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## Metacognition, Intelligence, and Academic Performance

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Metacognition is one important facet of human intelligence but it is also the aspect of intelligence that can be more easily promoted by education. The present chapter examines this issue on the basis of a cognitive model of intelligence. The model is presented in the first section, followed by an examination of the implications of the model for education and academic learning and a description of the place of metacognition in the model. In the final section, I present some data supporting the model, discuss group differences in intellectual functioning, and offer some educational implications of the model, in particular with reference to metacognition. Throughout the entire chapter, data and examples are focused on different categories of exceptional children.

### THE CONTRIBUTION OF COGNITIVE SCIENCE TO THE STUDY AND EDUCATION OF HUMAN INTELLIGENCE

It is by no means easy to talk about intelligence and its education, both because of the richness and heterogeneity of theoretical and methodological approaches and because of the vague and slippery nature of the intelligence construct. Nonetheless, in the past 30 years new elements

have emerged that allow us to approach the issue in a different way (for reviews, see Wilhelm & Engle, 2005). Mostly these elements are directly related to cognitive psychology and, more generally, to the cognitive neurosciences and the growing interest in the area of individual differences.

More specifically, what has clearly emerged in the last few years is how cognitive psychology has given “psychological” contents to an entity that had, until then, mostly been inferred through measurement testing and through presumed biological correlates. In particular, the psychometric approach had an important place in the history of research on intelligence, in the creation of measuring tools, and for its ability to identify critical issues. From a pure theoretical standpoint, the different positions within psychometrics were not particularly sophisticated and have given rise to the classical debate: “Is it possible to talk about intelligence as a single entity or are there many forms of intelligence?” From an educational point of view, psychometric theories proposed a core entity (the “*g* factor”) that had a statistical, but not a psychological, identification, and by consequence could not represent a target for education.

By giving a psychological identity to intelligence, cognitive psychology has provided education with an object and a method, which remained unidentifiable to the extent to which intelligence was defined on the basis of a statistical extrapolation or a neurological correlate. However, different cognitive theories have focused on different, although partially overlapping, cognitive constructs, like processing speed, attention, working memory, learning capacity, executive functions, and metacognition.

In a series of papers (e.g., Cornoldi, 2006, 2007; Cornoldi & Vecchi, 2003) I have developed a framework for the comprehension of issues related to the study of intelligence. The theoretical analysis begins with the contributions of psychometrics, psychopathology, classical educational projects, and psychobiology, but then moves on to the ambitious goal of going beyond these approaches. I argued that the contributions of neuroscience are critical to the identification of the basic factors essential to cognitive functioning, and of the compatibility between a psychological theory of intelligence and its neural substrates. In this respect, evidence is increasingly showing the importance of biological (genetic) factors (e.g., Plomin, DeFries, Craig, & Guffin, 2003) and favors the idea that the so-called executive processes, mainly related to cognitive control and associated with the functioning of prefrontal areas, are critically involved in intellectual functioning (Duncan, 2005). However, psychobiological studies typically focus on the basic structure of intelligence (BSI; associated with performance on neuropsychological tests) which must be distinguished from the use of BSI (UI; associated with success in everyday life activities). The framework sketched in the present chapter assumes that BSI is a powerful, but not the sole predictor of UI. A key

assumption of the approach is that psychological dimensions are continuous (Cornoldi & Vecchi, 2003). The assumption of continuity also applies to the distinction between BSI and UI. Pure BSI is a hypothetical construct because intelligence is always expressed in its use, but is better approximated by classical neuropsychological and IQ tests.

Concerning the basic aspects of intelligence, a hierarchical theory of intelligence seems to represent a good compromise, overcoming the limitations of both the unitary and the multiple approach. However, there is a need for a psychological theory of basic intelligence capable of going beyond the simple statistical analysis of intelligence and actually instilling a psychological content in the processes assumed to be located at the top of the hierarchical BSI. Different cognitive constructs, candidates mostly considered critical for explaining the central aspects of BSI, were contrasted (Cornoldi, 2007), using empirical evidence and the capacity of explaining exceptionality as criteria, and in particular the differences between groups assumed a priori to have a lower level of intelligence (animals vs. humans, young children vs. mature children, typically developing children vs. mentally impaired children with an associated genetic syndrome). More specifically, a number of assumptions were made, that is, that human beings' intelligence matures with age (with a specific decline in the elderly), that from a phylogenetic perspective human beings represent the highest form of intelligence, and that certain genetic conditions are associated with cognitive difficulties. Certain criteria were highlighted which, although not perfect, have solid foundations. A theory of intelligence must thereby be capable of accounting for the ontogeny, phylogeny, and psychopathology of this phenomenon while also being compatible with data emerging from biology, neuroscience, and genetics. Table 11.1 offers a synthesis of the analyses made by Cornoldi (2007) in order to compare the capacity of different cognitive constructs in explaining BSI specificities that can be found in different groups of individuals. No construct seems completely adequate, nor is clear evidence available for each slot, but working memory best fits with the overall pattern of data.

