing and representational efficiency (e.g., Gustafsson & Balke, 1993); others also include these later processes (e.g., Rindermann & Neubauer, 2001). Often, the definition of *g* and its ensuing technical identification varies from study to study. Therefore, the very nature of *g* is variable. These differences may explain the large disparity in the opinion of *g*'s influence. Also, the relationship between academic performance and cognitive or personality processes may be confounded due to their often overlapping. For instance, self-concepts mirror cognitive ability, at degrees varying with age (Demetriou, Makris, et al., 2019; Demetriou, Makris, Kazi, Spanoudis, & Shayer, 2018; Demetriou, Makris, Kazi, Spanoudis, & Shayer, 2018; Demetriou & Kazi, 2001). Finally, self-concepts, self-evaluations, and self-efficacy beliefs reflect a common stance toward self-presentation and self-evaluation and are also transformed with growth (Anusic et al., 2009; Demetriou, Makris, Kazi, Spanoudis, & Shayer, 2018). Therefore, if the relationship between these processes is not disentangled, the uncontaminated relation of each with academic performance cannot be specified.

Second, developmental changes in cognitive and personality profiles (Demetriou et al., 2017; Demetriou & Spanoudis, 2018) bear important implications for educational priorities associated with successive levels of education. Three periods of development are known to differ cognitively—early childhood (2–6 years), middle childhood (7–11 years), and adolescence (12–18 years)—which corresponds to three levels of education: preschool, primary, and secondary education, respectively. These levels place different demands and priorities on learning, which may not align with developmental priorities. It is important to disentangle the various cognitive, self-awareness, and personality constructs from each other if the precise relation of each with school performance at each level of education is to be specified.

Divided into three sections, this article first outlines the architecture and development of the human mind and personality. Second, we summarize studies exploring the relations of mental and personality processes with school performance. Third, an outline of general theory integrating cognitive, developmental, personality, and educational considerations into a comprehensive framework is offered.

Three key ideas are discussed:

1. How the relationship between cognitive processes changes with growth, altering developmental priorities into different cognitive processes in the formation of general cognitive ability.

2. Changes in developmental priorities in the formation of general cognitive ability, and how personality dispositions alter the cognitive and the personality basis for learning at school.

3. The need for an educational evaluation to capture mental priorities and personality profiles at each school grade, and how learning priorities and methods in the curriculum must be adapted accordingly.

The Architecture of the Human Mind

Architecture of Cognition

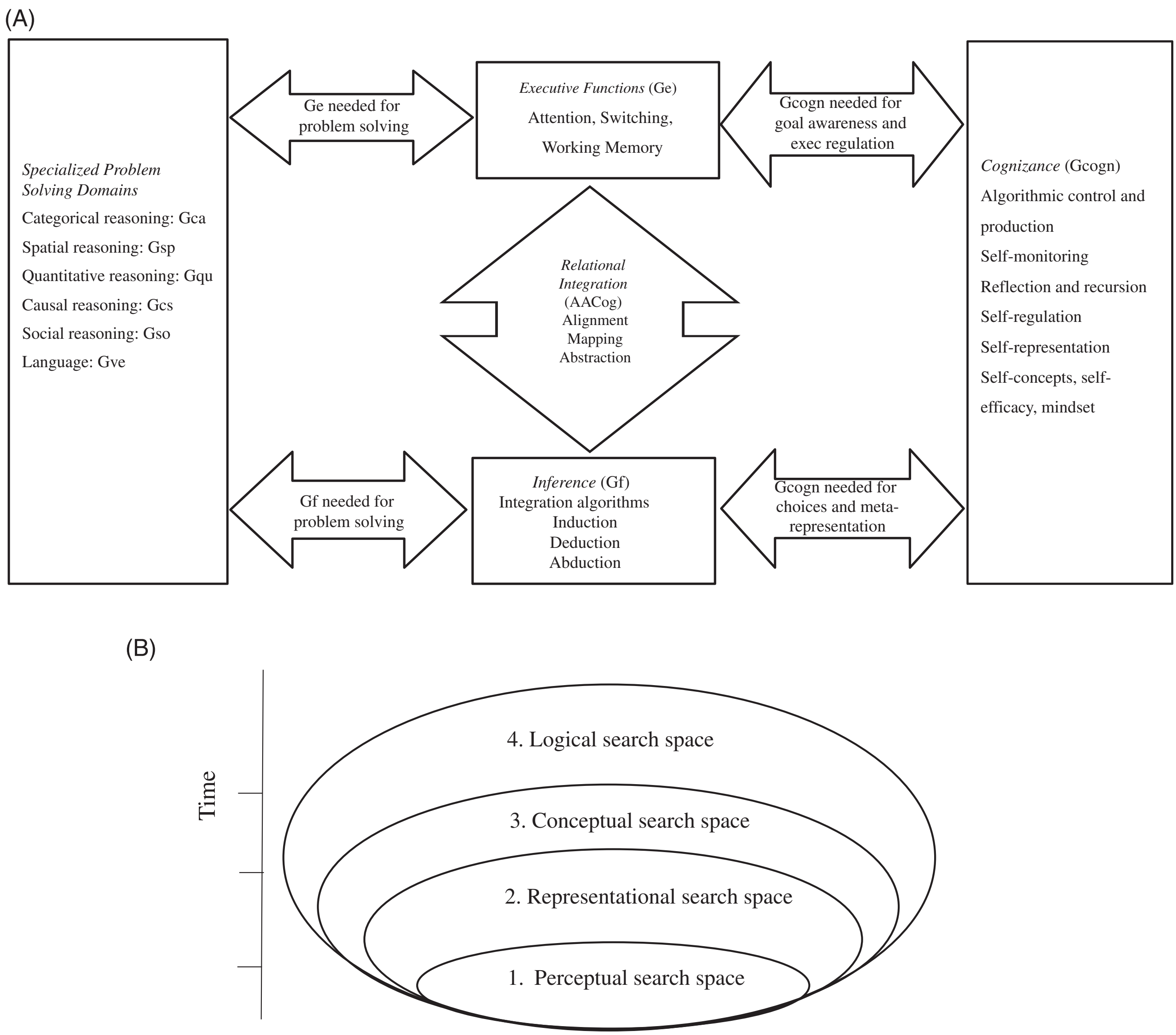
The human mind encompasses mental processes that carry out different tasks to facilitate understanding and problem-solving (e.g., Carroll, 1993; Demetriou, Makris, Kazi, Spanoudis, &

Shayer, 2018; Demetriou, Makris, Kazi, Spanoudis, & Shayer, 2018; Demetriou & Spanoudis, 2018; Hunt, 2011). We can define these mental processes as follows (see Figure 1A):

1. *Specialized problem-solving domains* (see Figure 1A) interface the mind with different types of relations in the environment, such as categorical (G*ca*; e.g., Is A like B?), quantitative (G*qu*; e.g., Is B larger than A?), causal (G*cs*; e.g., Did A cause B?), spatial (G*sp*; e.g., Where is A relative to B?), or social (G*so*; e.g., What does A think about B?). Domains are activated by the organization of information in the environment (e.g., colors, sounds, or shapes raise questions of class relations; interacting objects raise questions about causal relations; size differences raise questions of quantitative relations). Thus, domains bias the initial representations of the

Figure 1

(A) The General Architecture of the Human Mind. (B) The Development of the AACog Mechanism Across Developmental Cycles



Note. (1) Perceptual search space: alignment of perceptual properties; abstraction based on perceptual similarity or statistical regularities; expectations based on perceptual or episodic relations: (A and B) → (A then B) or (if not A then B). Awareness of episodic sequences. (2) Representational search space: alignment of representations. Abstraction of perception–representation and interrepresentational relations. Awareness of the representational role of perception. Inductive generalizations; deductions by representational bindings. A and B, if A then B. (3) Conceptual search space: rule alignment. Abstraction of relations between representational lines: mental number line, number names. Integrated deductions: A and B, if not B then not A. (4) Logical search space: multidimensional alignments. Multiple reductions: number line, size scales, weigh scales, speed scales, and so forth, fully integrated deductions: (A and B); (B, not sure about A); (not A, not sure about B).

problem space, framing an initial set of attentional and inferential constraints on processing.

2. *Executive functions* (G*e*, see Figure 1A) enable one to focus attention on stimuli or representations, inhibit attention or responses to irrelevant stimuli or representations, systematically switch between them (Diamond, 2013: Zelazo, 2015), maintain information in (working) memory when not currently perceptually present, and select actions as appropriate (Baddeley, 2012; Cowan, 2016; Jewsbury et al., 2016).

3. A foundational *relational integration* meaning-making core mechanism underlying all processes (*g*; see Figure 1A). This mechanism—henceforth AACog—draws on (a) alignment, (b) abstraction, and (c) cognizance processes (Demetriou et al., 2013; Demetriou, Makris, Kazi, Spanoudis, & Shayer, 2018), which enable a systematic search and comparison of information for the sake of relational integration at different levels—from perception to reasoning. For instance, in a recent study, participants searched a matrix of three-digit number sets to identify those ending with the same (or a different) number. Number sets were systematically searched and aligned with the rule represented, and set–rule relations were abstracted based on the last digit of each set (ignoring the other digits in the set), thus identifying (cognizing) sets consistent with the rule (Chuderski, 2014; Jastrzębski et al., 2020). At a higher level, representations (e.g., apple, cherry, fruit) could be searched and aligned along several properties (e.g., taste, smell) until a common property was identified and abstracted as the critical link (e.g., they are all sweet) amidst many differences. AACog generates meaning by (a) mapping perceived or conceived relations with criterion relations in memory (Hannon & Daneman, 2014); (b) identifying invariant characteristics across stimuli or representations (Burgoon et al., 2013), discriminating elements to be excluded (Reed, 2016); and (c) recognizing that the same representation may represent distinct elements if they meet the rule requirement implemented (Gilead et al., 2020).

4. Various forms of *inference*, such as inductive, analogical, and deductive reasoning (see Figure 1A), capitalize on experience or formal learning. This is done to crystalize the operation and the products of the AACog mechanism into rules governing differing forms of information integration, including reduction, generalization, filling in missing information, or evaluation of consistency or truth. Fundamentally, inductive, analogical, and deductive reasoning constrain how relations may be searched, abstracted, and evaluated by the AACog mechanism. Therefore, reasoning involves processes and standards for exploring possible relations between states of the world and their representations and evaluating the truth and validity of inferences (Johnson-Laird & Khemlani, 2013; Moshman, 2011; Piaget, 1970). After an initial representation of the problem space, problem-solving draws on reasoning processes to build strategies and algorithms that deal with the specificities of relations in each domain; for instance, varying one thing at a time enables to specify causal relations; mental rotation enables exploring spatial relations; counting or arithmetic operations enable one to specify quantitative relations.

5. *Cognizance* (see Figure 1A) is part of consciousness that allows for (a) awareness of mental content and processes (Dehaene, 2014; Demetriou, Makris, Kazi, Spanoudis, & Shayer, 2018; Seth & Bayne, 2022) and (b) ascription of intrinsic values to experience optimizing choices of actions (Cleeremans & Tallon-Baudry, 2021; Demetriou et al., 2022). Cognizance processes relations between perceptual and mental states, or between mental states, within or across individuals both online and retroactively; they gear on an automatic mechanism to allow for reenactment and reprocessing of past experiences for better current or future action or understanding (Demetriou, Makris, Kazi, Spanoudis, & Shayer, 2018). The following processes are manifestations of cognizance: (a) metacognition (Efklides, 2008; Flavell, 1979), theory of mind (Wellman, 2014), and central themes of developmental research; (b) self-concepts and self-evaluations (Harter, 2012; Vallacher et al., 2002), and central themes in clinical and social research; (c) self-efficacy beliefs (Bandura, 1997; Ehrlinger et al., 2016; Sedikides & Strube, 1997), self-esteem (Bosson & Swann, 2009; Orth & Robins, 2022), and self-regulation (Demetriou & Kazi, 2006; Zimmerman & Schunk, 2001), as well as central themes in social and educational research.

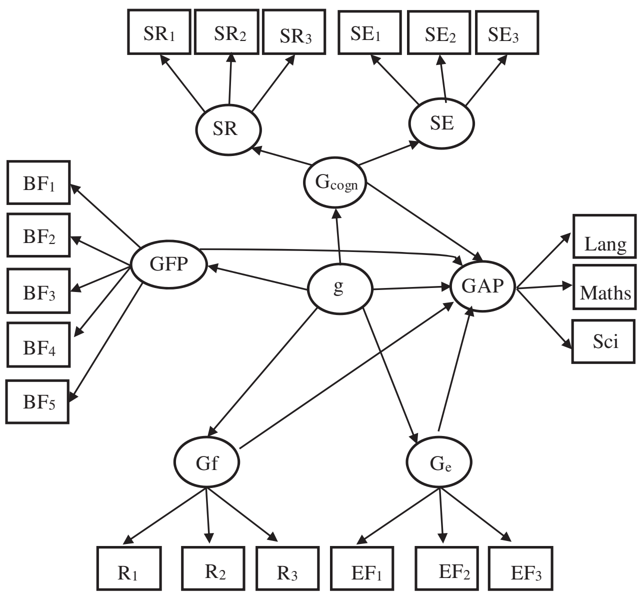
Modeling the Mental Architecture

Explaining school performance using fundamental psychological processes requires agreeing on the measurement and functional status of these processes. Structural equation modeling (SEM) dominated as the method of choice for capturing dimensions of performance demonstrably related to psychological processes, purified from measurement error, to specify their organization and interrelations at various levels, and test specific predictions about relations with school performance (Bentler & Wu, 2005; Bollen & Diamantopoulos, 2017; Marcoulides & Schumacker, 2013). In terms of SEM, a critical model for the present theory would have to satisfy the following requirements.

First, all processes specified by the theory emerge as distinct factors stated in Figure 1B and translated in Figure 2 into the conventions of SEM.

Second, processes relate variably, sharing components or interacting with each other. These relations may be specified in various forms. Globally, they may be specified as a general factor, *g*, related to all other factors. This model was confirmed in many studies (e.g., Demetriou et al., 1993, 2002, 2008, 2022; Demetriou, Kazi, et al., 2020; Demetriou & Kyriakides, 2006). The prototypical model in the literature is the Cattell–Horn–Carroll (CHC) hierarchical model of intelligence (Schneider & McGrew, 2018), whereby specific abilities relate to several broad factors standing for general psychological processes, such as fluid intelligence standing for reasoning; crystallized intelligence standing for knowledge, learning and memory, and processing speed, retrieval, acoustic and visual processing, as well as general speed and decision time. The model basically captures aspects of executive control (Jewsbury et al., 2016). Broad factors relate to a common factor of general intelligence: psychometric *g*.

Figure 2
Overall Template Model Implemented in All Studies



Note. The models used in each study are cases of this model adjusted to the specifics of each study. The specific models tested in each study are presented in Supplemental Material. This model involves all aspects of the mind: reasoning R, related to Gf; executive functions (EF), such as attention control, working memory, and shifting, related to Ge; self-representation (SR); and self-evaluation before (SE), related to a general cognizance factor (Gcogn); the Big Five factors of personality (BF), related to the general factor of personality (GFP); and school performance in several domains (language, mathematics, and science) related to a general academic performance factor (GAP).

Last, a special assumption of the theory is that self-representation and self-evaluation measures emerging from cognizance reflect the cognitive processes they relate to. In development, these measures involve factors mirroring cognitive performance factors with increasing accuracy (e.g., Demetriou & Efklides, 1989; Demetriou et al., 1993; Demetriou & Kazi, 2001, 2006). This assumption yields a seemingly paradoxical prediction about school performance. With increasing accuracy in reflecting actual cognitive performance, self-representations and self-evaluations become increasingly redundant to cognitive performance as predictors of outcome variables.

What Do Factors Stand for?

It is important to agree on what higher order factors represent. These factors are criticized as remote from performance; bereft of psychological identity causally affecting actual performance (Bollen & Diamantopoulos, 2017; Eid et al., 2017). Hence, higher order factors, especially psychometric *g*, are considered composites or indexes of interactions between the processes related to them; they are not accepted as representatives of psychological mechanisms distinctly owned by them but shared by other processes (Conway & Kovacs, 2018; van der Maas et al., 2006, 2017).

The present theory takes a middle ground. On the one hand, it postulates that AACog is a fundamental psychological mechanism in *g*. This mechanism operates as a unit sustaining stimulus search and identification in attention control, allowing inhibition when encountering inconsistent stimuli; it channels switching between search trials when the focus changes; it guides search, organization, and the update of stimuli in working memory; it monitors feedback from ongoing actions needed to evaluate choices and processes in cognizance; finally, it transfers identified relations across representations in inference. On the other hand, the theory also assumes that this mechanism is embedded into increasingly expanding rules and mechanisms enabling relational integration and meaning-making in different domains. Together, these assumptions suggest several patterns of relations between factors. Minimally, fundamental processes in AACog, such as relational integration, would saturate a higher order *g* abstracted from reasoning tasks and would account for the relations between this factor and executive factors, such as attention control and working memory.

