Cognitive Development and Information Behavior

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Inasmuch as information behavior (IB) is a pervasive and important aspect of people’s lives, it is somewhat surprising that researchers in the field of cognitive development (such as the present author) have not conducted many studies of IB, nor have they developed specific theories to explain or predict age differences in the tendencies to seek, interpret, or use information. The few studies that have explored possible age differences in IB have been conducted primarily by scholars in the IB field, who tend not to have extensive training in cognitive developmental theory. This unfortunate disjunction between the two fields of cognitive development and IB, combined with the limited number of age comparisons of IB, means that it is not possible to write a traditional developmental review in which one summarizes a large body of studies, explains age changes in terms of theoretical constructs, and proposes a set of guidelines for practitioners that are firmly rooted in a reliable empirical and theoretical base. As a result, a different approach has to be taken. Several alternative approaches include: (1) appealing to general theories of cognitive development that can be applied to any domain including IB (e.g., Piaget’s theory, Vygotsky’s theory, and so on), or (2) describing well-established age trends in the components of cognition (e.g., knowledge, working memory, etc.) and considering whether age changes in these components would be likely to lead to age changes in IB.

The latter approach is adopted in this chapter for two reasons. The first is that domain-general theories no longer predominate in the field of cognitive development and appealing to them would send the false impression to IB researchers (and other readers of this book) that these theories are widely espoused and utilized by mainstream developmentalists. The second is that these theories are too general to provide adequate guidance to IB researchers regarding what to expect when individuals of various ages are placed in a context conducive to IB. Thus, instead of organizing my cognitive developmental analysis by theory, I organize it by cognitive component and discuss general theories only when they have something to say about particular components. In what follows, I not only describe
the nature of each component of cognition, but also consider whether age changes in these components might precipitate age changes in IB.

**What is Cognition and How does it Develop?**

As Bjorklund (2011) notes, the term cognition is used to refer to aspects of the mind that play a central role in the acquisition, modification, or manipulation of knowledge in particular contexts. Examples of these aspects of mind include language, memory, concepts, and reasoning. When researchers study the development of cognition, they often focus on age-related quantitative and qualitative improvements in children’s language, memory, and so on. In what follows, I describe age changes in aspects of cognition that are likely to lead to age changes in IB. For expository purposes, it is useful to organize the discussion around whether the components reflect structural aspects of cognition or functional aspects.

**Age Changes in Structural Aspects of Cognition**

In a structural analysis of some physical or mental system, the focus is on the component parts of the system and how the parts are organized and interrelated. In a functional analysis, in contrast, the emphasis is on activities, operations, and processes within the system that are implemented to achieve certain goals (Byrnes, 1992). The structural and functional perspectives within some domain are intrinsically related to each other because the component parts both determine and place constraints on the way the system can carry out tasks or operations. For example, the fact that the human heart has several kinds of chambers arranged in a particular way (a structural analysis) determines how blood can circulate through the body (a functional analysis). In the case of cognition, there are three structural features that subtend, constrain, or direct the performance of mental processes and behaviors: knowledge, processing capacity, and affective orientations. When people have more knowledge and
more processing capacity, they can perform a wider array of mental tasks and carry out these tasks more accurately and efficiently. Affective orientations such as interest and values are primarily involved in determining the choices people make and the level of attention and effort allocated to specific kinds of information and tasks. In what follows, age changes in these three structural aspects are summarized in turn.

Age Changes in Knowledge. A number of studies have revealed that knowledge is not stored in the human mind as a large mass of isolated ideas. Rather, knowledge is organized along specific distinctions, kinds, or categories (Gelman, 2009). For example, one basis for organization is content domain (e.g., mathematics, science, history, music, etc.). Most people have varying levels of expertise in different domains and their knowledge in one domain may have little bearing on their knowledge and performance in another domain. The claim that cognition is domain-specific is supported by many traditional studies in the field of psychology, and also by studies conducted by neuroscientists and evolutionary psychologists in the sense that cognitive skills within domains cluster in specific regions of the brain (Byrnes, in press; Barkow, Cosmides, & Toomey, 1992).