### Intelligence and Atypical Development

As anticipated, the study of psychopathological profiles associated with cognitive deficits, emerging in the context of failures to life adaptation, offers the possibility of testing the theoretical constructs lying at the heart of our view of intelligence, both considering BSI and UI. In the developmental field, different disorders may offer important information for the development of a theory of intelligence. In particular, the presence of specific disorders, as is particularly evident in learning disabilities (e.g.,

**TABLE 11.1. Capacity of Different Constructs of Explaining the Basic Structure of Intelligence with Reference to Differences between Humans and Animals (A), Typical Development (TD), Mental Retardation (MR), Learning Disabilities (LD), Aging Impairment (AI), Giftedness (G), Biological Evidence (BE)**

	A	TD	MR	LD	AI	G	BE
Speed of processing	—	*	*	—	**	*	*
Executive functions	**	*	*	*	**	**	
Learning capacity	—	—	*	—	**	*	—
Temporary memory	—	**	*	—	*	*	
Working memory control	*	**	**	*	**	**	**
Metacognition	**	**	*	—	*	**	—

*Note.* A, differences between humans and animals; TD, typical development; MR, mental retardation; LD, learning disabilities; AI, aging impairment; G, giftedness; BE, biological evidence; \*\*, strong evidence in favor; \*, evidence in favor; —, contrasting evidence. Data from Cornoldi (2007).

developmental dyslexia) and in some neuropsychological dissociations, shows that intelligence cannot be considered as unitary, but rather articulated in a series of semi-independent abilities. However, the fact that these abilities do not have the same critical importance and overlap to different degrees of support the existence of an interconnected hierarchical intelligence system. Finally, the fact that some children, despite good BSI, fail in an impressive series of relevant everyday situations, or that, despite having equal levels of IQ, have different manifestations of intelligence, shows that BSI must be distinguished from UI.

Therefore, the present framework highlights the weakness of both the unitary and the multiple views of intelligence and includes a hierarchical organization that recognizes the existence of various forms of intelligence of differing levels of importance. However, in order to decide between different cognitive constructs candidates used to define the core of basic intelligence, as many criteria as possible must be taken into consideration. As Table 11.1 suggests, the construct of working memory control is the most adequate for explaining BSI. Indeed, the other candidates reveal some weaknesses with respect to some criteria. For example, speed of processing cannot explain why individuals with low intelligence may have high rapidity; on the contrary, individuals with specific failures, but relatively good (elderly), or average intelligence (e.g., individuals with learning disabilities), or even with high intelligence (e.g., gifted), may not have a speed corresponding to their level of intelligence.

When considering the three connected constructs of attention, temporary memory, and working memory control, the present view assumes that the most adequate explanation of intelligence must both consider

the functions of temporary maintenance and of attentional control. Indeed, for many years evidence has supported the claim that working memory is a critical factor of intelligence (e.g., Kyllonen & Christal, 1990). This conclusion has remained open to criticism. For example, the meta-analysis of Ackerman, Beier, and Boyle (2005) found an effect size corresponding to a medium correlation between IQ and working memory. However, this analysis did not consider the multiple facets of intelligence and the hierarchical organization of working memory. In fact, it is not realistic to assume that a single relatively simple cognitive system is able to explain all the manifestations of human intelligence. Thus, in the present framework, controlled working memory is not considered to overlap with intelligence, but rather to best predict the most central facets of the basic structure of intelligence. Furthermore, converging evidence shows that working memory can be distinguished in different aspects, in particular in the relatively passive processes involved in the simple maintenance of information and in active controlled processes involved in the manipulation of maintained information (e.g., Cornoldi & Vecchi, 2003; Kane & Engle, 2002; Lanfranchi, Cornoldi, & Vianello, 2004). BSI seems more directly related with active rather than with passive processes.

### **The Continuous Hierarchical Organization of Working Memory and Intelligence**

The distinction between simple maintenance processes and active controlled processes has usually been considered to be dichotomous. However, a hierarchical theory of basic intelligence based on the construct of working memory implies the need for a hierarchical model of working memory. Given the recognition that working memory (i.e., the ability to temporarily maintain and process a series of information and/or procedures) is an essential interpretative tool for the understanding of intelligence, the analysis of the hierarchical organization of working memory can be useful in understanding the hierarchical organization of intelligence. In this respect, the continuity model of working memory (Cornoldi, 1995; Cornoldi & Vecchi, 2003) seems appropriate for describing the cognitive basis of intelligence. The model assumes that working memory operations can be distinguished according to two main orthogonal dimensions, that is, content (e.g., verbal vs. numerical vs. visual vs. spatial) and active control; active control in the (vertical) dimension may vary along a continuum, moving from very passive maintenance processes (e.g., tapped by simple short-term recognition tasks) through to moderately active tasks still loading on the nature of the processed con-

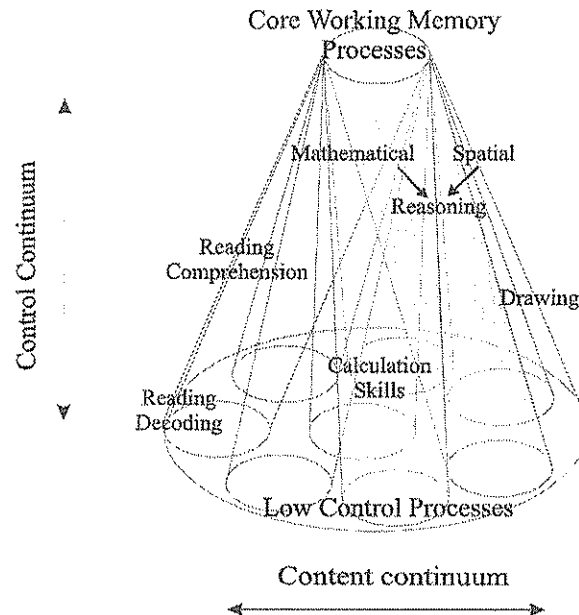
tent (e.g., backward word span, reading span tasks), to very active tasks (e.g., dual working memory tasks).