To test this assumption, we modeled the data of several studies that measured relational integration, attention control, working memory, and fluid intelligence. In one study, there was a factor for each of the following processes: attention control, short-term memory, complex working memory span, *n*-back working memory, reasoning (two tests of analogical reasoning and the Raven test), and relational integration (identifying patterns of digits or letters implementing a rule, among many other patterns; Chuderski, 2014). In the critical model, relational integration was taken as the mediator. Attention control and the three working memory factors were regressed on relational integration. Reasoning (Gf) was regressed on relational integration and the residuals of the attention control and working memory factors. The effect of relational integration on all four executive factors ($\beta > .6$) and Gf ($\beta = .77$) was very high. Notably, none of the effects of the residuals of the four executive factors on Gf was significant (all $\beta < .08$). Therefore, relational integration fully absorbed the relations between attention control and working memory on the one hand, and reasoning on the other hand. For comparative purposes, this model was retested using attention control or working memory factors as the mediator. In these models, the relations between the residuals of the remaining factors and Gf were significant ($\beta = .2–.6$), implying a variance in Gf that is not captured by attention control or working memory but is captured by relational integration, thus rendering relational integration as *g*'s core mechanism. Noticeably, another component process in AACog—discrimination between sensory stimuli—was found to completely saturate the relations between attention control, working memory, and Gf (Meyer et al., 2010).

In several studies, reference factors related to *g* abstracted from several specific problem-solving factors were regressed on attention control, switching, working memory, cognizance, and reasoning. All relations were significant, ranging between $\beta = .3$ and .5. Attention control (27%), switching (18%), working memory (27%), cognizance (7%), and inference (19%) accounted for significant amounts of the variance of *g*, amounting to 98%. This is an unusually high figure, implying that each of these processes individually contributes to the implementation of AACog processes in problem-solving across domains. The relative effect of these factors changes with age: Attention control increases from 4 to 8 years, and it decreases systematically thereafter; working memory culminates from 9 to 12 years; reasoning and cognizance are low initially and increase from late childhood through adolescence (Demetriou, Spanoudis, et al., 2018; Makris et al., 2017).

Integrating over this research, g is defined as a function of executive processes, fluid reasoning, and cognizance as specified in Equation 1:

$$g = f(\mathrm{Ge}, \mathrm{Gf}, \mathrm{Gcogn}) \cdot \mathrm{age}, \quad (1)$$

where g, Ge, Gf, and Gcogn stand for general intelligence, executive functions, fluid intelligence, and cognizance, respectively. Thus, g is a complex function of Ge, Gf, and Gcogn, and precise values change with age. For parsimony, the notation system of psychometric theory is used, where g denotes general intelligence and G with a subscript denotes a broad ability specified by the subscript (Carroll, 1993).

Each of the three fundamental constructs above is defined in terms of more specific processes:

$$\mathrm{Ge} = f(\mathrm{at}, \mathrm{fl}, \mathrm{WM}) \cdot \mathrm{age}, \quad (2)$$

where at, fl, and WM stand for attention control, cognitive flexibility, and working memory, respectively.

$$\mathrm{Gf} = f(\mathrm{RI}, \mathrm{Reas}_{\mathrm{I,A,D}},) \cdot \mathrm{age}, \quad (3)$$

where RI and $\mathrm{Reas}_{\mathrm{I,A,D}}$ stand for relational integration and reasoning rules underlying inductive reasoning ($\mathrm{Reas}_{\mathrm{I}}$), analogical reasoning ($\mathrm{Reas}_{\mathrm{A}}$), and deductive reasoning ($\mathrm{Reas}_{\mathrm{D}}$), respectively. The functioning of the central RI core is differentiated from mastering the rule sets needed to implement this core in different domains of reasoning, which may be partly independent of each other.

$$\mathrm{Gcogn} = f(\mathrm{A}_{\mathrm{m}}, \mathrm{S}_{\mathrm{e}}, \mathrm{S}_{\mathrm{c}}) \cdot \mathrm{age}, \quad (4)$$

where A_{m}, S_{e}, and S_{c} stand for awareness of mental processes, self-evaluation, and self-concept (including various forms of self-representation expressed in self-esteem and self-efficacy beliefs), respectively.

Development of Cognition

The operation of g generates the fundamental building blocks of language of thought (LoT; Fodor, 1975; Schneider & Katz, 2012), weaving perceptual experiences into representations integrated by various forms of reasoning. Relational integration and cognizance are applied to increasingly differentiated hierarchies of representations and use increasingly precise rule hierarchies. Searching for the relationship between any two entities or events (A R B) may take any form depending upon the domain involved or imposed by the thinker, such as quantitative (A R_{qu} B: larger than, more than, etc.), categorical (A R_{ca} B: similar to, belongs to), spatial (A R_{sp} B; above, left to, in), causal (A R_{cs} B; A caused B), social (A R_{so} B; What does A see, think, believe, about B?), and linguistic (A R_{ve} B patterns of sound mapped onto the identity of objects and their relations; R stands for relational integration, and the subscripts qu, ca, cs, so, and ve stand for its implementation in specific domains of relations). Organizing recurring and complementary relations and related actions within domains generates domain-specific knowledge and skills. Organizing patterns of relations across domains generates different types of reasoning. Changes in these patterns and the necessary demands on enablers are reflected in changes in the profile of g and its relations with executive functions, as outlined below (Demetriou et al., 2017, 2021; Makris et al., 2017). Figure 1B illustrates how changes in the AACog mechanism may be embedded in each other with a transition to each next developmental cycle. Technically speaking, developing command of relations in different domains is akin to the differentiation of a common LoT into largely autonomous LoT expressing the rules and constraints for representing and processing the relations specific to each domain. Notably, Dehaene et al. (2022) adopted a similar position, proposing "that humans possess multiple internal Languages of Thought, akin to computer languages, which encode and compress structures in various domains (mathematics, music, shape …)" (p. 1).

The cognitive profile of g varies with age, depending on the developmental priorities of successive phases. Developmental priorities change with the need to integrate and handle newly emerging representations and rules. Thus, g expands by integrating increasingly efficient levels of control, such as going from action control in infancy to representational control in preschool, then from inferential control in primary school to truth control in adolescence. Several studies explored how specific processes integrate with g or differentiate from it during development at critical transition points between phases. These studies demonstrated that, when a process is a priority for efficient functioning in a phase, this process and g increasingly integrate until the first becomes part of the second. At a point of integration, ensuring that the functional priorities of g have been met, any further improvement of this process is independent of changes in g, as g shifts to other processes important for its functioning, given the need for handling the mental content produced so far. Noticeably, decreasing correlations between processes with development does not necessarily imply that the processes tend to dissociate. This finding may well suggest that one process, such as speed in executing arithmetic operations (a specific mental process), automates and permanently integrates with general processes, such as quantitative reasoning: the first reaches a ceiling, while the others continue developing. Decreasing correlations may also suggest an increased dimensionalization of processes, such as tuning multiplication with different problem types (e.g., natural numbers vs. decimal numbers; Demetriou et al., 2013, 2017, 2021, 2022; Kazi et al., 2019; Makris et al., 2017). For clarity, to signify a specific cognitive developmental profile, g will henceforth be denoted with a cycle-specific subscript standing for a particular developmental cycle, that is, g_{rc} for the cycle dominated by representations and their control, g_{ic} for the cycle dominated by inference and its control, and g_{lc} for the cycle dominated by logical truth and cohesion control.

Although infancy is beyond our concern, it is noted that understanding in infancy is episodic: It depends on active interactions with persons and objects. Regularities in perceptual or activity patterns are abstracted by Bayesian inference rules that capture the frequency and distribution of events in the environment (Piantadosi et al., 2016). Also, 12-month-old infants reason deductively as an episode unfolds. For instance, they may infer the identity of a partially occluded Object B because they know that it is not Object A, implying disjunctive reasoning (Cesana-Arlotti et al., 2018). Self-awareness and cognizance emerge throughout infancy, including awareness of others' perceptions, their own body and face (Gallup, 1982; Povinelli, 2001), and executive sequences where past actions are intertwined with perceptions and current actions. *Episodic control* is the major priority in infancy, enabling infants to interact with objects and persons.

The proliferation of mental representations in preschool renders the necessity for attentional control. Mental functioning prioritizes "representation-object-action" relations to enable the representational mind emerging in this period; to direct action toward objects according to represented goals. Such functioning creates abstract patterns across representations, enabling one to draw inferences based on the flow of events, and makes pragmatic deals implying an understanding of mutual constraints between representations. Hence, attention control and representational awareness dominate in g_{rc} from 3 to 7 years because they enable children to focus on representations of interest and organize action accordingly. These processes are important for goal identification and selection emerging in this phase, self-directed action (Frick et al., 2022), and for mastering symbol systems in high demand (e.g., language). When mastered, these processes enable more complex cognitive tasks, such as planning and engagement, in ongoing verbal interactions (Demetriou et al., 2017, 2021; Makris et al., 2017).

When attention control and representational awareness are established, priorities change in middle childhood—from 7 to 11 years. Relations between representations must be worked out and explicitly represented. Hence, priorities are redirected from linking representations with the environment and controlling activities to relations between the representations themselves, resulting in a transition to g_{ic}. Connecting specific instances with extant concepts and interrelating concepts according to semantic, procedural, or functional constraints becomes important. In line with these priorities, inductive reasoning, some aspects of deductive reasoning implying grasping the biconditional integration of modus ponens and modus tollens reasoning, awareness of inferential processes, and working memory dominate in *g* from 7 to 11 years old (Demetriou et al., 2017, 2021; Makris et al., 2017).

In adolescence, between 12 and 18 years, relational integration, and awareness shift to relations between rules. Consequently, awareness of the constraints implied by relations directs the search to the principles that underlie rules, thus setting criteria for truth and consistency. Therefore, deductive reasoning and other advanced forms of reasoning, enabling resistance to logical fallacies, awareness of logical constraints, and precise cognitive self-representation and self-evaluation dominate in the formation of g_{ic} in this period (Demetriou et al., 2021; Kazi et al., 2019; Makris et al., 2017).

Gradually, with abstraction and concatenation, rules are integrated into increasingly complex forms of inference and problem-solving. For instance, analogical reasoning deals with increasingly abstract relations, going from perceptual relations (e.g., feet are for animals what wings are for birds) to abstract metaphorical relations (e.g., bright individuals fly). In deductive reasoning, with development, children understand that an implication relation (if A then B) allows one to infer *B from A* and *not A from not B*, but it does not allow one to infer *A from B* or *B from not A* because there may be an infinite number of other elements causing B (Demetriou et al., 2021; Demetriou, Makris, Kazi, Spanoudis, & Shayer, 2018). In causal reasoning, initial causal attributions based on spatial and time interactions yield a template model of causal relations first allowing trial and error control of possible causal factors, and, finally, the "vary one factor at a time" isolation of variables strategy. In quantitative reasoning, recognition of the numerosity of small sets gradually expands into a mental number that can be traversed both ways, allowing numerical comparisons, numerical operations, and algebraic reasoning. In spatial reasoning, initial perceptual relations in space (e.g., close-far, up-down, and top-under) yield templates for mental transformations, such as mental rotation or interchanging perspectives, on an increasing number of interconnected dimensions.

The likelihood of transition across the three levels of *g* (g_{rc}, g_{ic}, and g_{lc}) decreases in the general population (Demetriou & Spanoudis, 2017). Transitions depend on several factors: (a) precision and resolution of representations; (b) flexibility in aligning and precisely interrelating representations to accurately understand situations, enabling successful action; (c) generation of new representations reproducing old representations and predictively broadening the scope of understanding for future encounters; new representations are explicitly meta-represented and symbolized (conventionally or idiosyncratically) so that they may substitute the older representations. The transition may be handicapped by deficiencies in any of these factors. If representations are imprecise, relations between them may not be inducible, for instance, deficiencies in sound perception may cause difficulties in mastering language or related skills like reading (Franceschini et al., 2012), at the g_{rc} to g_{ic} transition. Deficiencies in self-directed attention may cause difficulties in aligning representations according to a goal, undermining the abstraction of relations. Deficiencies in awareness and production of representations may handicap attention-guided alignment and rule induction related to the g_{ic} to g_{lc} transition (Demetriou et al., 2021; Spanoudis & Demetriou, 2020). These deficiencies may relate to genetic, brain, and social factors, which are beyond the present concerns.

Architecture of Personality

Learning at school relates to personality and motivational processes, in addition to cognitive processes. Any theory aspiring to predict school performance must include provisions about these processes and their interaction with cognitive processes. The Big Five factors model, currently dominant in personality research, describes individual personality profiles using five factors (MacCrae & Costa, 1999): *agreeableness* (i.e., altruistic, helpful, trusting, and warm); *conscientiousness* (i.e., goal-minded, focused, organized, and determined); *neuroticism* (i.e., disturbed by variations in the environment, anxious, and moody); *extraversion* (i.e., sociable, talkative, and outgoing); *openness to experience* (i.e., being open to novelty and intellectual challenges).

Personality is also organized hierarchically. Three factors—agreeableness, conscientiousness, and neuroticism—express stability (the α factor) and efficiency in organizing one's own life and one's resilience in dealing with pressure. The two remaining factors—extraversion and openness—express plasticity, the β factor: They define flexibility in one's relation with the world (Ashton et al., 2009). In turn, these factors relate to a higher order factor—the general factor of personality (GFP)—that "predicts social efficiency in the way *g* predicts cognitive efficiency" (Rushton & Irwing, 2009, p. 564). GFP, like *g*, relates to actual life indicators, such as performance at school and work (e.g., van der Linden et al., 2010), and is defined as follows:

$$\mathrm{GFP} = f(\alpha_{\mathrm{A,C,N}}, \beta_{\mathrm{E,O}}) \cdot \mathrm{age}, \tag{5}$$

where α (the alpha factor) and β (the beta factor) stand for stability and plasticity, respectively. A, C, N, E, and O stand for agreeableness, conscientiousness, neuroticism, extroversion, and openness, respectively.

Notably, any study into personality draws extensively on self-reports or parents' reports about traits and dispositions, rather than on measures of actual behaviors or processes per se. This is in contrast with the study of cognition, which is dominated by performance measures evaluated according to criteria of adequacy or relevance. Therefore, cognitive measures stand for functional possibilities in reasoning and problem-solving; personality measures stand for self-representations about possibilities or for tendencies framing possibilities. Expectedly, personality measures should be weaker as predictors of real-life outcomes than cognitive measures (Back & Nestler, 2016).

Development of Personality

The difference between the functional status of cognitive measures as indices of competence and the measures of personality as indices of representations about competence also bears developmental implications. Specifically, developmental trends in the expansion of personality may reflect changes in the monitoring and/or representation accuracy of the respondent, rather than changes in personality processes or dispositions as such. For instance, likeability decreases with growth because self-monitoring and self-evaluation improve (Demetriou, Makris, Kazi, Spanoudis, & Shayer, 2018). This reservation withstanding, there is a notable difference between changes in cognitive and personality processes. On the one hand, cognitive changes are extensive, multidimensional, and readily apparent. On the other hand, personality changes are less dramatic. The study of personality development emphasizes stability rather than change, assuming that precursors of adult personality traits are established in early childhood. Temperament, which reflects differences between children in reactivity to external stimuli and the ability for self-regulation, is present since infancy. The tendency to independently explore the environment (predating openness) and the tendency to become distressed by variations in the environment (predating neuroticism) are present early in infancy (Rothbart, 2011). A recent longitudinal study of the connections between cognition and temperament indicated that an initial advantage in cognitive ability at 8–9 years is associated with decreasing reactivity and increasing persistence over 6 years. The increasing cognitive ability from 8 to 10 years was associated with declining reactivity and increasing persistence in this period (Sesker et al., 2021). This aligns with evidence that changes in conscientiousness reflect improvements in executive control, for instance, adaptability to changing environmental contingencies or demands (Fleming et al., 2010, 2016). Changes in openness reflect improvements in *g* (Demetriou, Spanoudis, et al., 2018; Gignac et al., 2020). However, although discernible in early childhood, four of the Big Five factors do change with age: openness, conscientiousness, and agreeableness increase, while neuroticism decreases; extroversion does not change (Soto et al., 2011). Their reliability and stability also increase with age (Asendorpf & Van Aken, 2003; Lamb et al., 2002), reflecting cognizance development (Demetriou, Spanoudis, et al., 2018).