Within each content domain, moreover, elements of an adult’s knowledge can be classified as being of one of three types: declarative, procedural, or conceptual (Byrnes, 2008). Declarative knowledge, or “knowing that,” is knowledge of facts in each domain (e.g., that 9 is the answer to $3 \times 3 = ?$; that Harrisburg is the capital of the state of Pennsylvania in the U.S.; that hydrogen is the first element of the periodic table; etc.). In contrast, procedural knowledge, or “knowing how,” is knowledge of actions, procedures or strategies that can be implemented to achieve a goal or solve a problem (e.g., how to search for information on the Web; how to add two fractions; how to fry an egg; how to ride a bike, etc.). Many educators and employers have bemoaned the fact that students often know their facts and procedures in particular domains, but are incapable of higher level problem solving and creativity
because they do not understand what they are doing. The third kind of knowledge, *conceptual knowledge*, helps to counteract the limitations of rote learned facts and procedures. It might be called “knowing why” because it reflects a deeper understanding of why facts are true and why procedures must be carried out in certain ways (e.g., why Harrisburg was selected as the capital, why the least common denominator method must be used to add fractions, and so on). Once again, the distinctions among declarative, procedural, and conceptual knowledge have been supported by both traditional psychological and neuroscientific studies (Byrnes, in press).

In addition to arguing for these distinctions, however, psychologists have created productive lines of research in which they specialize in characterizing and elaborating on the nature of one of these kinds of knowledge. For example, some have found it especially useful to elaborate on a specific kind of procedural knowledge that comes to play in recurring, culturally-defined contexts. All cultures have in common the tendency to create participatory structures for events such as birthday parties, religious services, trips to the post office, and so on, in which people in each culture know how to behave and what to expect (Nelson, 1986). To illustrate, consider the case of the so-called “restaurant script” (or more formally, an *event representation* for restaurants). Most citizens of the United States expect that when they first enter a restaurant, they will be greeted by a hostess who will first ask, “How many?” She will then select the corresponding number of menus, and escort them to a table. Soon, a waiter or waitress will appear and ask if they want drinks. Eventually they order a meal, begin to eat, and the waitress returns and asks how the meals are. The event continues with other sub-steps and ends when the couple pays the bill and leaves. Comparable descriptions could be made for a variety of other events such as weddings, university lectures, and so on. The scripts sometimes vary within subcultures of a population and across cultures. In some European countries, for example, there are no hostesses, couples seat themselves, and diners share tables in restaurants.
Besides the distinctions among content domains and types of knowledge, two other features of an adult’s knowledge base that influence their behavior and thinking include its associative structure and hierarchical structure. The associative structure derives from the fact that items of information or elements of experiences tend to co-occur (Anderson, 2009). For example, in the same recurring situations, a person’s face often co-occurs with his or her name being said. Or, a teacher may repeatedly ask a class, “What is 3 x 3?” and the class responds as a group “9.” When items co-occur, mental representations of these items become associated in a mutually evocative relationship; that is, when one thinks of one element of the associated pair (e.g., the mental representation of a person’s face), the other member of the pair comes to mind (e.g., the mental representation of the person’s name). The ability of one member of an associated representational pair to evoke the other depends, of course, on the frequency and recency of co-occurrence. Two aspects of experience that always co-occur over many years (e.g., your grandfather and his favorite fishing hat) creates a very high likelihood of mutual evocation (see one, think of the other). If two aspects only co-occur for a short time and only for a few repetitions, items of a pair tend not to evoke each other (e.g., the name of someone you only met once). The associative structure of knowledge is true of all domains and all three kinds of knowledge.

The hierarchical structure of the knowledge base, in contrast, mainly pertains to conceptual knowledge, and within that, categorical knowledge. All domains have categories that can be subdivided into subcategories, and categories themselves are often subdivisions of their own superordinate categories (Gelman, 2009). For example, most people’s biological knowledge contains categories such as “dogs,” superordinate categories such as “mammals,” and subcategories such as “terrier.” In music, there are notes, melodies, and musical keys, as well as categories of musical styles such as classical, R&B, rock, and indie (and representative artists within these styles). Moreover, across domains, individual phenomena can be represented and understood as instances of larger principles. For example, even though one homework problem in a physics textbook contains an inclined plane and the
other includes a balance with a fulcrum, the solutions to both problems may appeal to the first law of thermodynamics (Chi, Glaser and Rees, 1982). Similarly, the mathematical principle of inversion can be instantiated through an analysis of various pairs such as subtraction and addition, or derivative and integral.