The application of the continuity model to the structure of intelligence may offer a cognitive description of classical hierarchical views of intelligence. For example, Vernon's (1961) approach to intelligence considered some aspects of cognitive functioning to be more central than others. This position was revised by subsequent psychometric analyses and approaches (see, e.g., the radix models; Marshalek, Loman, & Snow, 1983).

It is interesting to notice that, according to these views, different aspects of learning were located at different hierarchical levels. For example, Vernon (1961) and Marshalek and colleagues (1983) located reading comprehension and arithmetic reasoning at more central levels than reading decoding and arithmetic calculation. The same conclusion is reached by the present approach. Consistent with this view and the working memory control approach, reading comprehension and arithmetic calculation are strongly associated with working memory operations requiring a high level of control, whereas the other skills are associated with low control working memory operations (see Cornoldi, Carretti, & De Beni, 2001) (see Figure 11.1). Furthermore, achievement attainments are not only distinguished on the basis of the degree of control, but also on the basis of the type of content—for example, verbal, numerical, visual. Indeed, in the present approach, a single basic academic ability, for example, reading decoding, is distinguished from another basic ability, for example, knowledge of arithmetic facts, with reference to the content dimension, and is distinguished from a more controlled ability, for example, reading comprehension, with reference to the active control dimension.

### **BSI and UI**

The description of academic abilities based on a working memory model does not take into account the observation that academic abilities rely on the basic structures of intelligence, but cannot be identified with them, as they represent a form of intelligence in use largely affected by experience and education. UI cannot be identified, nor is it totally explained, by the basic structure of intelligence; otherwise the concept would be useless. As already mentioned, there is evidence that the products of intelligence can deviate from what could be predicted by the levels of basic intelligence. Older people and people with high intellectual talent can perform at an intellectual level that other people with the same basic skills cannot. The same individual, under different conditions, can produce different intel-



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FIGURE 11.1 Cognitive components mainly involved, within a hierarchical structure of intelligence, with different academic competencies.

lectual results (Mueller & Dweck, 1998). A question to be answered is why certain people with highly developed cognitive faculties are unable to exploit their talents while others with rather less developed faculties are able to do so quite successfully. Furthermore, although basic intelligence is biologically rooted and modestly modifiable (Plomin, DeFries, Craig, & Guffin, 2003), there is evidence that genius and other aspects of intellectual development can be affected by experience, education, and emotional-motivational variables.

To account for the relationship between BSI and UI, Cornoldi (2007) presents a model (see Figure 11.2; Table 11.2 offers a synthesis of the main points of the model), where the cone, representing the hierarchical organization of the BSI, is described as being affected at different levels by three main categories of variables: experience, culture-values-motivations and emotional metacognition. Experience is a necessary condition for the development of intelligence and offers direct stimulation for the development of low level skills. Indeed, lower level skills are mainly content-dependent processes that are supported by content knowledge and repeated exposure. The second component is represented

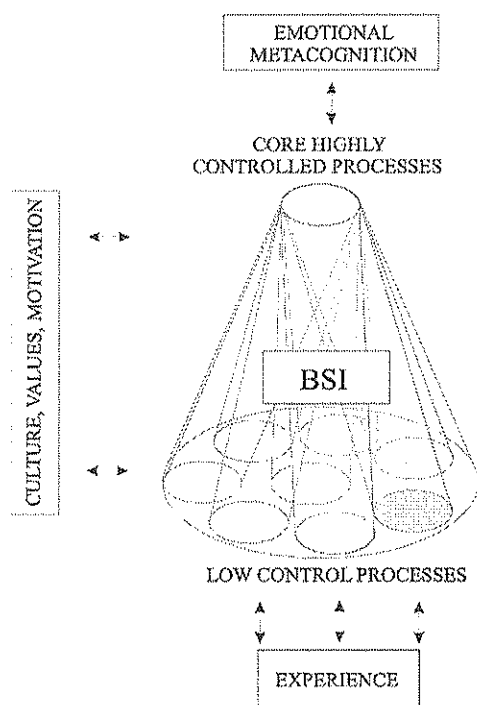


FIGURE 11.2. A contextualized model of intelligence based on metacognition and working memory control: the interaction between the basic structure of intelligence (BSI) and the three factors affecting the use of intelligence.

by a domain including culture, values, and motivation. In fact, a part of experience is socially and culturally mediated (Ceci, 1996; Vygotsky, 1978) and is acquired not only through education, but also through the immersion of an individual in a social community characterized by a particular cultural context. In this way not only knowledge is transmitted, but also an individual's values and motivation are modulated. This second component can influence intelligence at different hierarchical levels, depending on the particular case. For example, culture may influence the child's motivation to develop a great expertise in a specific skill, but can also motivate him to increase his general skills. The third component is represented by (hot) metacognition, that is, metacognition also including motivational-emotional aspects, as will be illustrated in the following paragraphs. Research on metacognition emphasizes how representations of the mind, strategies, and metacognitive control processes can actually influence the ways in which the basic structures are used. Thus, metacog-



**TABLE 11.2. Assumptions of the Metacognitive Working Memory Theory of Intelligence**

1. Intelligence in use in the real world is different from and is the consequence of basic intelligence in interaction with emotional metacognition, culture, and experience. A theory of intelligence in use must be able to explain the nature of intelligence expressions, from failures to genius productions.
2. Basic intelligence, as inferred from traditional IQ tests and other neuropsychological measures, is biologically rooted, mainly located in the prefrontal lobes.
3. Basic intelligence is adequately described by a hierarchical theory better than by the unitary and the multiple ones.
4. A theory of basic intelligence, in order to have psychological and educational implications, must give psychological meaning to its hierarchical structure.
5. A theory of basic intelligence must be able to explain exceptionality, for example differences between typically developing individuals and (a) younger children, (b) mentally retarded individuals with genetic syndromes, (c) animals, (d) gifted individuals.
6. Between the different cognitive constructs hypothesized to describe the core of human intelligence (speed, learning capacity, short-term memory, controlled attention, etc.) working memory control appears to be the most powerful and the most adequate for describing the hierarchical organization of intelligence.
7. A hierarchical model of basic intelligence founded on the notion of working memory control assumes that the functions at the low control level are less critical for intellectual functioning and are in direct interaction with experience, whereas the highest levels are the most critical and are in direct interaction with emotional and cognitive awareness of mind functioning. Culture-mediated values and experiences interact at all the levels of the hierarchical system.