Eysenck and Eysenck's (1969) theory includes another personality factor: likeability or lying, which relates strongly to cognitive development. This factor reflects self-characterizations that tend to be positive, in line with social expectations. Recent evidence suggests that likeability operates as a powerful *personality index*, varying negatively with cognitive development: It decreases systematically from childhood onwards, with development in all cognitive processes and the accuracy of self-evaluations of cognitive performance. Longitudinal evidence revealed that a decrease in likeability in late childhood increases the likelihood of transition to principle-based reasoning; inversely, a change from rule- to principle-based reasoning increases the likelihood that likeability shall drop soon (Demetriou, Spanoudis, et al., 2018). Changes in self-monitoring and self-regulation are associated with the transition from rule- to principle-based thought-tuning cognitive functioning with self-presentations, rendering them more accurate reflections of each other. In terms of the present theory, changes in likeability reflect changes in cognizance processes. The changes reflect increases in the accuracy of self-monitoring, the self-recording of cognitive and emotional functioning, as well as behavior and concomitant changes in the accuracy of self-concepts held about them. It was noted above that self-monitoring develops from noting associations between perceptual functioning and mental states reflected in theory of mind at 4–6 years to noting associations between mental processes as such and underlying rules, as reflected in inferential and working memory awareness in late childhood and logical rules awareness in adolescence (Demetriou et al., 2021; Kazi et al., 2019). These changes enable more accurate and differentiated self-representations and self-evaluations. However, some people may remain consistently unaware of their cognitive and learning weaknesses (Kleitman et al., 2019). This places them at a disadvantage at school, compared with individuals of the same cognitive competence (Ohtani & Hisasaka, 2018).

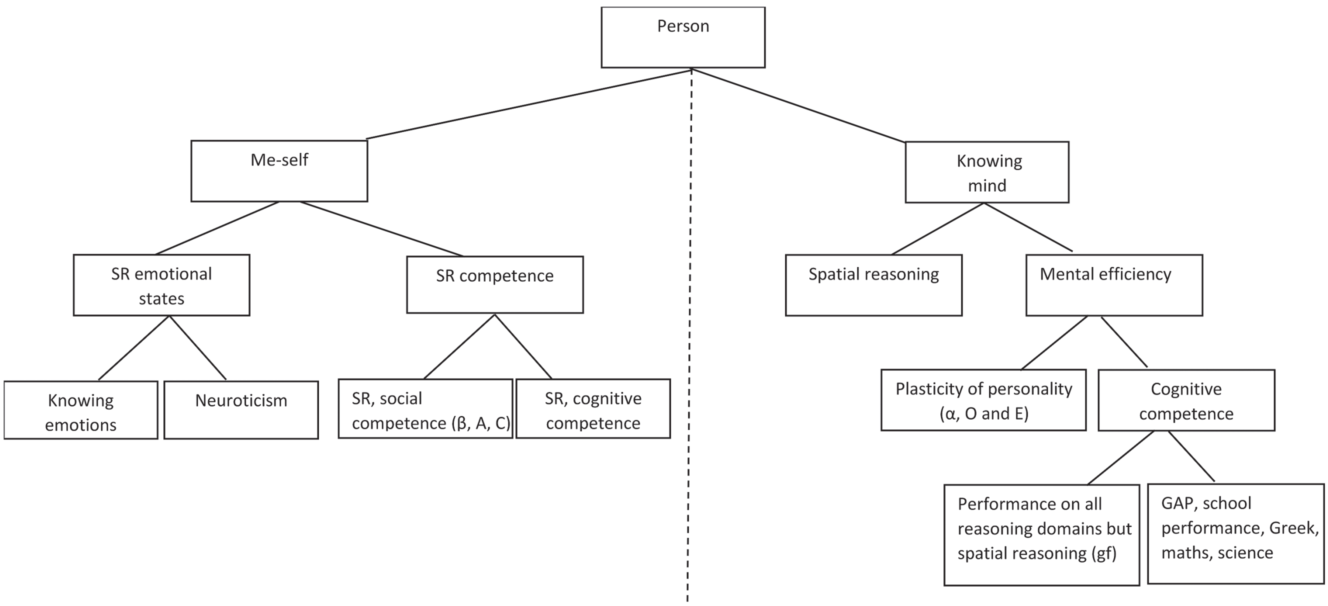
Overall Architecture and Development and Educational Outcomes

Cognition and personality are distinct but interacting. There is a consensus that *g* is related moderately but significantly with conscientiousness and openness ($r = \sim.2$; Schermer & Vernon, 2010) but not with the other factors; the relation between *g* and the GFP is slightly higher ($r = \sim.3$; Demetriou, Spanoudis, et al., 2018). A hierarchical exploratory graph analysis (Golino et al., 2020) of performance on a large array of reasoning tasks in different domains, cognitive self-concepts and self-evaluation of performance on cognitive tasks, the Big Five factors, various aspects of emotional intelligence (Petrides et al., 2007), and academic performance indicated that these processes were organized into two major systems (Demetriou, Spanoudis, et al., 2018): (a) the *knowing mind*, grounded on all reasoning domains and academic performance and thus reflecting overall cognitive competence. Noticeably, the factors standing for plasticity in personality—openness and extraversion—are clustered in this system; and (b) the *self-known mind*, grounded on self-representations about cognitive, personality, emotional, and motivational attributes other than those associated with plasticity reflects what James called the me-self (Harter, 2012). This model is summarized in Figure 3.

Cognizance is the mediator between cognition and personality. On the one hand, cognizance monitors and records mental processes, such as attention focusing, memory retrieval, and inference, and carries them forward to personality functioning. For instance, the evaluation of the distance between initial goals and the results of problem-solving may cumulatively strengthen or discourage personality dispositions to act in a specific fashion. On the other hand, personality dispositions and related action choices are also recorded

Figure 3

The Hierarchical Organization of Cognitive, Cognizance, Academic, Personality, and Emotional Intelligence Processes According to Hierarchical Exploratory Graph Analysis (Demetriou, Spanoudis, et al., 2018)



Note. Symbols α and β stand for plasticity and stability of personality; A, C, O, and E stand for agreeableness, conscientiousness, openness, and extraversion, respectively; SR stands for self-representation; GAP = general academic performance.

by cognizance, with likely long-term influences on cognitive functioning. For example, systematically avoiding a particular type of social interaction that is inconsistent with a personality-based preferred mode of interaction may gradually consolidate a specific mode of problem-solving rather than another. Some processes in each system are projected into the other system more clearly than other processes: The cognitive self-concept is projected from cognition to personality, thus expressed into aspects such as openness, self-efficacy, or growth mindset; stability and conscientiousness par excellence are projected from personality to cognition, influencing how exhaustive or organized mental processing may be (Demetriou, Spanoudis, et al., 2018).

The relations between cognition and personality, and the changes in these relations across developmental phases, must be explicitly specified if academic performance is to be accurately predicted from cognitive and personality processes. First, cognition and personality interact systematically via cognizance mechanisms. Cognizance translates experiences from cognitive and social interactions with the world into values of self-worth, confidence, and self-efficacy. Thus, processing, representational, and inferential efficiency (cognition) are expressed in a person's dispositional efficiency in handling their interactions with the world (personality). These values set the range of variation across personality dimensions, such as each of the Big Five factors, or broader dimensions, such as stability and plasticity. Therefore, to the extent that cognitive competence, cognizance, and personality partly mirror each other, any of them would relate to school performance because they partly reflect the same reality.

Second, if cognitive competence, cognizance, and personality are measured together, one of them—cognitive competence (Gf)—would dominate as a predictor of school performance: With increasing accuracy of cognizance in reflecting Gf, the predictive value of self-representations would decrease because they duplicate the competences they reflect; this is partly true for some personality measures, especially those reflecting cognitive competence, such as openness, which is associated with Gf. Therefore, purifying cognizance or personality measures from cognitive competence would render them redundant to cognitive competence as predictors of school performance. Other aspects of cognizance or personality that provide an added advantage for school learning, such as accuracy in self-evaluation, consciousness, or motivation, would provide added value to the prediction of school performance. Accurate self-evaluation, if compared with less accurate self-evaluation in individuals of the same competence, may help better capitalize on the available cognitive competence. Increased consciousness and motivation may help one to better capitalize on available cognitive competence.

Third, the predictors of academic achievement in each phase are the developmental priorities of this phase (Demetriou et al., 2021). This is also true for predicting school performance at the next phase from cognitive attainment in earlier phases. If a general cognitive ability is a predictor of any life outcome, this must come from the processes defining it in each phase because these processes reflect learning efficiency more than processes already fixed or yet to form. A special note about cognizance is in order. The processes surfacing to awareness in each phase reflect the cognitive processes weaved into cognitive ability during each phase: representational awareness, reflecting an understanding of the causal role of representations in preschool; inferential awareness in primary school, reflecting an understanding of the causal role of inference; and principle-based constraints of inference in adolescence, reflecting an understanding of the causal role of reasoning-based transformations of reality. We shall see that these changes are important for school performance in successive phases. Therefore, the following developmental predictions may be stated:

1. In preschool, attention control and representational awareness must dominate as predictors of school performance:

$$\mathrm{GAP}_{\mathrm{preschool}} = f(g_{\mathrm{rc}}) \approx (\mathrm{at}, \mathrm{A_m}), \tag{6}$$

2. In primary school, Gf—as captured by inductive reasoning and inferential awareness—must dominate. Personality measures would not appear as independent predictors in preschool and primary school because they are not yet accurate and reliable enough to systematically capture variation in school performance measures:

$$\mathrm{GAP}_{\mathrm{primary}} = f(g_{\mathrm{ic}}) \approx (\mathrm{IR}, \mathrm{A_{inf}}), \tag{7}$$

3. In adolescence, Gf—as reflected in both inductive and deductive reasoning, self-evaluation of cognitive performance, and domain-specific self-representation—must dominate. In this period, a personality emerges as a predictor, especially conscientiousness:

$$\mathrm{GAP}_{\mathrm{secondary}} = f(g_{\mathrm{lc}}, \mathrm{GEP}) \approx (\mathrm{R_D}, \mathrm{S_e}, \mathrm{S_c}, \mathrm{C}), \tag{8}$$

The Studies

Rationale and Design

Below, we summarize research exploring the relations between cognitive and personality processes and school performance; two studies were under review. First, we summarize and reanalyze five studies that explicitly examined how differences in the profile of cognitive, cognizance, and personality processes at successive phases relate to school performance. Second, we also review (in sections titled *Other Studies*) independent research which examined the influence of the various processes of interest at each of the levels of education addressed by each of the five studies reanalyzed and summarized here. To ensure comparability with the studies above, the results of the independent studies reviewed were also reanalyzed using the modeling approach adopted here (whenever possible), based on the information available. Reviewing these independent studies allows us to examine if findings converge across researchers.

In line with assumptions, the design and modeling of these studies satisfy two requirements: processes and educational levels. Specifically, these studies addressed several processes—cognitive, cognizance, and personality—together with school performance. Relations were modeled by structural equation models designed to purify constructs from each other or to capture their interactions. For instance, all studies modeled the relations between each type of process, such as executive functions, reasoning, or cognizance, and academic performance both in separate models for each and in a common model, including all processes involved in a study. Comparing the relationship of each process with the academic performance shown by the process-specific model, and with the same relation in the common model, highlights how each process stands as an independent predictor of academic performance, if at all.

To purify processes from one another in the common models, a hierarchy of factors was created, which involved three levels:

1. Domain-specific factors (i.e., attention control, shifting, and working memory in executive functions; inductive, deductive, mathematical, causal, and spatial reasoning in reasoning; awareness of cognitive processes, self-representation, and self-evaluation in cognizance; the Big Five factors of personality.

2. Process-specific factors (i.e., executive [Ge], reasoning [Gf], cognizance [Gcogn], stability, and plasticity, the two higher order personality factors).

3. *g*, associated with cognitive processes and personality factors.

In these models, domain-specific factors were regressed on the respective process-specific factors, and process-specific factors were regressed on *g*. Academic performance was regressed on the highest level factors involved in a model (g, Ge, Gf, Gcogn, GFP) and, additionally, on the residual factors of the domain- and process- or trait-specific factors involved. Thus, variance in academic performance was split between the highest common factor and aspects of the processes not included in the common factors. Figure 2 illustrates the overall template model implemented in all studies.

To ensure comparability across studies, these models were tested anew for the present purposes, although the original models presented in the published studies were close to the models presented. Table S6 (see Supplemental Materials) summarizes the results of all models across all studies. Model codes and background correlation matrices and sample statistics are also presented in the Supplemental Material.

For developmental or educational levels, all studies incorporated participants spanning at least two levels, such as preschool, primary school, and secondary school. Using appropriate modeling methods involving multiple groups, this sample composition allows us to specify how relations differ between educational levels, if at all. Taken together, these manipulations allow us to disentangle the relations between cognitive and personality processes and school performance and map possible changes as a function of educational level.

The studies presented in this article were not preregistered. However, all were published and, thus, available to the reader. Correlations, statistics, and model codes used for the models presented here are shown in the Supplemental Material. The data files, if needed, may be obtained from the first author.

Study 1: From Preschool to Primary School

Demetriou, Kazali, et al. (2020) aimed to disentangle the influence of each of various aspects of executive processes, cognizance, and reasoning in preschool on school performance in primary school. Preschool children (N = 57) were tested twice at 4 and 6 years, and then at 6 and 8 years of age using executive, reasoning, and cognizance measures and, once, 2 years later, when they were 8 and 10 years, on school performance. This study is part of a larger longitudinal study of the development of cognizance from preschool to late primary school (Kazi et al., 2019). Executive functions included attention control to manage interference. In one set of items, children judged if objects varying in similarity (identical, similar, and different) were the same or different; in another set, children mapped object attributes with acoustic labels. Working memory tasks required recalling backward sets of words and sets of number digits including from two to six items. For reasoning (Gf), a Raven-like test addressed inductive reasoning at three levels of complexity, requiring abstraction of relations across one, two, and three dimensions, respectively. A set of pragmatic syllogisms addressed modus ponens, conjunction, and disjunction relations in deductive reasoning. Cognizance tasks addressed three types of mental awareness:

1. Perceptual awareness requiring understanding that perception is a source of knowledge and mental states, and that each person's mental states relate to this person's perceptual access to information (theory of mind and specifically designed tasks were used).

2. Inferential awareness requiring understanding that inference creates mental states to fill in information lacking at a given moment.

3. Awareness of cognitive processes involved in the cognitive tasks solved; children evaluated the similarity and relative difficulty of several pairs of inductive, deductive, and awareness tasks.

Two years later, when children reached the third and fifth primary school grade, their school performance in (native) language and mathematics learning was evaluated by their teachers. Thus, this study specified how executive functions, reasoning, and cognizance in preschool relate to school performance in primary school. Three separate models examined how each type of process relates to school performance. The model that examined executive functions involved an attention control and a working memory factor, both regressed on a general executive functions factor, Ge. In this model, Ge accounted for 38% ($\beta = .62$) and attention control (inhibition) accounted for 61% ($\beta = .78$) of academic performance variance. Working memory was not involved as it was completely absorbed by the general factor involved ($\beta = 1.00$). In the model examining reasoning, the reasoning factor (Gf) was associated with two indicators: inductive and deductive reasoning. Academic performance was regressed on this factor; 77% ($\beta = .88$) of its variance accounted for Gf. The model examining cognizance involved two factors, one associated with perceptual and inferential awareness and one associated with awareness of the cognitive processes involved in tasks, which were regressed on a common cognizance factor, namely Gcogn. Academic performance was regressed on Gcogn and the residuals of each awareness factor. Gcogn accounted for 29% ($\beta = .54$), and awareness of cognitive processes accounted for 71% ($\beta = .84$) of general academic performance (GAP). The factor standing for perceptual and inferential awareness was not involved as it was fully absorbed by Gcogn ($\beta = 1.00$). In conclusion, in each of the three separate models, performance attained at the first testing wave on each of the three types of processes was highly related to school performance, accounting for between 77% (Gf) and 100% (Ge and Gcogn) of school performance variance (see Table S6, Study 1 column in Supplemental Material for process-specific models).

In the common model, all domain-specific factors of the separate models (i.e., Ge from the first model, Gf from the second model, and Gcogn from the third model) were regressed on a common factor standing for g_{rc}, that is, *g* dominated by representations and their control. Academic performance was regressed on *g* and the residual of each of the domain-specific factors. This model is illustrated in Figure 4.

The *g* factor was very powerful and highly related to all domain-specific factors (the *g*–Gf relation was lower than the rest, $\beta = .52$; all others were very high, $\beta > .84$). In this model, *g* accounted for 56% ($\beta = .75$) of academic performance; Gf standing for reasoning accounted for 17% ($\beta = .41$); and awareness of cognitive processes accounted for 27% ($\beta = .52$) of academic performance variance. The executive functions were not involved because they were fully absorbed by *g* ($\beta = 1.00$). In conclusion, in this age phase, g_{rc}—identified by executive functions, together with the residual variance that is specific to reasoning (Gf) and awareness of cognitive processes—fully accounted for academic performance.