So in the ideal case, the following would be true of the knowledge base of a well-educated adult: (a) it is extensive and contains all three kinds of knowledge (declarative, procedural, and conceptual) in many domains (e.g., mathematics, science, history, music, etc.), (b) it has an associative structure that maximizes the chances that related ideas within each domain will reliably evoke each other when needed, and (c) it is characterized by a hierarchical structure in which categories of information are arranged in ways that mirror the arrangements specified in professional disciplines, and organize facts, concepts, and procedures according to general principles in the fields.

In practice, however, the knowledge base of the average, college-educated adult is certainly more extensive than a child’s but often barely meets the minimum requirements for being able to say that the average adult is conversant in particular fields (Byrnes, 2008). More often than not, adults tend to be conversant in only one or two fields, and tend to have a knowledge profile opposite to that of a “renaissance man.” In addition, national and international studies suggest that high school students and adults tend to have more declarative and procedural knowledge than conceptual, so their ability to articulate a deep understanding of fields is limited, as is their ability to show higher level forms of problem solving (Byrnes, 2008, in press). To the extent that facts and procedures are not rehearsed or utilized after the end of coursework in an area (e.g., the end of a semester in which one completes a college level history course), moreover, there is fairly rapid decay of associations that makes recall of this information difficult in as little as a year later (Anderson, 2009). Finally, adults harbor many
misconceptions about key ideas in mathematics, science, and history, and tend not to organize information on the basis of principles (see Byrnes, 2008 for a comprehensive review).

Nevertheless, many adults acquire a fair amount of expertise in one domain (usually their professional domain but also sometimes in an avocation). Studies of the development of expertise reveal the following:

• If an individual engages in 3-4 hours per day of deliberate practice of skills in some field for 10 years, and has access to more competent mentors who provide feedback on strategies and approaches that the individual does not realize are faulty, he or she often attains the level of expert. Deliberate practice involves intensive concentration, challenging oneself, and concern about improvement (Ericsson, 2003);
• Experts learn from their mistakes (they make adjustments based on recognizing errors on their own or with the help of mentors);
• Experts are characterized by their extensive amount of declarative, procedural, and conceptual knowledge in their field that is organized around general principles;
• Through their extensive practice and experience, experts develop the capacity to recognize problems and solutions very rapidly;
• Early in the development of expertise, individuals are so immersed in the performance of activities in a domain that they cannot “see the big picture” or reflect upon their performance in a metacognitive way; after years of experience solving problems, however, they develop the capacity to take a bird’s eye view of their performance;
• Experts can be contrasted with “experienced non-experts” who may have similar years of experience in some field, but do not progress as far along the expertise continuum due to factors such as (a) a lack of deliberativeness in their practice (less concern about improvement or
the need to improve; uncritical monitoring of performance), (b) lack of access to mentors with helpful advice, (c) the tendency to repeat mistakes, or (d) lower levels of aptitude in the field;

- In addition to being distinct from experienced non-experts, experts also differ from novices (beginners) in the following ways: (a) novices have an impoverished knowledge base (far fewer facts, procedures, and concepts; absence of principles), (b) novices are much slower in solving problems and recognizing situations, and (c) novices are not very metacognitive in their approach (Chi. Glaser & Farr, 1988).

Children, adolescents, and adults can be said to fall on different points of the expertise continuum for different domains. Children nearly always fall near the novice end for all domains, but adults sometimes fall near the expert end if the first bullet point above is true of them for a specific domain. Otherwise, adults may fall near the middle of the continuum or even lower. Adolescents tend to fall somewhere in between children and adults for various domains. However, a particularly potent example of the importance of experience and practice rather than age per se in the development of expertise are various studies of 10 year old children who are experts in domains such as chess or dinosaurs and solve problems and remember domain-relevant information substantially better than adults who are relative novices for the same domain (Chi, 1978; Chi & Koeske, 1983). To get a sense of this phenomenon, perhaps readers of this chapter can identify with stories of adults asking their children for help with their cellphones.