*Note.* Data from Cornoldi (2007).

nitition guides the strategic and effective use of cognitive abilities while a correct cultural-motivational stance supports and reinforces the manifestation of intelligence.

On the basis of a model of intelligence including a basic component and three associated components, it is possible to make inferences concerning how intelligence can be enhanced through education. Indeed, education can affect the three associated components more easily than the BSI. Concerning the interactions between the three components and the BSI, practice and experience can enhance specific lower level abilities; positive cultural and motivational influences can affect competence in using basic cognitive structures at different levels, according to the type of accent given by the context; finally, effective metacognition is especially critical in affecting the central control processes of working memory. Consequently, if an educational effort is focused on the most central aspects of intelligence, high control working memory processes, modestly modifiable, and metacognition, more deeply modifiable, become critical.

### THE ROLE OF METACOGNITION

As discussed earlier, the role of metacognition in intellectual functioning (Hertzog & Robinson, 2004) can be better disambiguated by considering both the distinction between BSI and UI and by the fact that metacognition may imply many different aspects (Schneider, 1998). As is evident from the large body of literature produced in the field and from the various positions offered in this volume, the concept of metacognition is rather broad and can be articulated in various ways. However, a largely shared approach (e.g., Schneider & Pressley, 1989) makes a distinction between knowledge about mind functioning (we will call it “metacognitive knowledge”) and metacognitive procedures (for a conceptual discussion, see Schneider, 1998). These two components have been studied and considered either as substantially independent or strongly interconnected. Furthermore, metacognitive knowledge may be considered as a by-product of cognitive competence (e.g., Begg, Duft, Lalonde, Melnick, & Sanvito, 1989) or as a factor that has an important influence on cognitive performance via the metacognitive procedures. According to a strong metacognitive view (Cornoldi, 1998), an individual’s metacognitive knowledge is a complex system including attitudes, knowledge, and emotions concerning mind functioning, in general, and more specifically his or her own mind. Furthermore, metacognitive knowledge affects the selection and use of specific strategies and control processes, and this function affects performance.

To account for different facets of metacognitive knowledge, Cornoldi (1987) introduced the concept of *metacognitive attitude*, which concerns an emotionally positive subject’s attitude towards his or her mind and the possibility of understanding and using it effectively. The *metacognitive attitude* (Cornoldi, 1998) is a general tendency of a person to develop reflection about the nature of his or her own cognitive activity and to think about the possibility of extending and using this reflection. Cornoldi (1998) made a distinction between general metacognitive knowledge, specific metacognitive knowledge, and metacognitive attitude. He assumed that the tendency to think about a task (producing a metacognitive conceptualization of the task) and to use metacognitive knowledge (both preexisting and developed when facing the task) is affected by the metacognitive attitude. As metacognitive attitude develops with age, also the relationship between metacognitive knowledge and its application to the completion of tasks (if not automatized) develops with age, as confirmed by the fact that the correlation between specific metacognitive knowledge and cognitive behavior increases with age (see Schneider & Pressley, 1989).

### Emotional Components of Metacognition

Both the metacognitive attitude and general metacognitive knowledge (e.g., general ideas about cognitive functioning, naïve theories of intelligence, intellectual self-esteem, self-attribution) represent a mixture of cognitive and emotional aspects. In particular, the role of self-attribution has been repeatedly documented. Indeed, an effort attribution, that is, a self-attribution for the effects of effort on performance, represents a critical aspect of metacognitive knowledge and of the metacognitive attitude (in its implications for the tendency to reflect on the task and on the use of cognitively expensive strategies). For example, a method used for studying the child's self-attribution is based on questionnaires. The child is invited to give an explanation of why he failed or was successful in a particular engaging task and may choose between different factors either internal (effort, ability) or external (luck, received help, task facility). It has been shown (e.g., Pearl, Bryan, & Donahue, 1980) that children with learning difficulties also tend to give fewer effort explanations for the outcomes of their actions, especially concerning failures. The direction of this relationship could be questioned on the basis of the consideration that more successful individuals have better opportunities for developing a greater confidence in their effort. However, it has been shown that a modification of the attributional state plays a critical role in influencing the effects of a treatment (Borkowski, Carr, Rellinger, & Pressley, 1990).

### The Impact of Metacognitive Knowledge on Metacognitive Procedures and on Performance

As has already been discussed, it has been suggested that reflection cannot penetrate a series of cognitive processes (Fodor, 1983) or may be an epiphenomenon produced by the cognitive process itself (Begg et al., 1989; Kaufmann, 1996). On the contrary, in the present view, metacognition affects cognitive behavior through its influence on metacognitive procedures. For example, memory performance is affected by the specific strategies and processes the individual has decided to use, in a more or less aware way, and this decision has been affected by the subject's attitude and his metacognitive knowledge. However, this position assumes that the relationship between metacognitive knowledge and cognitive behavior is far from perfect, as the actual behavior will be influenced by a series of contextual and task constraints and by other subject's characteristics.