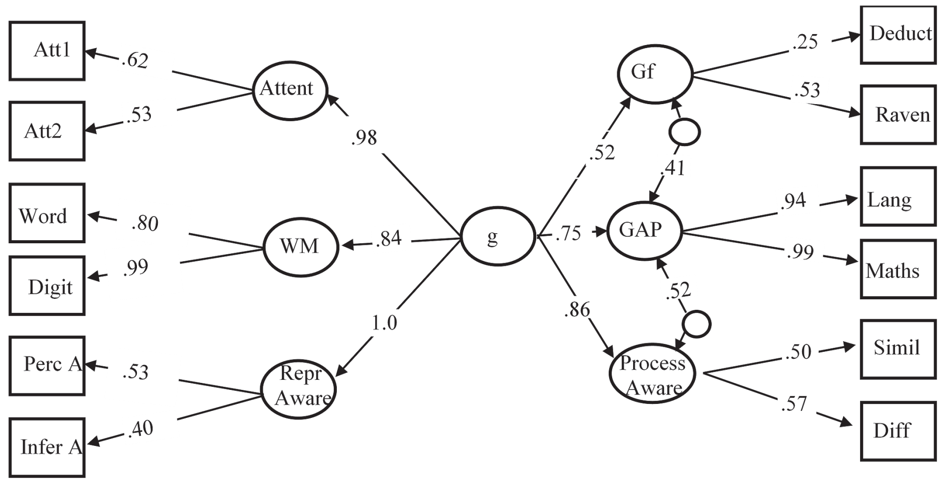
The longitudinal nature of the study allowed us to disentangle influences coming from an initial state of each process as measured at the first testing wave from influences coming from change as such from first testing to second testing. For the sake of this aim, academic performance was regressed on performance attained at the first testing on each process wave and, also, on change from first to second testing (see Figure 5).

Attention is first drawn to the negative relations between first and second testing across all processes, implying that children performing higher at first testing improved less at second testing than children performing lower. Under this condition, attention control at first testing accounted for 12% ($\beta = .34$) of variance in language and 6% ($\beta = .24$) in mathematics; working memory at first testing accounted for 7% of variance ($\beta = .26$) in language and 10% of variance ($\beta = .31$) in mathematics; noticeably, a change in awareness of the perceptual origins of knowledge and mental states accounted for 82% ($\beta = .90$) of variance in language and 73% ($\beta = .86$) of variance in mathematics. Therefore, in line with expectations, attention control processes and change in representational awareness of the perceptual origins of knowledge predicted school performance.

Other Studies

Several studies focusing on preschool and early primary school found similar trends to those reported above. Espy et al. (2004) showed that inhibitory control was central in mathematical learning in preschool. With entrance to first grade, working memory became central. Monette et al. (2011) demonstrated that working memory (25% of variance) and inhibition (6% of variance) in kindergarten predicted reading/writing and math achievement at the end of first grade. With various other factors controlled, only working memory contributed uniquely to school achievement. Later, executive mechanisms enabled focusing and manipulation of information when learning emerged as central. A longitudinal study involving first- and second-grade children found that updating (46% of variance) but not inhibition and shifting predicted mathematical learning. Moreover, changes in updating and mathematical learning were interlocked: working memory and updating facilitated mathematical learning and this facilitated both executive functions (Van der Ven et al., 2012). Altogether, these studies suggest that mastering

Figure 4
A Comprehensive Model Involving All Study 1 Processes



Note. Att1 = Attentional Task 1; Att2 = Attentional Task 2; Attent = attention; Word = word recall; Perc A = perceptual awareness; Infer A = inferential awareness; Gf = fluid intelligence; GAP = general academic performance; Process Aware = awareness of cognitive processes; Deduct = deductive reasoning; Raven = Raven-like matrices; Lang = language; Maths = mathematics; Simil = similarity awareness; Diff = difficulty awareness.

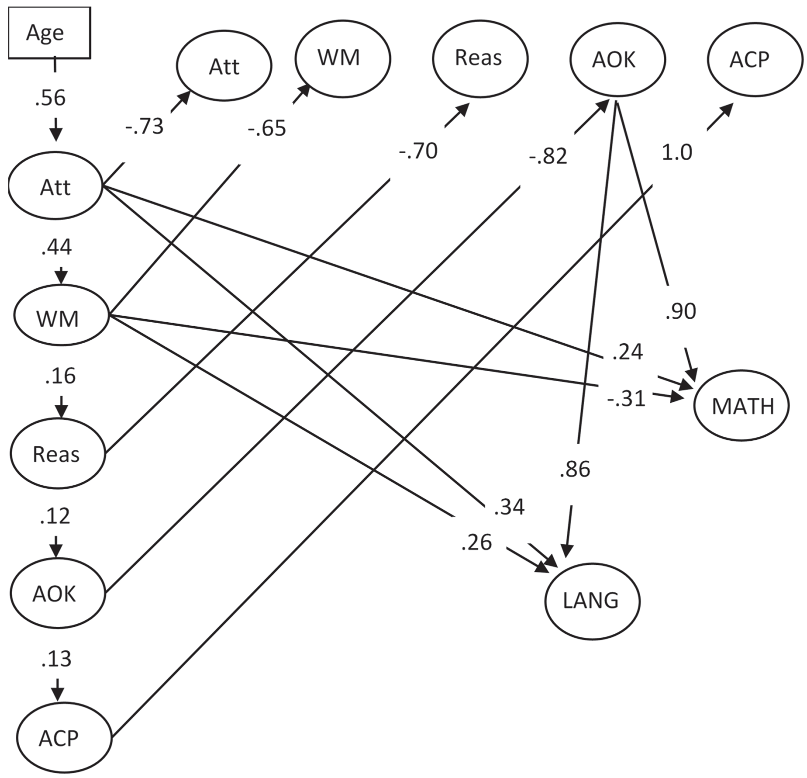
executive processes and representational awareness in preschool are critical for learning in primary school.

Study 2: From Primary to Secondary School

Demetriou, Makris, et al. (2019) addressed the processes above in primary (third and fifth grade) and secondary school children (seventh and ninth grade; N = 196). Executive functions were examined using Stroop-like attention control tasks, verbal and numerical short-term and working memory tasks, and dimensional change sorting tasks addressed to flexibility in shifting between rules. Reasoning was examined in several domains: verbal and numerical analogies addressed inductive reasoning; *modus ponens*, *modus tollens*, fallacies, and algebraic reasoning tasks addressed deductive reasoning; combinatorial and hypothesis testing and isolation of variables tasks addressed causal reasoning; mental rotation, visualization, and coordination of perspectives tasks addressed spatial reasoning. Language was addressed by several tasks examining vocabulary, mastery of syntax, and verbal comprehension, while two awareness tasks examined cognizance. Several tasks required self-evaluation of performance on the reasoning tasks above, both before and after completion ("How right do you think your solution on this task was?"), and awareness of the mental demands of tasks ("How difficult this task was for you?"). School grades in mathematics, science, and language were used. Therefore, this study disentangled the influence of cognitive, language, and cognizance processes on school performance in late primary and early secondary school. It was expected that working memory must be the stronger predictor of school performance in primary school. Reasoning should dominate as a predictor in secondary school; language and cognizance should also emerge as predictors.

Implementing the analytic rationale already explained, separate models examined the relations between each type of process and school performance, independently of the rest. In the model examining executive functions, a first-order factor standing for attention control (indexed by tasks involving compatible and incompatible Stroop-like tasks), a first-order factor standing for working memory (indexed by tasks involving visual, verbal, and numerical information), and a first-order factor standing for flexibility (indexed by tasks requiring rule-based shifting) were regressed on a second-order factor standing for the executive function (Ge). An academic performance factor indexed by grades on the three school subjects used (Greek, mathematics, and science) was regressed on Ge and the residual of the three domain-specific executive factors. All four factors accounted for a total of 21% of GAP; attention control was fully absorbed by Ge (both relations = .99); of this total, the effect of Ge was moderate but significant (5%, $\beta = .21$); the effect of working memory was also significant (10%, $\beta = .31$), but the effect of flexibility was nonsignificant (7%, $\beta = .26$). In the model examining reasoning, there were four first-order factors according to the reasoning domain: verbal (verbal analogies and syllogisms), quantitative (numerical analogies and algebraic), spatial (mental rotation and visualization), and causal (combinatorial and hypothesis testing) reasoning. These factors were regressed on a second-order factor standing for Gf. This model accounted for 34% of total GAP variance; the effects of Gf (11%, $\beta = .34$), quantitative reasoning (10%, $\beta = .34$), and deductive–analogical reasoning (12%, $\beta = .34$) were significant. In the model examining language, GAP was regressed on a language factor indexed by performance on each of the three aspects of language examined (vocabulary, syntax, and semantics). This factor accounted for 30% ($\beta = .55$) of GAP. Finally, the model examining cognizance involved two first-order factors, cognizance for rule-based and cognizance for principle-based tasks,

Figure 5
The Cascade Model of the Relations Between Cognition, Cognizance, and Academic Performance



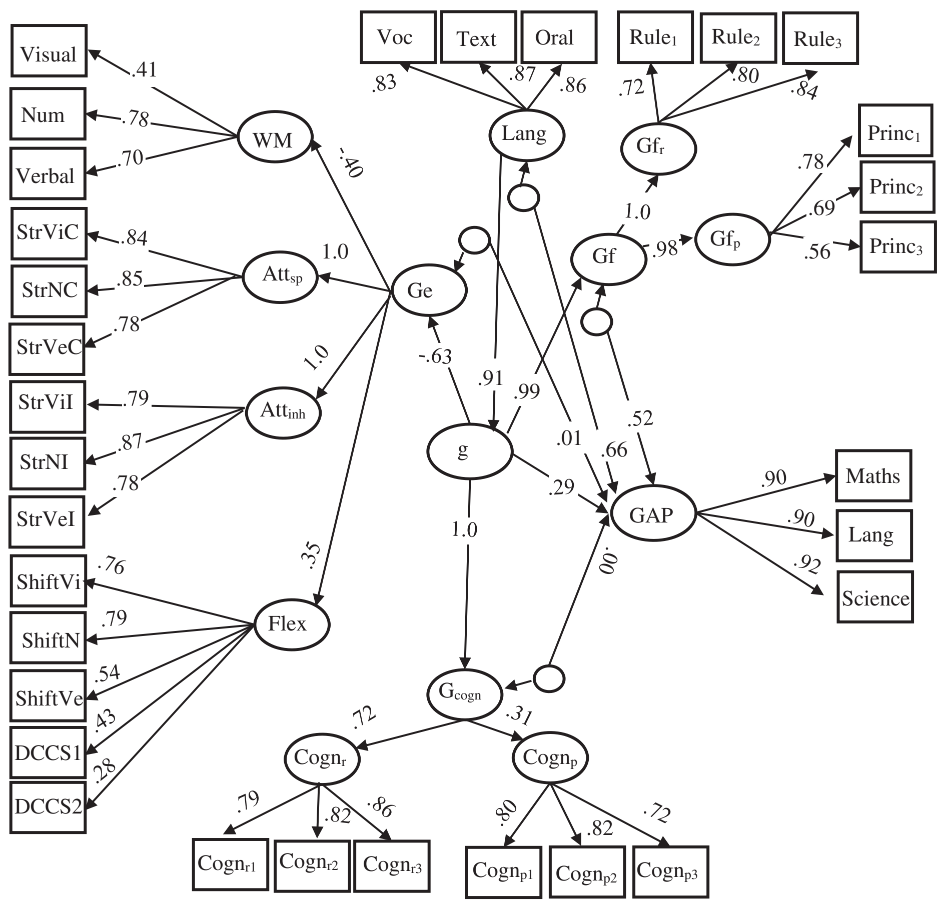
Note. The factors organized vertically stand for actual performance at first testing; the factors organized horizontally stand for change from first to second testing. Symbols Att, WM, Reas, AOK, and ACP stand for attention control, working memory, reasoning, awareness of the perceptual/inferential origins of knowledge, and awareness of cognitive processes, respectively. MATH and LANG stand for school performance in mathematics and language, respectively.

both regressed on a second-order factor, Gcogn. GAP was regressed on Gcogn and the two level-based residual cognizance factors. Altogether, the three factors accounted for a significant but moderate amount of GAP variance, 10%; of this, only the effect of Gcogn was significant (7%, β = .27; see Table S6, Study 2 column in Supplemental Material for a summary of the process-specific models).

In the common model (see Figure 6), the second-order factors (i.e., Ge, Gf, and Gcogn) and the language factor were regressed on *g*. GAP was regressed on *g* and the residuals of all four second-order factors. *g* was very powerful, and highly related to all domain-specific factors, ranging from −.63 (Ge, negative relation reflecting decreasing reaction times) to .99 (Gf). Altogether, these factors accounted for a large amount of GAP variance (85%). *g* accounted for a moderate but significant amount (7%, β = .29); both, Gf (27%, β = .52) and language (50%, β = .71) accounted for large amounts of GAP variance; the effects of executive (Ge) and cognizance (Gcogn) were practically nil, being almost fully absorbed by *g* (see Table S6, Study 2 column in Supplemental Material for the model, including all processes). There was a dramatic drop of variance accounted for by executive processes in this study compared to Study 1: 21% versus 100%, and the emergence of reasoning (Gf) and language competence, indicating a dramatic shift in the processes influencing school performance from preschool to primary and secondary school.

To further probe this difference, the common model above was tested in a two-group analysis comparing primary to secondary school participants. There were notable similarities and differences between the two groups. On the one hand, school performance was similarly dependent on *g* in both primary (12%, β = .34) and secondary school (17%, β = .41, $z = -.61$, $p > .05$). Notably, *g* fully absorbed attention control and Gf in both groups (all relations with $g = 1$), indicating that it reflects the common core involving executive control and inferential processes by the end of primary school onwards. Also, language was similarly influential in both primary (31%, β = .55) and secondary school (48%, β = .69, $z = -.99$, $p > .05$). On the other hand, the two levels of education differed in the role of working memory and cognizance. In primary school, working memory (10%, β = .32) accounted for a significant amount of GAP variance but not in secondary school (0%). Inversely, the two cognizance factors were not related to GAP in primary school (β = <10%); however, the effect of postperformance

Figure 6
A Comprehensive Model Involving All Study 2 Processes



Note. Visual, Num, and Verbal stand for visual, numerical, and verbal working memory tasks, respectively; Str = Stroop; Vi = visual; N or Num = numerical; Ve = verbal; C = compatible; I = incompatible; ShiftVi, ShiftN, and ShiftVe stand for shifting under visual, numerical, and verbal context, respectively; DCCS = dimensional change card sorting; Flex = flexibility; Ge = executive functions; $Cogn_r$ = rule-based cognizance; $Cogn_p$ = principle-based cognizance; Voc, Text, and Oral stand for vocabulary, written, and oral language, respectively; Rule and Princ stand for rule-based and principle-based reasoning, respectively; subscript numbers 1, 2, and 3 indicate difficulty levels.

evaluation, although negative, reached significance in secondary school, accounting for 3% of the variance ($\beta = -.18$, $z = 1.99$, $p < .05$). Obviously, an advantage in working memory in primary school is helpful for school learning; self-evaluation of cognitive performance in secondary school starts to connect with a performance at secondary school, even if negative. The studies below replicate and discuss this effect further.

Other Studies

According to a recent meta-analysis, the strength of relations between executive functions and academic performance in primary school is close ($r = .35$) to the strength of relations found here (Cortés Pascual et al., 2019). Notably, updating and task-specific metacognitive monitoring skills are important for learning arithmetic in the first two grades of primary school (Bellon et al., 2019). The trends from primary to secondary school are also similar, indicating that the predictive power of attention control drops drastically from primary ($R^2 = .41$) to secondary school ($R^2 = .13$; Zorza et al., 2016). Working memory and reasoning emerge as predictors of school performance in primary school (Giofrè et al., 2017); however, interference control and working memory ceased to predict school performance from seventh to ninth grade (Dubuc et al., 2020).

For comparative purposes, by implementing the model described above, we modeled the data presented by Giofrè et al. (2017), which examined the relations between working memory, Gf, and academic self-esteem with school performance in language and mathematics in the sixth grade. Working memory accounted for 38% and 22%, and Gf accounted for 34% and 43% of the variance in mathematics and reading, respectively. Self-esteem accounted for 1% and 14% of these subjects. Along these lines, Vernucci et al. (2021) found that verbal WM and Gf significantly predicted reading comprehension in fourth grade, but growth mindset did not.

Study 3: Self-Evaluation and Self-Representation From Primary to Secondary School

Demetriou, Kazi, et al. (2020) disentangled the influence of two aspects of cognizance, self-evaluation, and self-representation, from each other and from cognitive ability. They examined how school performance relates to reasoning and problem-solving in different domains (mathematical, causal, spatial, and social reasoning), self-evaluation in these domains (evaluating one's performance on tasks before; "Can you solve this problem well?") and after solving them ("How correct do you think your answer is?"), and self-concepts in these domains (e.g., "I immediately solve everyday problems involving numbers"). Individuals from late primary (5th and 6th grade) and high school (7th–10th grade) were involved ($N = 408$), and grades for Greek, mathematics, and science were used.