_Likely Effects of Knowledge Change on IB._ Assuming that (a) adolescents are farther along the expertise continuum than children for some search domain, and (b) adults are farther along the continuum than adolescents, how might these three age groups be expected to differ in terms of the ways in which they seek information, make sense of information, and use information? The answer would depend, in part, on the nature of the situation. Open ended, unstructured, and self-generated
tasks (e.g., a person decides on his or her own to understand the U.S. constitution better) would generally produce larger differences than highly constrained tasks provided by others (e.g., use an online encyclopedia to determine who were the most liberal of Supreme Court justices in the last 30 years). All age groups would tend to seek information to increase their knowledge rather than confirm something they already know within a self-generated search, so older and younger individuals (i.e., or more accurately, more knowledgeable and less knowledgeable individuals) would naturally tend to look for different kinds of information. In addition, studies in the expertise literature reveal that experts are more likely than novices to constrain and provide more definition to an open-ended task, which would thereby make the search more focused and efficient (Voss, Tyler, & Yengo, 1983).

But knowledge of a domain is also closely aligned with the vocabulary and conceptual structure of that domain (e.g., the main categories and hierarchical arrangement). It would be predicted, then, that individuals who are highly knowledgeable about a domain (e.g., adults) would be more likely to know the correct and most effective key words to use in a search than less knowledgeable individuals (e.g., children), and would find the information they seek more quickly and efficiently. In support of this prediction, Byrnes and Guthrie (1992) found that college students who were more knowledgeable about human anatomical and physiological systems (e.g., the digestive system) found the correct answer to questions in both a traditionally organized text (e.g., in which text on salivary glands, the stomach, and small intestine could be found in the same chapter on the digestive system), and an experimenter-created version that crossed system boundaries (e.g., in which the gall bladder, stomach, and urinary bladder were all grouped in a contrived section called “temporary storage areas”). The experimenter-created version caused particular problems for the low knowledge students. Azevedo and colleagues (e.g., Moos & Azevedo, 2008, 2009) likewise found that more knowledgeable individuals located the correct answers to open-ended prompt questions more effectively than less knowledgeable individuals when searching for information in a hypermedia environment.
Differential levels of knowledge would also lead to the prediction that more knowledgeable individuals would be more equipped to make sense of any information that they discover in their searches. As the level of difficulty of the material increases, the gap in performance between those with less knowledge and those with more should increase. Classical constructivist theories of cognition (e.g., Piaget, Vygotsky) argue that the level of understanding of 4-year-olds is qualitatively distinct from that of 8-year-olds, which is qualitatively distinct from 13-year-olds, which is qualitatively distinct from adults (Piaget & Inhelder, 1969; Vygotsky, 1978). Similar predictions would emerge from scholars who espouse expertise theory (Ericsson, 2003) and advocates of the frameworks emphasizing the theory-like nature of children and adults’ cognition (so-called “theory theory”; Carey, 2009). The primary difference among these theories is that the advocates of the more contemporary approaches believe that younger children (especially preschoolers) have more intellectual competence than Piaget or Vygotsky believed. Existing knowledge structures allow for an assimilative base for incoming information. The more abstract the content and the more it appeals to general principles, the more likely it would not be comprehended by searchers with less knowledge. So, children and adults may locate the same information, but adults would be more likely to understand it if it is complex and abstract.

It is not immediately clear whether age differences in knowledge would lead to the prediction that older searchers would be more likely to use information once it was retrieved. It would seem the key variable that predicts a higher likelihood of use is whether the searcher considers the information to have met their goals (it is useful for the original purpose). It is possible that information that is poorly comprehended could be misused (e.g., cited in a school paper as backing up an assertion when it does not; ignored entirely when it truly is the right information; etc.).

One final form of knowledge that could affect the manner in which information is sought, interpreted, or used pertains to the searcher’s understanding of the information media or resources
available. In the case of written materials, individuals who understand that a book has both a table of contents and an index, and how these components function, will utilize them more effectively than individuals who do not appreciate these components. For example, children looking up information on a particular science topic such as erosion may not know that a book has an index with an entry for erosion. They may scan chapter titles in the table of contents or scan through a book from front to back and never find the text on erosion. Similarly, individuals who do not know about internet search engines (e.g., the elderly), how they work, and how they are helpful may flounder in a similar fashion. The present author knew an elderly gentleman who loved his computer (to read the obituaries!) but did not understand the difference between applications that worked within the confines of his PC (e.g., Microsoft Word) and applications that were on the web (e.g., Google). He never understood when he was on the web and when he was not. As both of these examples suggest, the ideal combination is someone who has both the content knowledge of some domain and knowledge of the structure, features, and benefits of the medium or resource. Librarians often have highly refined versions of the latter knowledge but not necessarily the content knowledge of an expert.