The relationship between different aspects of metacognitive knowl-

edge and metacognitive procedures related to self-regulation can be exemplified by a study that established the role of metacognitive factors on academic achievement of students in our university (Cornoldi, De Beni, & Fioritto, 2003). A group of 240 randomly selected students attending the second year in different faculties of the University of Padua, and assumed to represent the population of the undergraduate students at this university, were administered a series of questionnaires which respectively assessed four main metacognitive knowledge variables: the student's attitude toward the modifiability of his or her own intelligence (implicit theory) with its associated belief on the role of effort (effort attribution), his or her perception of self-efficacy (self-efficacy), and knowledge and use of study strategies (strategies). A fifth questionnaire concerned the adequate use of metacognitive procedures (self-regulation) and a final questionnaire collected information on the student's academic achievement. In order to test our model of the factors producing self-regulation we looked for the best structural equation describing the pattern of relationships between the overall variables measured. This was done using the LISREL program. We tested a series of models which described different patterns, proceeding toward the best description. Figure 11.3 shows how the final empirical model (Figure 11.3a) substantially corresponded to the hypothesized pattern of relationships between the variables (Figure 11.3b). The obtained indexes were rather satisfactory.

### **GROUP DIFFERENCES IN INTELLECTUAL FUNCTIONING AND EDUCATIONAL IMPLICATIONS**

The intelligence model proposed here can be used in trying to understand the differences between groups and the most adequate types of educational approaches. Superior performances are not the focus of the present chapter, nor were they tested by our research, but will be considered briefly as they well represent the differences between the outcomes mainly due to the BSI and those outcomes due to the critical intervening role of the three associated variables (see Figure 11.4). In fact, giftedness is typically considered with reference to high performance in IQ tests and has been shown (e.g., Johnson, Im-Bolter, & Pascual Leone, 2003; Swanson, 2006) to be highly related with the performance in high-control working memory tasks. On the contrary, biographical studies and some experimental evidence show that the attainments of people, unanimously considered as geniuses, are the result of a mixture of basic abilities, creativity, and metacognitive, emotional, motivational, and cultural influences (Runco, 1999). In a similar vein, talent can be considered

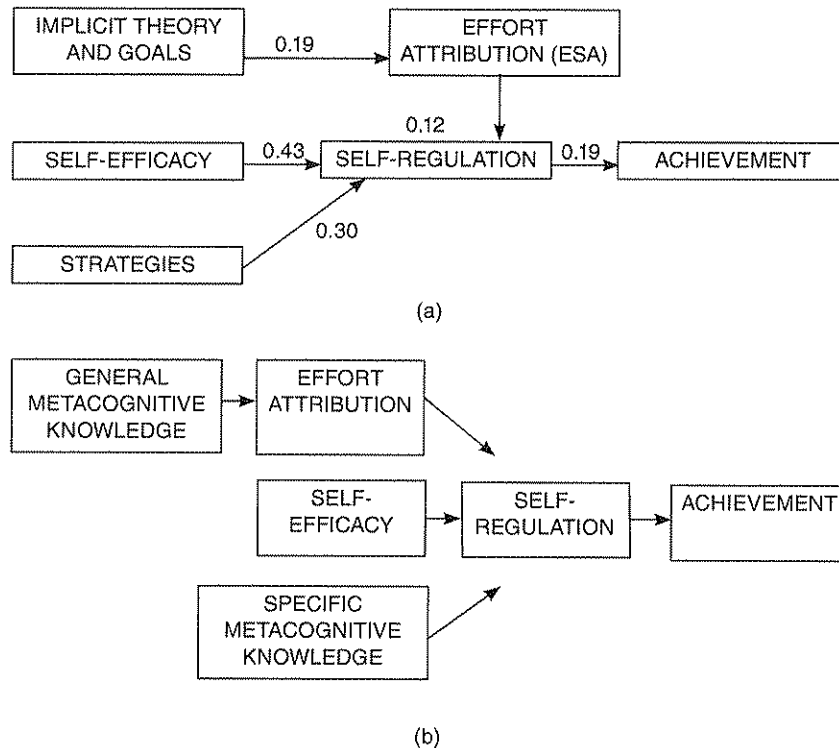


FIGURE 11.3. Example of interaction between different aspects of emotional metacognition affecting cognitive performance: (a) empirical data and (b) theoretical framework. Adapted from Cornoldi, De Beni, and Fioritto, (2003). Copyright 2003 by Emerald Group Publishing Ltd. Adapted by permission.

as a specific, probably innate, exceptional ability, whereas expertise in a particular field is probably inspired by an innate talent, but is mainly the result of an interaction between motivation, culture, and prolonged experience and practice. Finally, the superior performances reached by the so-called idiot savants could be the product of interaction between specific competence in a very low control skill and repeated specific experience (with the support of specific motivation).