In the separate models, for cognitive competence, four first-order reasoning factors had regressed on a second-order reasoning factor (Gf). GAP had regressed on Gf and the residuals of the domain-specific factors. Gf accounted for 35% ($\beta = .59$), and social reasoning accounted for 6% of GAP ($\beta = .24$); the other domain-specific factors were fully absorbed by Gf. For cognizance, four first-order factors (pre- and post-solution evaluation and self-representation of reasoning in the cognitive domains above, and self-representation of mental efficiency) had regressed on a second-order general cognizance factor, Gcogn. These factors accounted for 32% of the GAP variance. Gcogn accounted for 6% of GAP variance ($\beta = .25$). Self-concept of reasoning in the cognitive domains was negatively related to school performance, accounting for 6% ($\beta = -.24$) of GAP variance; self-concept of mental efficiency was positively related with GAP (4%, $\beta = .21$). Noticeably, self-evaluation before solving the tasks was positively related with school performance, accounting for 10% of GAP variance ($\beta = .31$); postperformance evaluation was negatively but nonsignificantly related, accounting for 2% of GAP variance ($\beta = -.14$). In the common model (see Figure 7), the second-order factors above were regressed on *g*. All relations with *g* were strong ($\beta > .39$) although the two self-evaluation factors and Gf dominated ($\beta = .75–.79$). In this model, the various factors accounted for a total of 68% of GAP variance. The effect of *g* was moderate, although significant (5%, $\beta = .22$); residual Gf accounted for the lion's share of the total (44%, $\beta = .67$), residual self-concept of mental efficiency (8%, $\beta = .27$), and residual preperformance self-evaluation accounted for 9% of GAP variance ($\beta = .31$).

There was a large difference between primary and secondary school in the association between *g* (i.e., g_{ic} and g_{lc}, respectively) and Gcogn: weak in primary school but strong in secondary school, with g_{ic} accounting for only 5% of Gcogn variance in primary school but g_{lc} accounting for 45% in secondary school. Cognitive self-evaluation and self-concept reflected cognitive ability in adolescence much more accurately than in childhood. Importantly, about the same amount of variance of GAP was accounted for at primary (38%, $\beta = .62$) and secondary schools (31%, $\beta = .56$) by Gf. However, the pattern of relations between GAP and the other factors was very different at the two levels of education. The effect of g_{ic} on GAP was very low and nonsignificant in primary school (<1%, $\beta = -.08$), but the effect of g_{lc} was moderate and significant in secondary school (7%, $\beta = .26$). Notably, self-representation of mental efficiency was highly related with GAP (58%, $\beta = .76$) in primary school but it was not related in secondary school ($\beta = .001$); inversely, the relations of pre- and post-performance evaluation with GAP were low and nonsignificant in primary school but significant in secondary school. Notably, preperformance evaluation was positively related with GAP (8%, $\beta = .28$), but postperformance evaluation (5%, $\beta = -.23$) was negatively related with GAP.

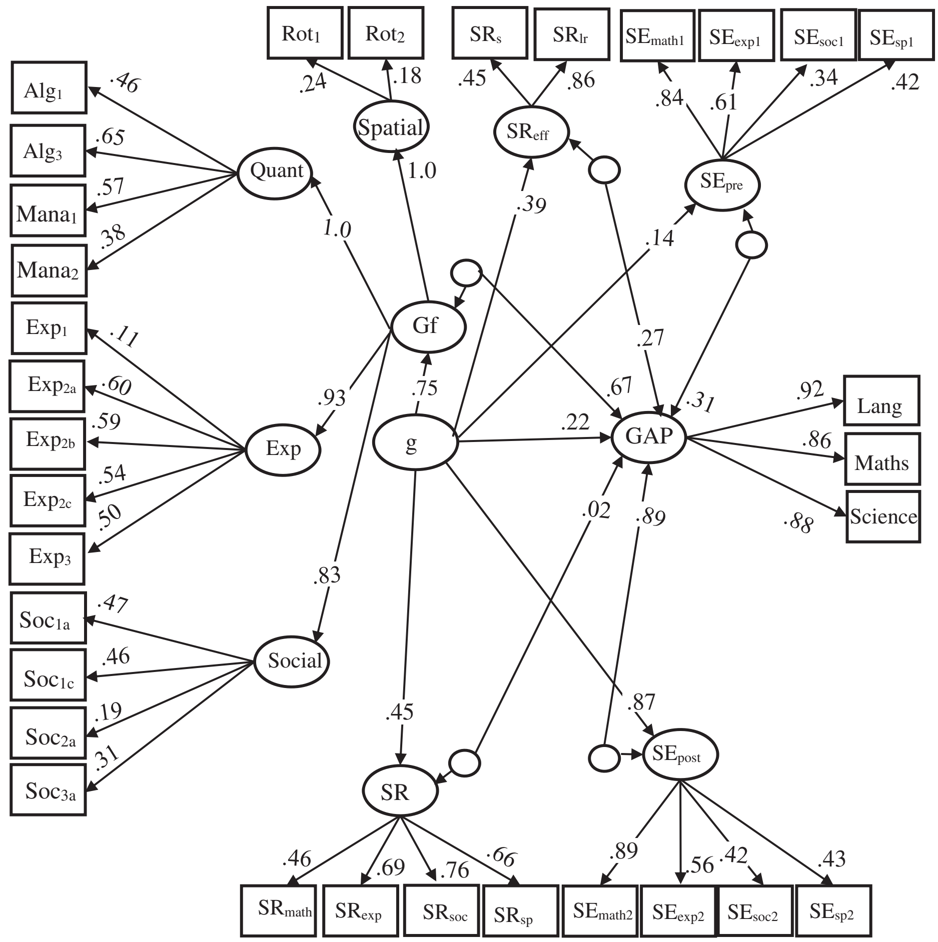
These patterns are highly interesting in differentiating cognitive ability from self-representation and self-evaluation as predictors of school performance. Precise self-concepts and self-evaluations involved in Gcogn are not yet powerful components of g_{ic} in primary school; thus, self-evaluations are not accurate enough to represent actual performance in this period. These become influential in the formation of g_{lc} in secondary school, representing actual performance with increasing accuracy. Self-representation of reasoning in cognitive domains is very weak as a predictor of school performance because it covaries with cognitive competence, by and large. Self-representation of mental efficiency, standing for speed of understanding (e.g., "I am fast in understanding a new concept explained to me"), learning (e.g., "I am fast in learning new concepts"), and working memory (e.g., "I can easily hold in memory a new phone number"), preserves a significant predictive advantage, additionally to Gf standing for reasoning. Also, self-evaluations do provide additional information in predicting school performance from adolescence onwards, if measured with cognitive ability. Specifically, self-representations become increasingly accurate in reflecting cognitive ability; thus, general cognitive self-concept, as a proxy of cognitive ability, does predict academic performance, if taken alone; however, cognitive ability masks self-concept, if measured.

Differences in the relations between pre- and post-performance evaluations with academic performance are interesting in their implication for the interaction between cognitive ability, cognitive self-concept, self-evaluation, and problem-solving. Evaluations prior to solving the tasks increased predictability on top of cognitive ability in secondary but not in primary school children. In contrast, evaluations after solving the task were negatively related to secondary school. Perhaps, an advantage in self-evaluation before solving the tasks in adolescence signifies an overall improvement in cognizance, enabling one to call upon cognitive ability and general self-concept to evaluate the demands of a specific task, as well as one's own possibility of solving this task. This better reflects self-monitoring and sensitivity to feedback facilitating learning as it allows one to efficiently capitalize on available cognitive ability. The negative relation to postperformance evaluation indicates that evaluation is still contaminated by likeability, alluding individuals to being lenient to themselves (Demetriou, Spanoudis, et al., 2018).

Study 4: Cognitive Ability, Cognitive Self-Representation, and Personality

Demetriou, Kazi, et al. (2019) sought to disentangle the influence of personality from cognitive ability and cognitive self-representation. In addition to the domains of reasoning and self-representation above, their study addressed the Big Five factors. Primary, junior high, and senior high school participants, from 10 to 18 years, were involved ($N = 689$). Performance in Greek, mathematics, and science was again utilized (see Figure 8).

Figure 7
A Comprehensive Model Involving All Study 3 Processes



Note. Alg = algebra; Mana = mathematical analogy; Exp = experimental; Soc = zocial; Rot = rotation; SR = self-representation; SE = self-evaluation; Quant = quantitative thinking; GAP = general academic performance factor.

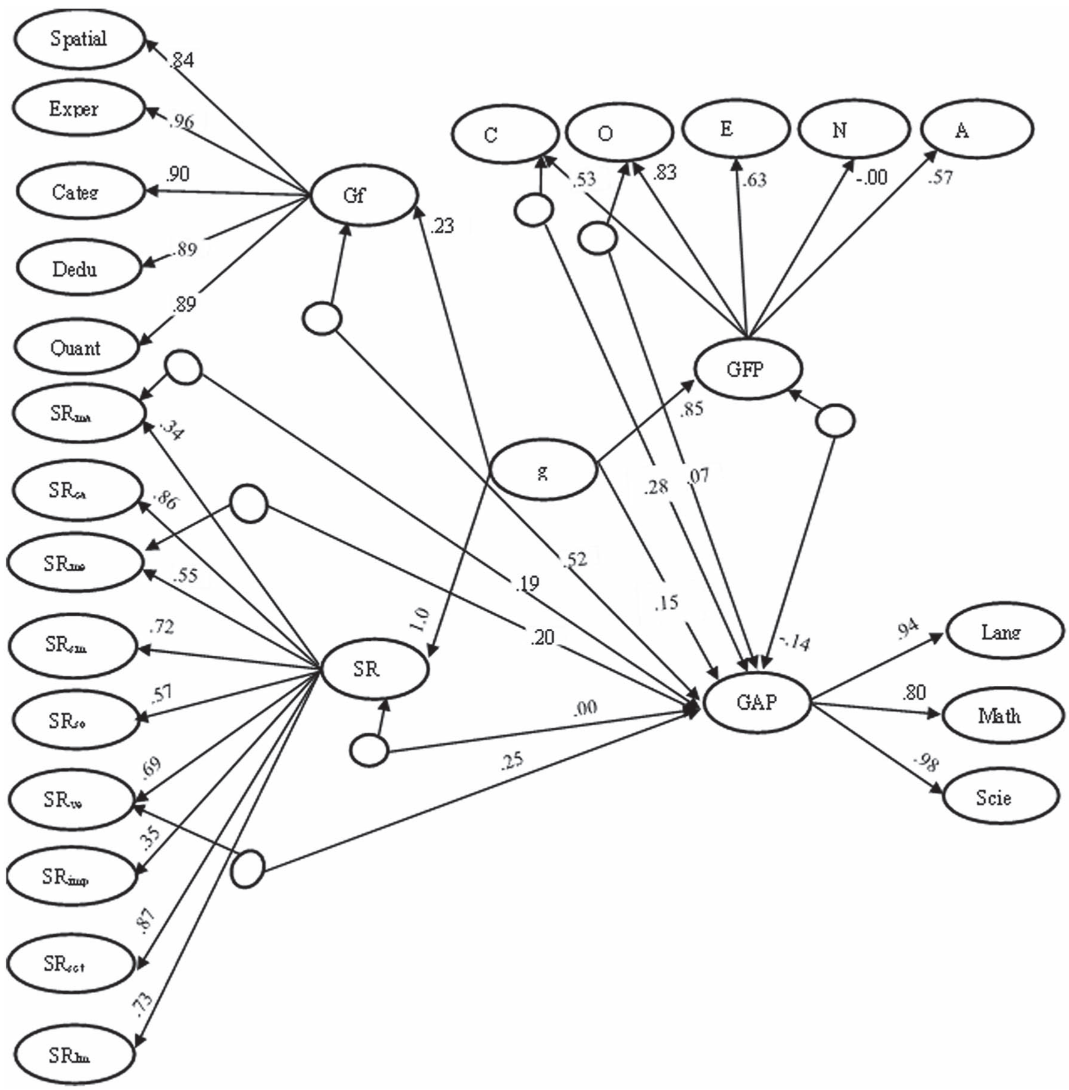
In the separate models, the model examining cognitive processes involved first-order factors for inductive, deductive, quantitative, causal, and spatial reasoning and a second-order Gf factor related to all domain-specific factors. Altogether, performance on the reasoning battery accounted for 40% of GAP variance. In line with the other studies, Gf accounted for 25% ($\beta = .50$) of GAP variance—more than half of the total variance accounted for by the model. Of the various domain-specific factors, only residual quantitative reasoning accounted for a significant amount of GAP variance (5%, $\beta = .23$), reflecting the relevance of mathematical reasoning in school performance.

The model examining only self-representation included first-order factors for all domains of reasoning above and, additionally, factors for mental efficiency (memory, speed of understanding, and self-regulation). These factors were regressed on a second-order general cognizance factor, Gcogn. Altogether, these factors accounted for 28% of GAP variance. The effect of the general self-representation factor on GAP, although significant, was small (1%, $\beta = .11$). The majority of the influence of self-representation was captured by the residual factor of self-representation of mathematical thought (24%, $\beta = .49$); the residual of deductive reasoning also accounted for a significant amount of GAP (3%, $\beta = .18$).

In the model involving only the Big Five factors, there was a first-order factor for each of the Big Five, all related to a second-order GFP (a model involving factors for stability and plasticity is not discussed here). Altogether, these factors accounted for 36% of GAP. The relation between GFP and GAP was negative (4%, $\beta = -.19$) but nonsignificant, implying that this factor may have reflected the likeability aspect of personality. Of the Big Five factors, only conscientiousness (18%, $\beta = .42$) and openness (12%, $\beta = .35$) accounted for considerable amounts of GAP variance and in the expected direction.

The common model involved all factors of the separate models above. The second-order factors detailed in Figure 8 were related to a third-order *g* factor. The *g* factor in this model was dominated by self-representation: both GFP ($\beta = .85$) and Gcogn ($\beta = 1.00$) were very highly related; the relation with Gf was significant but moderate ($\beta = .23$). Altogether, the various factors accounted for 54% of total

Figure 8
A Comprehensive Model Involving All Study 4 Processes



Note. Exper = causal–experimental; categ = categorical; dedu = deductive; quant = quantitative; SR = self-representation component of cognizance; subscripts ma, ca, me, sm, so, ve, imp, sct, and lm stand for self-representation in mathematics, categorical reasoning, mental efficiency, self-monitoring, social reasoning, verbal reasoning, impulsivity, self-control, and learning, respectively. C, O, E, N, and A stand for the Big Five factors as specified above. GAP = general academic performance factor; GFP = general factor of personality.

GAP variance. The amount of GAP variance accounted for by *g* in the common model was small and nonsignificant, 2% (β = .15). Noticeably, the relative influence of the three types of processes (cognitive, self-representation, and personality) was redistributed drastically, relative to the three separate models (see Figure 8). Specifically, more than half of the total amount of variance captured by this model (i.e., 30% out of 54%) was accounted for by cognitive factors. Gf captured most of this amount, 27% (β = .52); none of the domain-specific factors was significant. Impressively, self-representation diminished drastically. Gcogn vanished completely but self-representation of mathematical (4%, β = .20) and deductive reasoning (6%, β = .25) preserved moderate but significant predictive power.

Expectedly, in the corresponding separate model seen in Figure 8, self-representation factors functioned as proxies of cognitive competence to a considerable extent. With the cognitive factors present, most self-representation factors lost their role as predictors. Also, the predictive power of personality diminished extensively compared to the corresponding separate model, but less so than self-representation. GFP accounted for 2% (β = −.14) of GAP variance. Of the Big Five factors, conscientiousness (6%, β = .24) continued to have a significant impact on GAP. Openness was absorbed by the other cognitive self-representation factors. To further decompose these relations, the common model above was tested in two models involving multiple groups: one according to educational level and one according to ability level. In the model testing the possible differentiation of relations according to educational level, three groups were formed: primary, junior secondary, and senior secondary school; in this model altogether, the various factors accounted for 77%, 54%, and 53% of total GAP variance, respectively.

There were interesting similarities and differences between the three groups. The predictive power of *g* was very limited in all three groups (β < .10 in all groups). Gf was strong in all three groups but decreased from primary to secondary school (β = .55, .40, and .36 for the three groups, respectively). Interestingly, deductive reasoning was influential in the two younger groups but not in the older group (β = .36, .39, and −.06 for the three groups, respectively). Self-representation in mathematics (β = .38, 26, and .19 for the three groups, respectively) and deductive reasoning (β = .33, 28, and .21 for the three groups, respectively) were influential in all three groups. There is a trend for the various relations to decrease across the three levels.

To examine if this trend is related to cognitive ability, three populations were formed according to cognitive ability: low, including participants performing 1 *SD* or more below the mean of the cognitive battery; the middle group included participants performing 1 *SD* ± 1 from the mean; and high, performing 1 *SD* or more above the mean. The influence of *g* on academic performance was very weak in all three groups (β < .10 in all groups). However, the influence of Gf decreased systematically across the three groups (β = .58, .21, and .05 for the three groups, respectively), dropping below significance in the ablest group. Only Gf was significant in the lower ability group. In the average-ability group, self-representation in mathematics (4%, β = .21) and deductive reasoning (4%, β = .19), and openness (3%, β = .19) were significant; in high-ability individuals, only self-representation of mathematical ability was related to school performance (16%, β = .40). Obviously, cognitive processes and personality processes operate differently in different educational, developmental, or ability levels.