Age changes in processing capacity. In addition to knowledge, a second structural aspect of the mind that can facilitate or impede knowledge acquisition and use is the processing capacity of working memory. Psychologists divide the human memory system into two components: permanent memory and working memory. Permanent memory is the storehouse of a person’s knowledge. It was referred to earlier in this chapter as the knowledge base. Working memory, in contrast, refers to “...a limited capacity system responsible for the simultaneous storage and manipulation of information during the performance of cognitive tasks” (Bayliss, Jarrold, Gunn, & Baddeley, 2003). Working memory (WM) is a concept that has supplanted the notion of short term memory (STM) in contemporary Cognitive Psychology. STM highlights the storage function but not the processing function of WM. Baddeley and Logie (1999) suggest that WM is principally involved in tasks such as comprehending and mentally
representing the immediate environment, retaining information about immediate past experiences, supporting the acquisition of new knowledge, solving problems, and formulating, relating, and acting on current goals. WM is considered a transient form of memory because information will fade from it within a few seconds if it is not maintained through rehearsal or transferred to permanent memory.

WM is assumed to contain two systems for rehearsing information and keeping it in mind in a temporary fashion. The phonological loop is used to maintain verbal information in WM by saying it to oneself over and over. For example, imagine the case in which one person gives another person her phone number but the listener cannot find a pen and paper to write it down. He may keep the number in mind by repeating it over and over. The visuo-spatial sketchpad works the same way for visual information. The existence of these two distinct rehearsal systems was originally confirmed in traditional laboratory experiments conducted by psychologists. Over the past 20 years, however, their existence has been corroborated in research using neuroimaging techniques. In particular, whereas tasks requiring spatial working memory activate regions of the right hemisphere, tasks requiring verbal working memory activate regions of the left hemisphere (e.g., Smith, Jonides, & Koepp, 1996).

Psychologists also assume that WM contains both a short-term “buffer” that temporarily holds information and a “processing space” that is utilized when information in working memory is operated on (Halford, Mayberry, O’Hare, & Grant, 1994). To understand this distinction, it is helpful to consider the following analogy. When people are engaged in a home repair project, they usually need some space to do their work (e.g., a corner of their basement, garage, or tool shed). This part of your home is like your memory’s “processing space.” Note that materials cannot be stored in the processing space of your home, because you would be unable to move about and do your project. Hence, there is also a need for space that temporarily holds materials until they can be worked on (e.g., a room or closet adjacent to the room for working on projects). The latter is like the buffer.
At one time, moreover, psychologists used to think that the phonological loop had a fixed capacity of between 5 and 9 units (e.g., "the magic number 7"; Miller, 1956). Thus, if someone has a "span" of, say, 7 units and she heard someone call out 6 letters (one at a time), she could recall all 6 of them. In contrast, if this person heard someone call out 12 letters in sequence, she would probably fail to remember about 5 of them. These days, we recognize that it is not the number of items per se that influences what we recall, it is how many we can rehearse before the sensory trace for each item fades that matters. For example, since we can say "wit, sum, harm, bag, top" in 2 seconds, we could recall all five of these words if they were called out. However, we typically cannot say "university, opportunity, expository, participation, auditorium" in 2 seconds, so we would probably only recall about 2 or 3 of these words (Baddeley, 1990). Interestingly, this word length effect was replicated in a study of hearing-impaired individuals who used sign language. Some signs take a longer time to perform than others. Participants recalled fewer items when lists contained time-consuming signs than when lists contained shorter signs (Wilson & Emmorey, 1998).

Baddeley likens the process of rehearsal to that of a circus performer spinning plates on top of sticks. Each time we rehearse, we "spin the plate" for that item of information to keep it going. If we have many items (e.g., 12) or items that take a lot of time to "spin" (e.g., 5-syllable words), the "plates" for those items will stop before we can keep them going. A plate stopping is analogous to a sensory trace fading.