Figure 11.5 describes the application of the model to the case of developmental disabilities. This application is partly the consequence of the model presented in Figure 11.1 and can be used for understanding which areas of the working memory system are mainly involved in children's weaknesses. Children specifically failing in different areas of

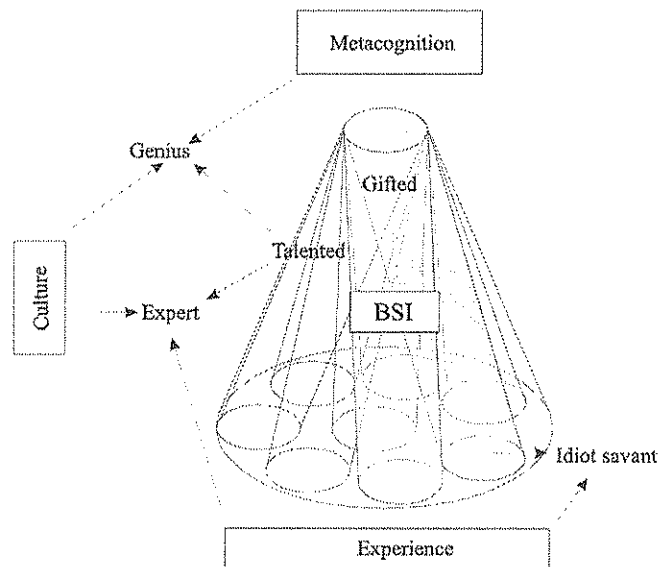


FIGURE 11.4. Components critically involved within a contextualized hierarchical model of intelligence in different types of exceptionality.

academic achievement are located in the position of the intelligence cone corresponding to the position occupied by the corresponding ability, as also confirmed by the specific working memory deficits presented by these groups (see Cornoldi & Vecchi, 2003). For example, dyslexic children are located in correspondence with low-control verbal processes; dyscalculic children are located at a relatively low level in correspondence with a different position of the content continuum. All these children are able to take advantage of specific practice in the area of weakness. Children with visuospatial (nonverbal) learning disabilities represent a rather heterogeneous group defined by the presence of specific learning difficulties in association with high verbal abilities and poor spatial abilities and can have difficulties in the visuospatial part of the working memory cone, but at different levels of the control continuum (Cornoldi & Vecchi, 2003).

### Effects of Metacognitive Training: Low-Level versus High-Level School Abilities

An assumption of the present approach is that metacognition is closer to the high-control processes than to the low-control ones, and a modification in the metacognitive state will affect the latter to a lesser extent. For

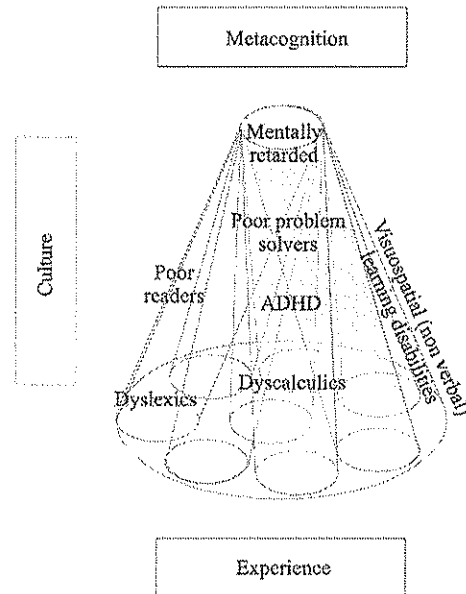


FIGURE 11.5. Typical cognitive failures within a hierarchical basic structure of intelligence in different developmental disabilities.

example, in the area of basic learning skills, it is assumed that metacognition has a greater influence on controlled processes of reading comprehension, writing expression, and problem solving, than on basic processes of reading decoding, orthography, and calculation. Decoding, orthography, and calculation are progressively automatized, offering further evidence in favor of the modest penetrability of these processes. In fact, automatization is a typical feature of low-control processes. However, a partial automatization through repeated practice also applies to high-control processes. Indeed, low- and high-control processes remain distinguishable even at equal levels of practice, as it obviously is in the case of reading which, at certain levels of learning, simultaneously involves lower and higher control skills, that is, decoding and comprehension. In general, the approach assumes that even at early stages of learning, decoding, orthography, and calculation are more affected by specific cognitive processes than by metacognition, whereas metacognition is directly involved in text comprehension, expressive writing, and problem solving both at low and at high levels of expertise. In fact, there is substantial evidence that people with good text comprehension skills also have higher metacognition (Cornoldi & Oakhill, 1997). The evidence concerning expressive writing

(e.g., Re & Cornoldi, in preparation), study skills (e.g., Meneghetti, De Beni, & Cornoldi, 2007), and problem solving (e.g., Lucangeli & Cornoldi, 1997) is less extensive, but is still in the same direction and shows that children who are more competent in academic abilities also have higher metacognition.

From an intervention point of view, the most interesting evidence concerns the effects of metacognitive training on reading, writing, and mathematics. Considering the particular case of children with reading difficulties, it is interesting to note that the effects of training may be greater for reading comprehension than for reading decoding (Swanson & Sachse, 2000). More specifically, effective programs on reading comprehension include a series of metacognitive elements.

A study that directly tested the hypothesis that metacognitive training affects higher level reading and mathematics (comprehension and problem solving), but not lower level reading and mathematics (decoding and calculation), was conducted by Lucangeli, Galderisi, and Cornoldi (1995, Study 2). In the study, 111 children, third to fifth graders, mainly with learning difficulties, were divided into a control group trained according to a traditional approach (based on practice and language skills) and an experimental group that underwent a reading metacognitive program, developing knowledge about reading, reading strategies, reading sensitivity to different texts, and monitoring skills. At the end of the program, the metacognitive group was better than the other group on a measure of reading comprehension but the two groups had a similar performance on a reading decoding test. It is interesting to notice that similar results can also be found with a metacognitive program focused on a different area. Indeed, the results were replicated by Cornoldi and Lucangeli (1996) in a study examining the effects of a metacognitive program aimed at improving children's study skills. Also in this case, the metacognitive group outperformed the other group in the controlled learning areas but not in the low-control learning areas. In a further study Lucangeli, Cornoldi, and Tellarini (1998) examined the effects of a metacognitive program focused on mathematics (enhancing metacognitive knowledge, attitude, and procedures) on primary school children. In one study (Study 2) 30 trained children outperformed the control group in logical thinking and problem solving, but not in arithmetic and geometrical information.