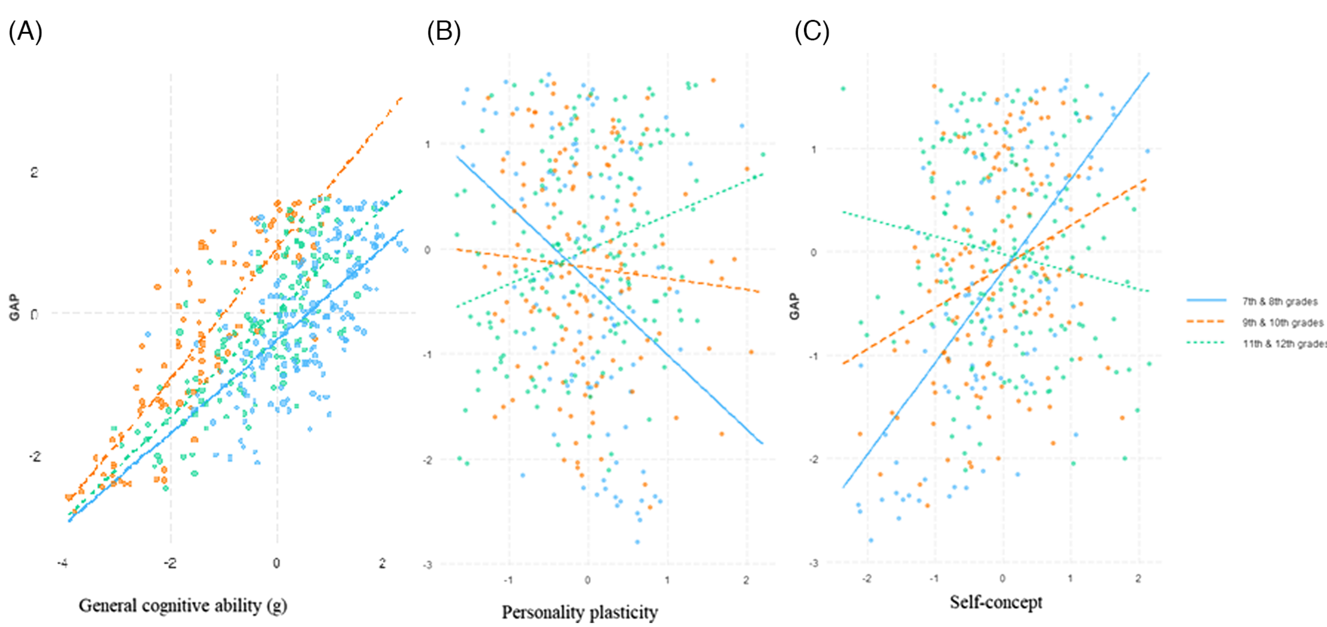
Specifying Interactive Effects

A nonlinear structural equation model was also applied. This approach allows the capture of interactive effects in addition to relations between pairs of individual processes (Tucker-Drob, 2009). The tested model involved general cognitive ability, *g*; GAP, the common factor emerging from performance on the three school subjects; and the two major personality dimensions: stability (a factor underlying agreeableness, conscientiousness, and neuroticism) and plasticity (a factor underlying extraversion and openness). The general factors standing for each of these processes, their quadratic version, and their interaction with age were also involved. Significant relations are illustrated in Figure 9.

Figure 9A illustrated the strong and linear relation between GAP and *g* (45% of variance); it is noted that the quadratic *g* was minimally predictive of academic performance when purified from the linear effects of *g* (β = −.04, *p* > .07). Notably, the relation of academic performance with stability (3%) and plasticity (2%) in personality was low and varied in opposite directions: negative for stability and positive for plasticity. The relations of academic performance with interactive factors involving stability were consistently low. However, the interaction of plasticity with age related positively and strongly with academic performance (29% of variance); also, the interaction between *g* and plasticity

Figure 9

Relations of Academic Performance With Cognitive Ability, Personality Plasticity, and General Cognitive Self-Concept



Note. (1) To highlight interactions with age without making the figures unnecessarily complicated, secondary school Grades 7 and 8, 9 and 10, and 11 and 12 were pulled together. (2) A (general cognitive ability, factor scores on *g*): R^2 = .45, $F(1)$ = 334.21, p < .001; B (plasticity of personality): R^2 = .29, $F(1)$ = 155.72, p < .001; C (and self-concept): R^2 = .12, $F(1)$ = 57.39, p < .001. GAP = general academic performance factor. See the online article for the color version of this figure.

is related highly to GAP (21%). The relation of academic performance with the product of cognitive self-concept by age was negative (12%). Inspection of Panels B and C suggests that these effects are informative for the extreme parts of the respective scales. Specifically, these scales minimally differentiate between individuals of average competence. However, on the one hand, with development or increasing *g*, plasticity becomes increasingly important for academic performance. On the other hand, inflation of self-concept with age does not necessarily better reflect academic performance. Perhaps, increased plasticity enables students to tune their cognitive ability to varying school demands; inflated self-concept may divert them from the effort required to cope with learning demands at school.

Study 5: Cognitive Ability, Self-Representation, Self-Evaluation, Personality, and Emotional Intelligence

Demetriou, Spanoudis, et al. (2018) included emotional intelligence additionally to the factors listed above. We included emotional intelligence to examine its possible predictive power on top of the cognitive and personality factors of concern to the present theory. Initially, Goleman (1995) proposed the construct of emotional intelligence to account for cognitive and emotional processes that allow for understanding and managing emotions, and motivational factors that were allegedly unaccounted for by the dominant psychometric theories of intelligence and personality (Goleman, 1995; Mayer et al., 1999; Mayer & Salovey, 1997). However, recent research suggested that measures of emotional intelligence assess aspects of personality addressed by traditional personality or intelligence research (Matthews et al., 2004, 2005). In line with this argument, other contemporary studies demonstrated that trait emotional intelligence appears as a direct measure of GFP, indexing social effectiveness (van der Linden et al., 2017). Thus, emotional intelligence may not be a useful construct for understanding academic achievement (Waterhouse, 2006). This study tests if this critique of emotional intelligence is valid. The study involved fifth-grade (11 years) primary school children and seventh- (13 years), ninth- (15 years), and eleventh-grade (17 years) secondary school adolescents.

These participants were examined using cognitive (inductive, mathematical, causal, and social reasoning) and cognizance tests (self-representation and self-evaluation in these domains). The Big Five personality factors test was also utilized, as was a battery of emotional intelligence tests. We examined trait emotional intelligence using a self-rating inventory concerning knowledge about emotions (e.g., "I know why my emotions change"; "I recognize someone's emotions") and emotional self-regulation (e.g., "I control my emotions"). Emotional intelligence was examined through several tests. First, items were examined to understand how emotions (anger, sadness, joy, disgust, fear, and surprise) may be involved in real-life episodes. Second, participants constructed stories capturing how such emotions change as a consequence of experiences with their heroes or interpersonal interactions.

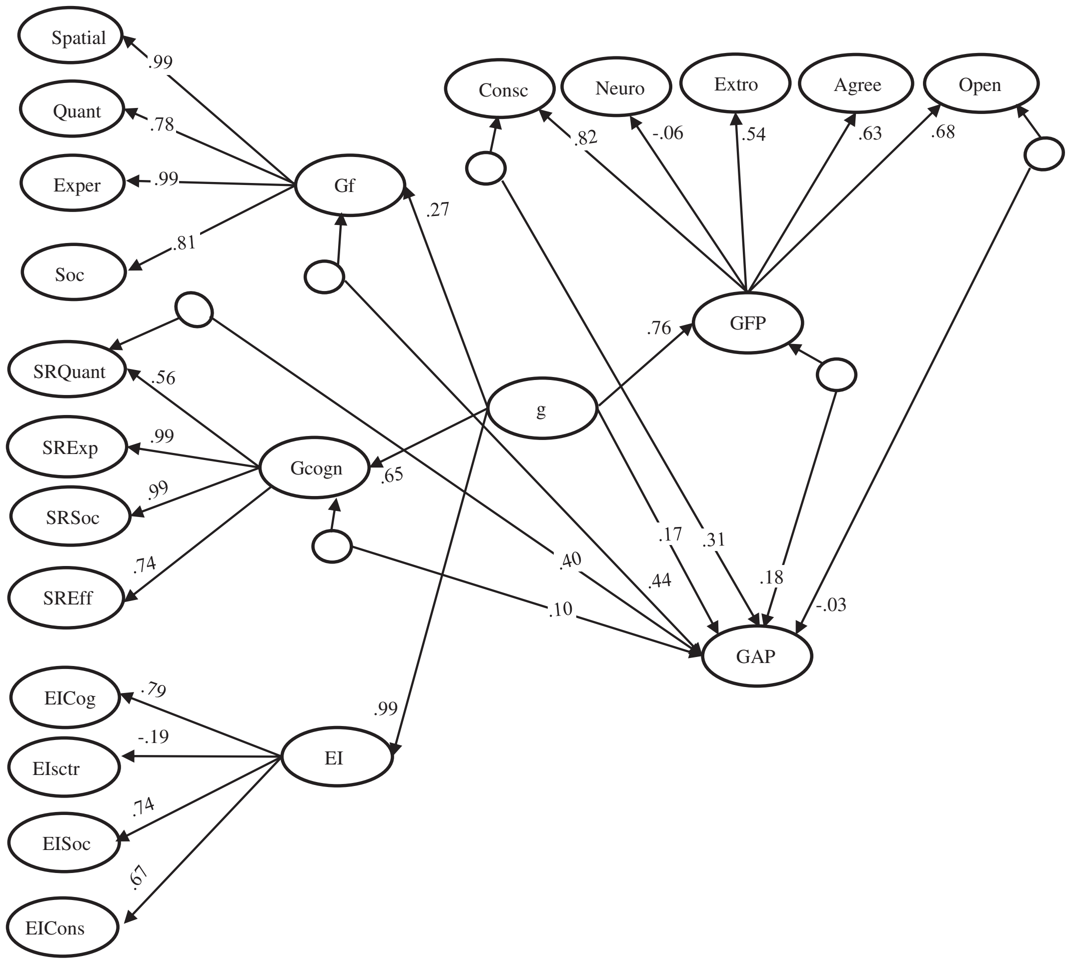
In the fashion described above, separate models examined how each construct and its components relate to academic achievement independently of the other constructs. The present findings generally validated the findings above. In the model involving the cognitive domains, Gf accounted for 18% ($\beta = .43$) of GAP variance; no domain-specific factor was related. In the model involving self-evaluation and self-representation, the effect of Gcogn was moderate but significant (5%, $\beta = .22$); the residual mathematical reasoning self-representation factor accounted for 20% ($\beta = .45$) of GAP variance; the effect of the residual self-representation of mental efficiency on GAP was negative 12% ($\beta = -.34$). In the model involving emotional intelligence, all factors together accounted for 17% of GAP variance. The effect of the general emotional intelligence (Gei) factor was nonsignificant (2%; $\beta = .15$). Of the domain-specific factors, only two cognitive factors, understanding emotions (6%; $\beta = .25$) and reconstructing emotions according to situational demands (8%; $\beta = .29$), related significantly to GAP. In the model involving personality, all personality factors together accounted for 22% of GAP variance; the effect of GFP was moderate and significant (11%; $\beta = .33$); the effect of conscientiousness was close to the corresponding effect of the other studies (5%; $\beta = .24$); the effect of neuroticism was significant and, expectedly, negative (5%; $\beta = -.22$). In the comprehensive model including all factors (Figure 10), Gf, Gcogn, Gei, and GFP were regressed on *g*. In the fashion of Study 4, where self-representational factors dominated, Gcogn, Gei, and GFP were highly related with *g* (all $\beta > .65$); the relation with Gf was significant but moderate ($\beta = .27$). In this model, the effect of *g* on GAP was nonsignificant (3%; $\beta = .17$); in line with all other studies, purified Gf dominated, accounting for 19% ($\beta = .44$) of GAP variance; the effect of quantitative reasoning (16%, $\beta = .40$) was also significant; none of the other three purified general factors (i.e., cognizance, emotional intelligence, and GFP) accounted for any significant effect (all accounting for less than 3% of GAP; $\beta \leq .18$). Notably, however, two specific factors did have a significant effect: self-representation of mathematical problem-solving (16%, $\beta = .40$) and conscientiousness (10%, $\beta = .31$).

In conclusion, the present findings align with earlier research indicating that emotional intelligence is redundant to cognition and personality. When measured alone, it does have a certain predictive power, emerging from its cognitive processes that enable an understanding of the role and functions of emotions. However, when measured together with cognition and personality, emotional intelligence vanishes entirely as a predictor. The patterns of intelligence and personality were very similar to the corresponding patterns of the other studies. That is, when examined alone, both self-evaluation and self-concepts, as well as personality, were related to school performance. However, to a very large extent, these factors resonate with Gf rather than standing on their own. In the comprehensive model including all constructs, only Gf remained unaffected by the inclusion of the other factors, accounting for ~20 of GAP variance as in all studies. Notably, Gf dominates over *g,* together with two specific factors: one from self-representation and mathematical competence and one from personality and conscientiousness.

Other Studies

Studies including cognitive and personality measures found a similar distribution of predictive power between the two systems. Neuenschwander et al. (2013) found that in early primary school (first and second grade), executive functions (updating, inhibition, and shifting) accounted for 26% of grades in reading, writing, and mathematics; plasticity accounted for 23% and stability accounted for 16% of the variance in these grades. Laidra et al. (2007) found

Figure 10
A Comprehensive Model Involving All Study 5 Processes



Note. Spatial, Quant, Exper, and Soc stand for spatial, quantitative, causal–experimental, and social reasoning, respectively. SRQuant, SRExper, SRSoc, and SREff stand for self-representation in quantitative, causal–experimental, social reasoning, and mental efficiency, respectively. EICog, EIsctr, EISoc, and EICons stand for the cognitive, self-control, social, and conscientiousness aspects of emotional intelligence, respectively. Gf, Gcogn, EI, and GFP stand for fluid intelligence, cognizance, emotional intelligence, and the general factor of personality, respectively. Consc, Neuro, Extro, Agree, and Open stand for the Big Five factors. GAP stands for general academic performance.

that general intelligence (measured by advanced progressive matrices) accounted for 20%–30% of school performance throughout primary and secondary school. Agreeableness, conscientiousness, and openness accounted for 4% each. Heaven and Ciarrochi (2012) found that conscientiousness exerts a small but significant effect on school performance in secondary school (~3% of variance) on top of Gf (~25%). Openness exerts a similar effect but only among high cognitive ability students. Andersen et al. (2020) found that conscientiousness appears as a predictor of school performance (reading) from fourth grade, retaining a significant relation varying circa $r = .3$; relations of other stability factors, such as agreeableness and emotional stability, are due to their covariation with conscientiousness. Zuffianò et al. (2013) found that self-regulated learning emerging from self-efficacy accounted for a small but significant amount of school performance variance (2%), on top of Gf and the Big Five factors.

Along similar lines, Furnham et al. (2009) examined if the Big Five factors of personality, typical intellectual engagement, and learning styles possess any predictive power of academic performance on top of intelligence. Goff and Ackerman (1992) proposed typical intellectual engagement as a construct bridging fluid with crystallized intelligence. That is, it reflects an active search for knowledge in different domains and engagement in problem-solving. Learning styles reflect habits in the systematicity and exhaustiveness of processing new information when working on learning tasks (Biggs, 1999). This study found that intelligence accounted for ~53% of the variance of performance on the General Certificate in Secondary Education exam scores in English and mathematics at the age of 16 years. The Big Five factors were unrelated. Typical intellectual engagement and learning style added little predictive variance on top of the variance accounted for by intelligence (~3%). Analyzing the data presented by Furnham et al. (2009) by the present approach indicated that even this amount of variance reflected the state of cognitive ability addressed in this study. When used alone, these constructs do predict ~2%–3% of academic performance variance. However, Gf fully absorbed them when used in a common model. These studies strongly suggest that self-representational constructs of mental competence (openness, typical intellectual engagement, learning styles, self-efficacy beliefs) are complementary or overlapping (e.g., Rocklin, 1994) reflections of a central construct—the cognitive me-self—that in turn reflects actual cognitive competence (Gf).

Integrated Cognition-Personality-School Performance Model

In this section, we first summarize the main trends across the five studies before discussing the theoretical implications of these trends for cognitive, psychometric, and developmental theories. Finally, the implications of these findings for education are addressed. Table 1 outlines the fundamental constructs in each system and the basic principles for their handling in education.