The visuo-spatial and verbal components of working memory are said to be "slave" systems to a central executive that is thought to be responsible for (a) managing the flow of information in and out of the two slave systems through selective attention and (b) planning, monitoring, and retrieving information about specific operations to be used in a particular task. Moreover, it is thought to off-load some of its own short-term functions to the slave systems in order to free its own capacity for
performing more complex tasks (Baddeley & Logie, 1999). Studies have shown that whereas there is a
degree of domain-specificity associated with working memory related to different codes (verbal versus
spatial), there is a domain-general aspect to it that applies to any cognitive task that requires temporary
storage and attentional processing of information (Barrett, Tugade, & Engle, 2004).

Barrett et al. (2004) argue that individual differences in working memory capacity (WMC) are
extremely important because WMC relates to success on a wide variety of skills such as reading
comprehension, math problem solving, learning, cognitive inhibition, and resistance to distraction. They
suggest that the central component of WMC is the ability to control attention to activate, maintain, or
suppress knowledge representations. In a common task used to measure WMC, a person may be asked
to read a series of sentences and then recall the last word of each of the sentences. People who can
recall more of these words are said to have a larger WMC. Those students with a larger WMC perform
better in school than students with less WMC. Although some scholars have suggested that working
memory and intelligence are the same, a recent meta-analysis showed that these constructs tend to
correlate $r = .48$, which is far less than the perfect correlation of $r = 1.0$ (Ackerman, Beier, & Boyle,
2005). Thus, working memory and intelligence are related, but nevertheless distinct.

Whereas cognitive psychologists have investigated the nature of WM and its subdivisions,
developmental psychologists have studied the development of WM. With respect to the phonological
loop and the visuo-spatial sketchpad, children would not be able to utilize the phonological loop until
they develop language skills (between the ages of one and five). Of course, having this ability available
for use as a rehearsal system and actually using it in this way are two separate things. As for the visuo-
spatial sketchpad, the vast majority of studies have focused on children older than 6, though a few have
examined this component in 4-year-olds using standard sorts of spatial WM tasks (e.g., Luciana &
Nelson, 1998), and also in infants using variants of Piaget’s “A-not-B” task (Schwartz & Reznick, 1999). In
the latter (which was originally designed to be a measure of Piaget’s construct of object permanence), one successively hides an object in two locations. Young infants usually make the error of looking under the first location. By 9-months, however, infants often look under the last location. Hence, it would appear that the spatial component of WM comes “on line” earlier than the verbal component. These findings for WM in infancy are similar to those found for studies of short term memory (STM). One study found that less that 25% of 5-month-olds and 7-month-olds could hold as many as three to four items in STM. By 9-months, nearly half could hold this many items in memory (Rose, Feldman, & Jankowski, 2001). Infant memory was tested by showing a succession of four pictures to infants and seeing how many they recognized on later trials.

After the infancy period, various cross-sectional studies have shown largely linear increases with age on both verbal WM and spatial WM tasks (e.g., Luciana, Conklin, Hooper, & Yarger, 2005; Swanson, 1999). For example, Swanson (1999) reported that ten-year-olds show a greater WM span than 6-year-olds (effect size or $d = .37$), and 24-year-olds show a greater WM span than 10-year-olds ($d = .63$). Performance only started to decline after age 45. Riggs, McTaggart, Simpson, and Freeman (2006) found that the capacity of visual WM seemed to double between the ages of 5 and 10. Such age-related increases in performance reflect increases in the ability to (a) process information quickly, (b) store larger chunks of information temporarily, and (c) shift attention (Cowan, Nugent, Elliott, Ponomarev, & Saults, 1999). Using structural equation modeling, Gathercole, Pickering, Ambridge, and Wearing (2004) found good evidence for the tripartite model of WM described earlier (i.e., the phonological loop, visuospatial sketchpad, and central executive) in children as young as 6 years old. They also found large, comparable increases with age in each of these three components.