### **Effects of Metacognitive Training: Generalizability**

Another prediction concerning metacognitive training concerns its capacity to produce generalization effects. It is well known that training focused on a specific ability, and based on repeated practice, often fails to produce skills that are generalizable to similar skills and contexts. In the case



of metacognition, it has been shown that individuals with higher metacognition are better at transferring learned strategies to new contexts (e.g., Cavanaugh & Borkowski, 1980). This effect is consistent with the assumption that metacognition affects central cognitive functions that rely, to a lesser extent than low-control processes, on the specific content domain.

In the previously cited research by Lucangeli et al. (1995), the first study showed that children who were trained in metacognitive knowledge were better in transferring a learned strategy to a new context. In the study, both the metacognitive group and a control group were trained in the use of the alphabetical strategy, consisting in the orderly scanning of the alphabet to get a phonological cue for retrieving information. At the end of the training, the two groups obtained a similar performance in a task requiring the use of the strategy. However, when the task request was modified and thus required an adaptation of the strategy, the metacognitive group outperformed the control group. In their second study, Lucangeli et al. (1995) supported the generalization hypothesis in two ways. First it was shown that the group that underwent the reading metacognitive program was not only better than the other group in reading comprehension, but also in problem solving, whereas the two groups were similar not only in decoding but also in calculation. The same study included another group that used a metacognitive program which did not have a direct relationship, with either reading or with mathematics. In fact, this third group was administered a metacognitive program focused on knowledge about memory, actually the same program used in the first study. Results were even more exciting than for the other conditions, because the children who had worked on metamemory were better in reading and problem solving than the children who had practiced their reading and problem solving. Also the other previously mentioned study on mathematical metacognitive training (Lucangeli et al., 1998) produced a similar outcome: Indeed, the metacognitive group outperformed the control group not only in controlled mathematics but also in reading comprehension.

## CONCLUSIONS

The present chapter offers an overview of an approach to human intelligence that shows how basic cognitive structures, biologically deeply rooted, can be described and how they are affected by other variables more susceptible to modifications due to education. It is argued that controlled working memory represents the core component of basic intelligence: the relationship between intelligence and working memory

increases in correspondence with increases in the degree of attentional control of working memory, thus taking into account the hierarchical structure of intelligence.

In fact, working memory also better explains some crucial differences between groups assumed to have different intellectual abilities. In particular, individuals with mental retardation function poorly in central components both of intelligence and working memory. On the contrary, individuals with specific learning disabilities function poorly in more peripheral working memory and intelligence components. Furthermore, controlled working memory is a key construct for understanding the biological bases of intelligence associated with the development of executive functions, and there is evidence that controlled working memory training may affect fluid intelligence, probably modifying the subject's ability to use controlled processes.

In fact, basic intelligence is affected, in its use, by three main variables: experience, culture, and metacognition. Metacognition is the most critical variable as it affects the core components of intelligence. In the chapter evidence collected in our laboratory was presented to show the efficacy of metacognitive programs in improving higher level academic skills (reading comprehension and problem solving), but not lower level skills (reading decoding and arithmetic). The fact that a metacognitive approach produced important transfer effects constitutes further evidence of its role on more central, less domain-dependent effects.

In conclusion, the debate concerning the modifiability of human intelligence can be solved by distinguishing between a biologically rooted basic intelligence, somewhat modifiable, that is strictly associated with working memory, and components that make basic intelligence applicable to real-life situations. Of these components, metacognition appears particularly critical because it affects the most central aspects of basic intelligence and may directly contribute to a better capacity to control working memory operations. Another important reason for paying particular attention to the educational implications of metacognition is that usual life events and traditional cultural and educational efforts do not necessarily guarantee the development of metacognition.

## REFERENCES

- Ackerman, P. L., Beier, M. E., & Boyle, M. O. (2005). Working memory and intelligence: The same or different constructs? *Psychological Bulletin*, 131, 30–60.
- Begg, I., Duft, S., Lalonde, P., Melnick, R., & Sanvito, J. (1989). Memory predictions are based on ease of processing. *Journal of Memory and Language*, 28, 610–632.