Main Findings and Trends

The patterns of relations between cognitive, cognizance, and personality factors highlight how they are interwoven in development, thus influencing school performance. First, all three types of processes do significantly predict a considerable amount of school performance variance, ranging from ~17% (emotional intelligence) to 100% (executive processes or cognizance at preschool), if measured alone (Table S6 in Supplemental Material). A very high amount of school performance variance was explained when all constructs were taken together in the comprehensive models across all studies ($M = 71\%$ across the five studies). This is an impressive relation if considering that the measures of school performance were completely independent of the measures used in the various studies: Teachers scored their students' classroom performance unbeknown to their performance in these studies. However, when examined in comprehensive models, the relative predictive power of factors varies as a function of (a) their role in satisfying developmental priorities in successive developmental phases and (b) the extent to which they mirror each other. Thus, specifying how they appear in models is important for understanding their contribution to life outcomes.

The second-order general factors stand for different sets of processes activated for sake of distinct mental needs. Identifying a general factor in each set may reflect their sharing of a minimal mental core present in all processes in the set. The critical process in Ge is focusing attention on real or mental objects, refocusing if necessary, and holding in mind the information needed to do so. The critical process in Gf is abstraction implementing relational integration across representations and evaluation of the relevance of abstractions, considering inferential and domain constraints. The critical process in Gcogn is awareness of experiences or mental objects which may vary from qualia in visual perception ("I know that this is red") to mental processes ("I visualize how to fit all objects in the box," "I multiply numbers," etc.). Each of the processes may be relatively modular in that they are independently executable, but they are mutually constrained in that they are activated in sequences of meaning-making attempts and each may affect the efficiency of the other. In short, each G is an overlapping set of processes drawing on a core process and mutually supporting each other.

Third-order *g* expresses three distinct but complementary types of effects: (a) overall quality in efficiently running the AACog mechanism; (b) interactions between this mechanism with the quality of representations and rules in different domains targeted, such as relations in verbal, mathematical, and spatial contexts; (c) interactions with processes in specific Gs, such as focusing (Ge), reasoning rules (Gf), process-specific awareness (Gcogn), and commitment to complete processing (GFP; see Table 1). So defined, in developmental time, *g* and the specific G factors are both reflective and formative (Bollen & Bauldry, 2011). They are reflective of the specific experiences that contributed to their formation so far; they are formative because, from this time onwards, actual problem-solving is influenced by them. Identifying any higher order factor at any time is constrained by the limitations of the measurement instruments or the mathematical methods used (Borsboom, 2005).

g: Mechanism or Composite?

There are two approaches to examining *g* as a predictor of academic performance:

1. *g* may be specified as one of several components whose effects must be distinctly identified together with other components.
2. *g* may be taken as a comprehensive function expressing all components jointly activated by school learning.

The two approaches are complementary. The first assumes that *g* reflects a specific mental process that is important for learning at school together with other processes. This is the approach adopted in the comprehensive models tested in each study (see respective figures and Table S6 in Supplemental Material), where academic performance was regressed on *g* and the residuals of specific Gs or more specific factors. Under this approach, the contribution of *g* may be exceeded by specific *g* factors as a predictor of academic performance (or other actual life outcomes) because their relative contribution is based on developmental priorities. We demonstrated that different processes dominate over *g* as predictors of academic performance: attention control and representational awareness in preschool; inductive inference, working memory, and inferential awareness in primary school; deductive reasoning, truth control, self-representation precision, and personality dimensions related to self-management in adolescence. Also, the predictive power of *g* varies inversely with the dimensions defining it. The broader the components of *g* are the less predictive power is left to *g*, being captured by the specific *g* factors. This is the pattern found across the three developmental levels of *g*, g_{rc}, g_{ic}, and g_{lc}, successively constructed across the three levels of education, respectively. There is a strong message here: *g* as a process may be important for the functioning of other processes it interacts with but, when we come to real-life outcomes, it is largely expressed through other processes in which it is invested.

The second approach takes *g* as a composite function of the processes involved, specifying their combined influence on academic performance. This approach may capture interactive influences on academic performance that may escape the first approach.

Table 1
Central and Derivative Constructs Across Fields

Processes	Common core (*g*)	Understanding/action frames (Gf, Big Five)	Cognizance (self-awareness)
Cognition	Attention control processes enable focusing on stimuli (Ge); alignment–abstraction processes, channeled along a represented goal (Gf), minimally cognized for the sake of goal-specific action control (Gcogn).	Inference integrates representations according to rules of different reasoning forms. It enables property- or rule-based transfer of relations (induction, analogy) and truth evaluation (deduction).	Perceptual/situational, attention, and processing awareness; awareness of mental content; maps of mental processes and personal mental history; self-evaluation standards and weights.
Personality	Fundamental goal commitment and characteristic level of engagement directed to behavioral and social efficiency (GFP).	Big Five stand for dispositions of behavioral and social engagements. They guide social inference by integrating social information according to social/moral rules and given dispositions.	Dispositional, emotional, and motivational awareness. Behavioral and social self-monitoring; maps of personality and social characteristics and self-worth values associated with social desirability.
Individual differences	Genetic differences in brain formation and differences in neuronal matter, networks, and functioning serve as attention mechanisms, quality of representations, and relational binding.	Different networks serve different forms of inference or dispositions in the brain or learning. Social/educational experiences enable control of the inferential process.	Differences in self-monitoring and self-recording precision cause differences in the accuracy of self-representations and self-evaluations, self-supervision, and top-down control of functioning.
Education			
Preschool	Mapping executive functions. Build the self-representational mind: Take control of executive processes, including attention, representational awareness, and one's activity with others' activities and minds.	Systematic observation of objects and events. Note similarities and differences generate hierarchical representations. Class and pragmatic reasoning. Practice in recurrent activities, for example, counting, pattern specification, and so forth.	Learn self-monitoring skills and compare performance with goals. Monitor cognitive and behavioral changes under different levels of executive control, for example, attention; or awareness, for example, self-observation.
Primary school	Identify and remove deficiencies in attention control. Build inferential awareness. Train in representational flexibility and management of representations in memory.	Explicit induction of rules. Practice different forms of inference in different contexts. Explicit encoding of inferential processes in language and use of other symbol systems to denote them.	Observe performance relative to standards. Identify strengths and weaknesses in different domains. Control preferences and dispositions relative to school expectations. Awareness of alternative means for learning.
Secondary school	Long-term goal and related strategy formation. Build goal hierarchies and priorities. Strategies for handling disruption.	Explicit awareness of different forms of reasoning and dispositions. Awareness of context. Differentiate between logic and context-based interpretations. Handle dispositions relative to choices and contexts.	Refine standards of self-evaluation. Associate with strengths and weaknesses. Control social desirability. Awareness of life paths vis-à-vis preferences and possibilities.

Note. GEP = general factor of personality.

Interactive influences would indicate that the total is more than the sum of the parts. To examine this assumption, the relations between predictors with academic performance were integrated into a composite function, which is a multistep process. Specifically, the fitted line plots for the regression of academic performance on mean performance on each process and their underlying mathematical functions are specified first. In the case of Study 2, the fitted line plots and the mathematical functions for attention control (GAP = *f*(Att)), working memory (GAP = *f*(WM)), reasoning (GAP = *f*(Gf)), language (GAP = *f*(language)), and cognizance (GAP = *f*(Gcogn)) were first specified. Using the curve estimation procedure, the dependent variable (GAP) was better predicted by sigmoidal curves. The five specific functions of each predictor were then mathematically added to create a new function: the composite function. This function synthesizes the effects of all predictors, representing their simultaneous effects on the variable of interest (Graybill & Iyer, 1994). The composite function for Study 2, with the coefficients for each predictor and GAP as the dependent variable, is expressed as follows:

$$g_{\text{composite}} : f(x) = ax^3 + bx^2 - cx + e, \tag{9}$$

where $a = 0.08$, $b = 0.22$, $c = -0.06$, and $e = 4.29$ (resulting through a series of iterations); x is the sum of the values of each of the five predictors as provided by the raw data of the study.

This composite function accounted for 91% of the variance of GAP and is illustrated in Figure 11.

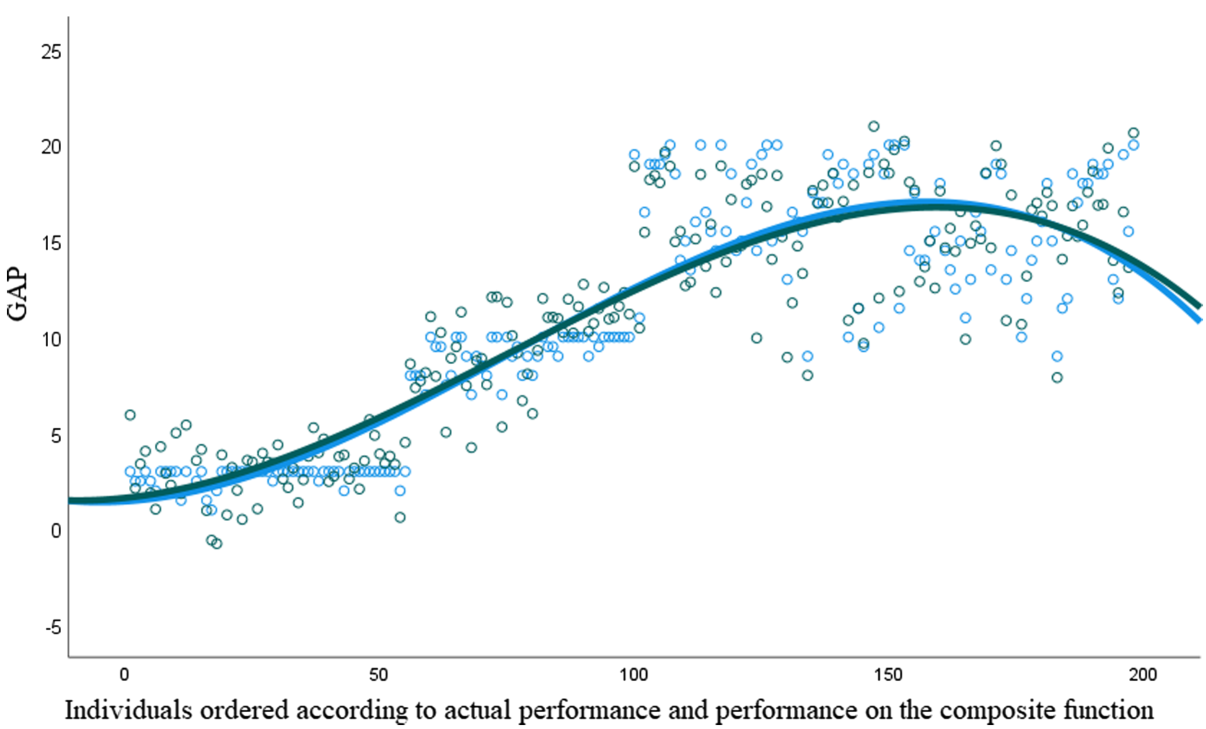
In the comprehensive model presented above (Figure 6), *g* together with Ge, Gf, Gcogn, and language accounted for 85% of the variance. Thus, the composite function (Figure 11) accounted for 6% more variance than this model, implying that there may be interactive effects additional to the sum of individual effects to be considered when predicting school performance. Inspection of performance in the lower or intermediate range rather than in the top range. Therefore, this approach captures nonlinear relations in a more precise manner than SEM.

Theoretical Implications

It should now be apparent that *g* in this theory integrates mechanisms originating in three traditions of research on the human mind: psychometric, cognitive science, and developmental. Therefore, *g* here is broader than the psychometric *g*. In the CHC model, the psychometric *g* emerges from performance on executive and reasoning tasks, and it does not include cognizance (Carroll, 1993; McGrew, 2009). Here, *g* additionally reflects representational awareness and awareness of cognitive processes, expressed variably across the five studies. Thus, it captures the relational binding background of Spearman's (1904, 1927) eduction mechanisms and restores its lost first law of *g*, apprehension of experience. Also, in psychometric theory, *g* is a measure of individual differences, reflecting, among others, the strength of relations between cognitive processes. Spearman's law of diminishing returns postulates that correlations between processes diminish with the increasing ability

Figure 11

The General Function of Study 2



Note. Green stands for the distribution of actual academic performance scores and blue stands for the distribution expressed by the general function, that is, x = individuals are ordered on the x-axis according to their performance on the composite function specified in Equation 9. The coefficients for the processes involved and the composite function were derived using nonlinear regression software (SPSS 26.1). GAP = general academic performance factor. See the online article for the color version of this figure.

(Jensen, 1998; Spearman, 1927). The studies presented here showed that correlations between processes are a function of developmental priorities rather than of sheer level of ability, concurring with research questioning this law (Fogarty & Stankov, 1995).

As a developmental construct, the theory is also broader than the mechanisms discussed in developmental theories. These theories emphasized one dimension of intellectual development at the expense of others. Piaget (1970) emphasized reasoning and underlying logical mechanisms, ignoring executive or processing functions. Post-Piagetians emphasized the later functions, underestimating reasoning or awareness processes (e.g., Case, 1985; Halford, 2014). Theory of mind (e.g., Wellman, 2014) and metacognition theories (Efklides, 2008; Flavell, 1979) focused on awareness and underestimated the rest. Executive control theories focused on representational efficiency and flexibility in an early period of life, underestimating the underlying processing efficiency or reasoning processes (Diamond, 2013; Zelazo, 2015). No earlier theory specified the changes in the importance of all processes according to developmental priorities. In the present context, *g* fleshes out Piaget's (2001) reflective abstraction, specifying its forms and role in successive developmental phases. In this regard, the AACog mechanism integrates Karmiloff-Smith's (1992) representational redescription (RR) in its operation. RR is a "process by which information that is *in* a cognitive system becomes progressively explicit knowledge *to* that system" (Karmiloff-Smith, 1992, p. 693). Progressive explicitation begins at an initial level when knowledge and mental processes are only implicit to an ultimate level when knowledge is both consciously accessible and available for verbal reporting. So defined, AACog is a self-modified mechanism altering developmental priorities and transforming *g*. Thus, *g* here brings the currently thriving research on consciousness (Seth & Bayne, 2022) in the study of intelligence and intellectual development, showing that it is an important part of the learning process in school.

The theory and research reviewed here resolve an ongoing dispute: If *g* should be replaced by specific *g* factors in predicting life outcomes, such as fluid reasoning (Gustafsson & Undheim, 1996) or executive control (Blair, 2006; Diamond, 2013). This theory suggests that, depending on the developmental phase, any specific *g* may extensively overlap with *g*. In early childhood, it may overlap with executive control; in young adulthood, it may overlap with Gf. We found here that the predictive power of Gf increased from preschool to middle primary school, becoming the dominant predictor thereafter. Therefore, inferential processes and problem-solving skills invested in various domains, such as inductive, deductive, mathematical, causal, and spatial reasoning, are central to school learning. Both *g* and Gf are reflected in all forms of cognizance guiding online task-specific performance evaluations and offline general and domain-specific self-concepts. They are also reflected in personality influencing goal-oriented self-management dispositions framing problem-solving and learning performance (conscientiousness) and attitudes for handling challenges (openness). Thus, when measured alone, self-evaluations, self-concepts, and some personality dispositions do predict a considerable amount of school achievement (20% or higher). However, their predictive power dissipates when purified from this reflection. Only self-evaluation, school-related self-concepts in mathematics and verbal reasoning and conscientiousness survive, accounting for about 3%–5% of school performance variance each. Admittedly, change in the predictive power of various constructs with age may partly reflect increasing precision in school performance measures themselves, rather than cognitive or personality measures. For instance, teachers rely increasingly on performance on tests with advancing grades rather than on personal judgment. Future research would have to disentangle these effects.

Nevertheless, many aspects of the mechanisms in *g* and their relations need to be further specified. For instance, research needs to specify how AACog operates under a hierarchy of goal representations, including domain-specific biases about the relations to be processed, general plans for stimulus search, alignments, abstractions, and evaluations, and a mixture of domain-specific and domain-general standards for evaluation of truth and adequacy of solutions. It is accepted that problem-solving is based on the construction of simplified representations of the problem under consideration, which reduce the dimensions needed to solve the problem. These simplified initial representations bias where attention is to be initially committed and refocused in the process, interchanging between covert attention to a goal hierarchy and overt attention to information changing online (Weichart et al., 2022). They also affect the value of representations, balancing the cost of action plans with their utilities (Ho et al., 2022).

These considerations have important developmental implications if related to the developmental priority model. First, at preschool (3–6 years), when attention control and representational awareness are still under formation, an optimized reduction of the problem space into a simple but accurate representation, an accurate representation-based search of information and related alignments, and awareness-guided abstractions are weak. Thus, difficulties in handling and solving problems in this phase emerge from deficiencies in construing the problem situation and ensuing planning of problem solutions. Later, in primary school, problems may be represented more adequately, but the imprecision of inferential awareness and self-evaluation may blur the formulation of alternative solutions or their evaluation when conceived. Even later, in adolescence, when these limitations are overcome, the lag of an adequate truth control process may lead to accepting wrong interpretations because their complete evaluation is not possible.