- Borkowski, J. G., Carr, M., Rellinger, E., & Pressley, M. (1990). Self-regulated cognition: Interdependence of metacognition, attributions, and self-esteem. In B. F. Jones & L. Idol (Eds.), *Dimensions of thinking and cognitive instruction* (pp. 53–92). Hillsdale, NJ: Erlbaum.
- Cavanaugh, J. C., & Borkowski, J. G. (1980). Searching for metamemory–memory connections: A developmental study. *Developmental Psychology*, 16, 441–453.
- Ceci, S. J. (1996). *On intelligence: A bioecological treatise*. Cambridge, MA: Harvard University Press.
- Cornoldi, C. (1987). Origins of intentional strategic memory in the child. In B. Inhelder, D. De Caprona, & A. Cornu-Wells (Eds.), *Piaget today* (pp. 183–201). Hillsdale, NJ: Erlbaum.
- Cornoldi, C. (1995). La memoria di lavoro visuo-spaziale. In F. Marucci (Ed.), *Le immagini mentali* (pp. 145–181). Rome: La Nuova Italia Scientifica.
- Cornoldi, C. (1998). The impact of metacognitive reflection on cognitive control. In G. Mazzoni & T. O. Nelson (Eds.), *Metacognition and cognitive neuropsychology* (pp. 139–159). Mahwah, NJ: Erlbaum.
- Cornoldi, C. (2006). The contribution of cognitive psychology to the study of human intelligence. *European Journal of Cognitive Psychology*, 18, 1–17.
- Cornoldi, C. (2007). *L'intelligenza*. Bologna: Il Mulino.
- Cornoldi, C., Carretti, B., & De Beni, R. (2001). How the pattern of deficits in groups of learning-disabled individuals help to understand the organization of working memory. *Issues in Education*, 7, 71–78.
- Cornoldi, C., De Beni, R., & Fioritto, M. C. (2003). The assessment of self-regulation in college students with and without academic difficulties. *Advances in Learning and Behavioral Disabilities*, 16, 231–242.
- Cornoldi, C., & Lucangeli, D. (1996, July 18–22). *The effects of a metacognitive study skills program on reading and mathematical skills*. Paper presented at the Memory Conference, SARMAC Symposium, Abano Terme, Italy.
- Cornoldi, C., & Oakhill, J. (Eds.). (1996). *Reading comprehension difficulties: Processes and intervention*. Mahwah, NJ: Erlbaum.
- Cornoldi, C., & Vecchi, T. (2003). *Visuospatial working memory and individual differences*. Hove, UK: Psychology Press.
- Duncan, J. (2005). Frontal lobe function and general intelligence: Why it matters. *Cortex*, 41, 215–217.
- Fodor, J. A. (1983). *The modularity of mind*. Cambridge, MA: MIT Press.
- Hertzog, C., & Robinson, A. E. (2004). Metacognition and Intelligence. In O. Wilhelm & R. W. Engle (Eds.), *Handbook of understanding and measuring intelligence* (pp. 101–123). Thousand Oaks, CA: Sage.
- Johnson, J., Im-Bolter, N., & Pascual-Leone, J. (2003). Development of mental attention in gifted and mainstream children: The role of mental capacity, inhibition, and speed of processing. *Child Development*, 74, 1594–1614.
- Kane, M. J., & Engle, R. W. (2002). The role of prefrontal cortex in working memory capacity, executive attention, and general fluid intelligence: An individual-differences prospective. *Psychonomic Bulletin and Review*, 9, 637–671.
- Kaufmann, G. (1996). The many faces of mental images. In C. Cornoldi, R. H.

- Logie, M. A., Brandimonte, G., Kaufmann, & D. Reisberg (Eds.), *Stretching the imagination* (pp. 77–118). New York: Oxford University Press.
- Kyllonen, P. C., & Christal, R. E. (1990). Reasoning ability is little more than working memory capacity? *Intelligence*, 14, 389–433.
- Lanfranchi, S., Cornoldi, C., & Vianello, R. (2004). Verbal and visuo-spatial deficits in children with Down syndrome. *American Journal on Mental Retardation*, 6, 456–466.
- Lucangeli, D., & Cornoldi, C. (1997). Mathematics and metacognition: What is the nature of the relationship? *Mathematical Cognition*, 3, 121–139.
- Lucangeli, D., Cornoldi, C., & Tellarini, M. (1998). Metacognition and learning disabilities in mathematics. *Advances in Learning and Behavioral Disabilities*, 12, 219–244.
- Lucangeli, D., Galderisi, D., & Cornoldi, C. (1995). Specific and general transfer effects following metamemory training. *Learning Disabilities: Research and Practice*, 10, 11–21.
- Marshall, B., Lohman, D. F., & Snow, R. E. (1983). The complexity continuum in the radex and hierarchical models of intelligence. *Intelligence*, 7, 107–127.
- Meneghetti, C., De Beni, R., & Cornoldi, C. (2007). Strategic knowledge and consistency in students with good and poor study skills. *European Journal of Cognitive Psychology*, 19, 628–649.
- Mueller, C. M., & Dweck, C. S. (1998). Praise for intelligence can undermine children's motivation and performance. *Journal of Personality and Social Psychology*, 75, 33–52.
- Pearl, R., Bryan, T., & Donahue, M. (1980). Learning disabled children's attributions for cognitive behaviors and failure. *Learning Disability Quarterly*, 3, 3–9.
- Plomin, R., De Fries, J. C., Craig, I. W., & McGuffin, P. (Eds.). (2003). *Behavioral genetics in the postgenomic era*. Washington, DC: American Psychological Association.
- Re, A. M., & Cornoldi, C. (in preparation). *Metacognition and expressive writing in ADHD*.
- Runco, M. A. (1999). A longitudinal study of exceptional giftedness and creativity. *Creativity Research Journal*, 12, 161–169.
- Schneider, W. (1998). The development of procedural metamemory in childhood and adolescence. In G. Mazzoni & T. O. Nelson (Eds.), *Metacognition and cognitive neuropsychology* (pp. 1–21). Mahwah, NJ: Erlbaum.
- Schneider, W., & Pressley, M. (1989). *Memory development between 2 and 20*. New York: Springer-Verlag.
- Swanson, H. L. (2006). Cognitive processes that underlie mathematical precociousness in young children. *Journal of Experimental Child Psychology*, 93, 239–264.
- Swanson, H. L., & Sachse, L. (2000). A meta-analysis of single-subject-design intervention research for students with LD. *Journal of Learning Disabilities*, 33, 114–136.
- Vernon, P. E. (1961). *The structure of human abilities*. London: Methuen.

- Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.
- Wilhelm, O., & Engle, R. W. (Eds.). (2005). *Handbook of understanding and measuring intelligence*. Thousand Oaks, CA: Sage.