These questions withstanding, a drastic cleanup of theoretical constructs is required. A recent study showed that tens of constructs about self-concept, self-efficacy, self-esteem, life satisfaction, mindfulness, need for cognition, intellectual engagement, and so forth can be subsumed under the overall scheme of the Big Five factors as expressions of already extant facets (Bainbridge et al., 2022). The evidence discussed here suggests that an even larger reduction is needed in concern to the predictors of school performance. Personality itself may reflect academic performance if measured alone but this is a projection of cognitive competence in personality; when this projection is removed, all aspects of the Big Five but conscientiousness become redundant to cognitive and other self-representation processes. By late childhood (Andersen et al., 2020), conscientiousness may stand for a refined self-reflected expression of executive control embedded in planning and self-management strategies, allowing better use of one's cognitive competence. Notably, some constructs, such as emotional intelligence, were completely absorbed by cognition and personality. Therefore, compared to intelligence, the influence of personality on school achievement is much weaker than claimed by other studies (e.g., Borghans et al., 2016). The influence of personality on achievement in other more complex domains of life, such as the workplace, social activities, and politics, is stronger than found here. Admittedly, interested users would need a more precise mapping of this influence.

An Overarching Cognitive Developmental Educational Model

To be able to direct educational practice, the relations between school and cognitive and personality development would have to be analyzed at two related but distinct levels. On the one hand, general trends in development may guide overall educational policy and planning. For instance, general trends may guide the formation of the curriculum so that overall learning demands align with general trends in the population according to age. On the other hand, individual differences in the development of each process may guide the tuning of specific demands teaching practices according to individual developmental rates and possibilities. Often, what appears to be appropriate for a population at the global level, may not be appropriate for individuals developing slower or faster than their agemates. Slow developers may not be able to cope, and fast developers may not be able to profit from school. Thus, in this section, we will first draw the implications of the present findings for the global alignment of development with school demands. We will then focus on the implications for the individualization of teaching. Educational priorities according to educational level are summarized in Table 1.

Developmental Profiles and Educational Demands

Overall learning demands of successive school levels appear well coordinated with general changes in mental possibilities, probably reflecting the progress made in our understanding of intellectual development and learning after more than a century of research. In preschool, building the self-controlled representational mind is critical for learning. These processes relate to the main demands imposed on preschoolers: (a) coordinate their activity with organized school life; (b) take others' minds seriously; (c) translate one's representations and mental states into arbitrary representations and knowledge prioritized by teachers. Executive processes are more relevant than reasoning in preschool because they enable children to engage with time-organized activities in the classroom, such as attending to the teacher's instructions, inhibiting distracting responses, holding information in mind, and flexibly adjusting to changing instructions (Nelson et al., 2017). Also, the mediational role of cognizance in the transition to rule-based thought is much stronger in the period from 5 to 7 years than later. Representational awareness and ensuing precision in focusing on representations facilitate grasping representational links that will feed into the inferential processes dominating in the next period.

Also, representational awareness at preschool enables children to show interest in others' knowledge, including teachers and classmates. These processes are needed to carry on the representational integration required for learning in the subjects introduced in early primary schools, such as reading and arithmetic; these tasks require matching and interlinking mental states with symbols and their relations as deployed by the teacher (e.g., Altemeier et al., 2006; Nelson et al., 2017). Notably, linguistic awareness is highly important for building this awareness in preschool (Demetriou et al., 2021).

In primary school, fluid reasoning, working memory, and language dominate. The first two reflect control of the representational field in which concepts are inferentially connected. Reasoning ensures the integration and abstraction required to build new skills, such as reading and arithmetic, which require the integration of representation chains. Working memory reflects the facility of handling blocks of representations and their interrelations. Learning mathematics requires increasing precision in focusing on specific individual representations, such as specific numbers, and increasing flexibility in mentally moving across them to grasp relations. Grasping science requires understanding causal relations between variables at multiple levels. Language is the basic medium of teaching. Mastering language requires commanding increasingly demanding grammatical and syntactical rules defining semantic relations.

Self-concepts and self-evaluations in this phase are not good predictors of school performance. Often, in this phase, these indices are negatively related to school performance, for two possible reasons. On the one hand, inferential awareness in this period is still imprecise, lacking standards for truth and validity. On the other hand, self-value judgments are inflated by likeability, reflecting an interaction between a nascent sense of mental power with a need to project an image of success. These weaknesses may be reflected in adjusting self-regulation activities according to the learning demands of tasks. There is evidence that the flexibility to monitor and adjust learning activities according to different learning tasks at school is still under formation even at the end of primary school (Gönül et al., 2021).

These weaknesses diminish with principle-based thought, emerging with refined self-monitoring and self-knowing. Deductive reasoning dominates as a predictor of school performance in secondary school. Additionally, self-evaluation and self-concepts emerge as relatively accurate predictors of school performance because they become more precise in monitoring and evaluating performance, allowing updating when needed and recognition of one's own mental and personality constraints (Demetriou, 2020; Demetriou, Makris, Kazi, Spanoudis, & Shayer, 2018; Demetriou, Spanoudis, et al., 2018). It seems that in this phase, the self-system gradually builds pointers to different combinations of (a) problem-solving skills and awareness processes, (b) dispositions to act with a particular pattern of activity, and (c) feedback received about successes and failures and the ensuing feelings of satisfaction and dissatisfaction. As a result, crudely self-represented executive control processes and dispositions of the child are elevated into the self-organization and achievement plans of the adolescent, explaining the emergent role of conscientiousness in adolescence.

These changes go well with learning in secondary school, introducing the formal style of science in modeling the world. Advanced mathematical skills, grasping science concepts, and decoding meaning in literary works require taking the suppositional stance and organizing information according to general principles. This stance requires differentiating between concepts in their resistance to understanding and thus working on ad hoc self-regulated learning strategies (Capon & Kuhn, 2004). Thus, thinkers may transform an advantage in task-specific self-evaluation into an advantage to tune their cognitive strengths with the demands on abstraction imposed by concepts; hence, their extra value as predictors of academic performance.

Gaps Between Individual Development and Educational Demands

Not all children function at the modal level expected according to their age. Therefore, gaps often exist between individual possibilities and demands of learning tasks associated with typical age levels. Gaps reflect deviations between concepts and skills prescribed for learning for a specific population and the readiness of individuals in this population to cope with the demands of these concepts and skills. These gaps are often related to major transitions between education levels, such as the transition from preschool to primary school, from primary to secondary, or from secondary to tertiary education. Also, there may be gaps at transitions of smaller scale, such as the progression from one school grade to the next. Individuals delaying the consolidation of the dominant profile of each school level would not follow the pace of learning in the classroom.

For instance, individuals delaying in preschool to master attention control and awareness involving visual and phonological information would face difficulties in learning skills which are central in this period. Evidence shows that attention and awareness of language-related information are important for learning to read and write. Deficiencies in control of attention allowing systematic spatial search and orienting at the early stages of reading hinder learning to read even after IQ, hyperactivity, and other behavioral problems are controlled (Franceschini et al., 2012; Rabiner et al., 2000). Representation of magnitude and awareness of the relations between magnitudes and number names are important for learning arithmetic. Difficulties in numerosity coding hindering mapping symbols onto representations of quantities would make counting difficult, as counting words would lack the exact representations to be associated with (Butterworth, 2010). In turn, these difficulties relate to attention control and phonological awareness (Clark et al., 2010). Special diagnostic tools must target these processes.

Later in primary school, not all children progress at the same rate in mastering inferential processes and working memory management in integrating new knowledge with extant knowledge. Many children lack the representational precision in mentally integrating representations at the microtime required, probably in the range of days. In early primary school, some students fall back on the representational awareness necessary to identify representations of relevance to learning tasks and manipulate them to process their relations. In later primary school, students face difficulties in rule abstraction and rule use in integrating representations. For instance, they face difficulty in generalizing arithmetic rules across levels, such as applying the same rule on numbers of increasing magnitude (e.g., tens, hundreds) or kind (e.g., integers vs. fractions).

A gap also exists for a relatively large number of students in the transition from primary to secondary school (Demetriou, 2020). According to the results of the Program of International Student Assessment (2012), about 20% of junior secondary school lack the necessary abstraction skills needed to identify the main idea of a text, apply algorithms to solve simple mathematical problems, interpret simple observations and design-controlled experiments to specify the cause of phenomena. These students have difficulties in generating principles by concatenating rules into higher level rules, they are not aware of their difficulties, and they do not have the motivation to work to build these skills.

Educational Implications

These considerations bear implications for school evaluation and the mental strengthening of students: both must be adapted to the developmental/educational level of students.

Evaluation. An evaluation must be able to diagnose the strengths and weaknesses of students according to their developmental level. In preschool, a cognitive evaluation must focus on precisely mapping executive control and representational awareness processes (see Zelazo et al., 2003) to capture possible weaknesses in processes related to school's important learning, such as reading/writing and arithmetic learning. These processes must be especially targeted by diagnostic tools addressed to this age phase. Later, in primary school, a diagnosis must be able to identify problems in the awareness and relational integration processes which were left over from preschool and focus on the command of representational integration needed in inductive reasoning and working memory. In secondary school, a diagnosis must focus on uncovering problems in the command of higher forms of deductive reasoning and the refinement of self-monitoring and self-representation processes according to the school subject.

Cognitive Training. There is extensive research examining if cognitive training increases cognitive ability and if gains generalize to school learning. There is general agreement that cognitive training does succeed to cause near-transfer gains, but it is disputed if it can cause far-transfer gains: Training improves performance to nontrained cognitive tasks like the tasks trained but these gains do not generalize to nonrelated tasks, derived from changes in general cognitive abilities (Sala & Gobet, 2019; Smid et al., 2020). It is beyond the present concerns to delve into this literature. However, the lack of consistent far-transfer gains is to be contrasted with the consistent findings that education does change Gf by about one to five additional IQ points for each extra year spent at school (Ritchie & Tucker-Drob, 2018). The reason may be that education lasts for years, affecting successive cognitive profiles expressed in *g*. By implication, far transfer may affect *g* sustainably only if training addresses phase important cognitive processes, such as attention control in preschool, relational thought in primary school, and cognizance and logical awareness in secondary school, which contribute to the formation of *g* in each phase (Demetriou & Spanoudis, 2018).

Evidence is supportive. Specifically, training attention control in 5-year-old children enabled them to activate the executive attention network faster and more efficiently than untrained children several months after training, which transferred to fluid intelligence (Rueda et al., 2012). Gizzonio et al. (2022) trained 4-year-old preschoolers on age-appropriate tasks simultaneously focusing on visuospatial, narrative, and motor abilities and fluid reasoning. They reported domain-specific gains of training but also transfer to working memory and mathematical reasoning skills.

Training working memory in 11–12 years old children improved the processes trained and transferred to school performance in English and mathematics (Holmes & Gathercole, 2014), a proxy of *g* (Jensen, 1998). Training attention control and working memory in later years did not transfer to relational processes nor does it increase *g* (Melby-Lervåg et al., 2016; Sala & Gobet, 2020; Shipstead et al., 2016). However, training relational integration (Klauer & Phye, 2008; Papageorgiou et al., 2016; Shayer & Adey, 2002; Shayer & Adhami, 2007; Vainikainen & Hautamäki, 2020) and awareness and modeling deductive reasoning schemes (Christoforides et al., 2016) in late childhood and adolescence did improve reasoning and transferred to attention control and working memory. In conclusion, cognitive training is not universally effective. It is effective if it specifically targets processes central to the formation of *g* in the developmental phase involved. Also, in terms of the multiple LoT model (outlined in the introduction), transfer of learning would require learning to specifically focus on the specificities of the rules, principles, and constraints as implemented in each domain. This would have to extend from each domain-specific LoT to its implementation in the curricula of different school subjects, such as mathematics, science, language, social understanding, and so forth.

There is extensive discussion of the role of "learning to learn" and self-regulated learning (Dignath et al., 2008; Dignath & Veenman, 2021). The present theory, in combination with the findings summarized above, suggests that training programs addressed to self-regulated learning must be tuned to the developmental priorities of successive phases to be successful. In preschool, self-regulated learning requires awareness of attention processes and their relations with perception as a source of knowledge. It also requires one to be able to direct attention to perceptions of interest, inhibit turning to interesting or attractive stimuli that are not relevant, and think about the relationship between perceptions and representations. Knowing that mentally restoring episodic sequences of interest and talking about them enhances understanding and retention. In primary school, self-regulated learning requires focusing on relations between representations, varying them and choosing relations as inclusive as possible for representations of interest. Such learning also requires an understanding that covert attention on representations is the equivalent of overt attention on perceptions. Finally, self-regulated learning requires an understanding that relations not well integrated may be forgotten. These considerations apply especially to average-ability students. These students must be guided to understand the limitations of rule-based thought and be reflective on their successes and failures so that they may take compensatory action accordingly. Special programs must focus on learning skills that facilitate the depth of information processing and understanding at several levels in a text (e.g., Catrysse et al., 2018).

In secondary school, self-regulated learning requires an understanding that abstracting principles involves a systematic and exhaustive search of assumptions standing for possible rules and that there may always be evidence against a principle. It also requires understanding that some types of relations are easier to grasp and elaborate upon due to differences in the facility of representing different types of representations standing for specific relations. Thus, education must enable adolescents to construct accurate self-representations about their cognitive and personality profiles; this would enable them to embark on appropriate choices and acquire problem-solving strategies and interests tuned to their profile to maximize the output of their activity.

Special attention should be given to individualizing these programs according to the level of the individual student. We remind that the relative influence of the various processes varies with the level of ability. In low-ability individuals, only Gf counted. Even small differences in cognitive ability among low-ability individuals result in differences in school learning. At this level of ability, cognizance was not a predictor of school learning and personality did not count. Perhaps, the education of low-ability students may need to develop the skills lacking: mental awareness, self-regulation, and self-management that would allow for better use of available cognitive competence. In average-ability individuals, all factors (cognitive ability, cognizance, and personality) are counted equally. At this level, the cognitive competence available is enough for school learning if used systematically. Strengthening inferential abilities may be needed at the middle level, which would allow more systematic learning. In high-ability individuals, it is "yours to lose" (Gottfredson, 2002) because the ability needed for complex learning is available. However, some self-representations and conscientiousness did count; excellence in self-awareness together with commitment to long-term goals at this level of ability reflect efficiency in investing available ability for the sake of school learning. At this top level of ability, building epistemological awareness and investment in the learning of concepts and skills requires high levels of abstraction (and thus high levels of *g*)—for example, mathematics—may help direct the choices of learning paths for demanding subjects, such as Science, Technology, Engineering, Mathematics (STEM) disciplines (Coyle, 2018). Helping overoptimistic individuals to come down to earth may be helpful for their overall developmental prospects. Alternatively, it would be helpful for high-ability students to know that their high ability is not always enough for success at school; often sustained effort and long-term organization is needed to fully capitalize on the ability and talent available.

Unresolved Issues for Future Research. This theory focused on cognitive and personality processes in development. Its power to predict real-life outcomes and inform practice would be increased if it would integrate brain, genetic, motivational, and social mechanisms into its postulates. Here, we only hint at this integration, ideally explicating how the AACog mechanism functions, from perception through high-level reasoning and problem-solving hierarchies (Spanoudis & Demetriou, 2020).

On the one hand, genetic differences in specific aspects of the genome account for 7%–10% of individual differences in intelligence (von Stumm & Plomin, 2021). We must show that these differences are related to differences in the functioning of the AACog mechanism in the brain. Neural variability is an important aspect of how the brain represents the environment (Waschke et al., 2021). Perception is based on a gain control mechanism involving variation, search, and integration processes (Buzsaki, 2019). How is this variability related to the information variability, search, and abstractions implemented by AACog? Does multimodal perception produce multiple object representations across senses and brain regions (Nanay, 2018)? How are abstractions affected across them converging to a common representation? How is this meta represented as a novel mental object (Ferguson & Cardin, 2020; Gómez-Ocádiz et al., 2021; Guimarães et al., 2022). Presumably, initial genetic differences guiding the structural and functional formation of brain mechanisms, such as density of neuronal networks, neurotransmission, and oscillatory interactions between regions, are reflected in individual differences in the investment of AACog into reasoning patterns associated with developmental priorities in the formation of *g*.

On the other hand, the variation, search, abstract, and cognize processes are related to environmental influences framing learning. Setting goal structures for learning tasks is affected by one's school and family goal culture, to degrees varying with age (Gonida et al., 2009, 2014). In turn, these factors interact with social factors such as the socioeconomic and educational level of the parents. An initial advantage of socioeconomic status (SES) facilitates attitudes, motivation, and work habits related to school learning, regardless of cognitive potential (Figlio et al., 2017; Kriegbaum et al., 2018). Low SES students benefit from training directed to mindset attitudes to cognitive change more than high SES, better tuning their learning activities to school demands (Sisk et al., 2018; Yeager et al., 2019). Further study of these assumptions would be useful.

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