**Likely Effects of Processing Capacity Increases on IB.** How might increases in WM processing capacity lead to age differences in the manner in which information is sought, interpreted, and used?
People seek information because it helps them accomplish a goal that they have set for themselves or have been given by others (e.g., teachers). Processing capacity would only make a difference in information seeking for complex goals that require the coordination and prioritization of multiple subgoals (e.g., Klahr, 1985). For simple goals, age differences in knowledge would matter more than age differences in WM. In a related sense, WM capacity would also be important in situations in which individuals are trying to make sense of complex, multifaceted information. When the amount and complexity of information exceeds the WM capacity of an individual, they can be said to suffer from “information overload.” Inevitably, searchers resort to intentional truncation of the information to deal with the overload and make it more manageable, but this truncation will often be unprincipled and random. To truly understand and integrate a large number of items of information (e.g., on a website discussing health issues), it is important to focus on key ideas and arrange them in conceptually canonical ways. If adults are able to process the majority of items of information but children can only process a small subset of these items, age differences in use would be expected as well.

Age Changes in Affective Orientations. In addition to representing information in the form of declarative, procedural, or conceptual knowledge, the human mind assigns various kinds of affective orientations to knowledge. For example, I may know that a close friend passed away (declarative knowledge), but consider this fact upsetting and depressing (affective orientation). Or, I may find it very interesting (affective orientation) that the ancient Egyptians and Mayans used sophisticated mathematics to construct their pyramids (declarative knowledge). When psychologists refer to the affective orientation called values, they mean the assessment that the information is considered important to an individual or, more colloquially, that the individual “cares about” the information. Psychologists are not referring to the lay construct that might be championed by conservative or religious groups (e.g., “family values”; being raised with “good values,” etc.). People care about such things as being on time, having a tidy home, getting accepted into a prestigious college, their
appearance, their health, and so on. There is some overlap between the constructs of interests and values (in fact some scholars argue interest is a subcategory of values), but it is possible for people to be interested in things that really do not matter to them and are not very important in their life (e.g., celebrity gossip). Conversely, many things that are very important to a person would not be considered interesting per se (e.g., a person who obsesses about her grades in school would probably not say that the topic of good grades is interesting in the normal sense of this world).

Affective orientations probably have their largest effect on behavior when tasks are open-ended and self-generated. For example, students who really care about getting admitted to an Ivy League college in the United States might spend an inordinate amount of time searching the internet for sites devoted to tips for getting into Ivy League schools. Similarly, a spouse who finds the idea of being divorced disturbing and considers it very important to not break a marriage vow might spend a considerable amount of time looking for and reading self-help books on how to fix a troubled marriage. When given free rein, values and interests are likely to drive searches in a variety of disparate directions (unless there were a set of topics that most people rated very high on interest and importance). In contrast, when goals are assigned by others, it is likely that interest and values would mainly affect the amount of time devoted to completing the task and the level of attention allocated (i.e., low interest topics would make it hard to stay focused and not be distracted).

Adults, adolescents and children obviously care about different things. Given free rein to search, they would seek out different kinds of information and spend a different amount of time on sites if they happen to end up on the same sites or are directed to these sites through assignments. Age differences in values would also likely affect the extent to which information is used. For example, adults tend to care more about their health then younger people, so adults may be more likely to use information about unhealthy behaviors to change their behaviors than young people. A handful of developmental
studies of interests and values show that children start out reporting strong interest in a variety of topics including math and reading. Over time, however, there are fairly constant drops in interest in school-related topics, and comparable drops in the importance of many of these topics (Wigfield & Eccles, 1992), but interest in social relations and peers increases with age (Wentzel & Wigfield, 1998).

**Summary of Structural Aspects.** Knowledge, processing capacity, and values all change with age and these changes are likely to lead to age differences in the kinds of information sought, how information is interpreted, and whether information is used. However, studies of academic achievement show that knowledge explains 50-60% of the variance in knowledge growth across an academic year, processing capacity explains 10-15%, and interest and values explain an additional 10% of the variance. It is possible that a comparable ordering of importance could occur in studies of IB. That is, if adults, adolescents, and children all differ in terms of their knowledge, processing capacity, and affective orientations, these differences could collectively produce large differences in their IB but knowledge differences might be the most important or potent source of differences.

**Age Changes in Functional Aspects of Cognition**

As noted above, a functional analysis of cognition pertains to the activities, operations, and goal-directed behavior of people. That is, it focuses on what people do and how they reason rather than what they know. Defined as such, IB would be an example of the functional aspect of cognition because it is goal-directed. As noted earlier in this chapter, functional behaviors of any type are constrained by, or dependent upon, corresponding structural components in the same domain. For example, in order for functional memory processes such as retrieval (what is recalled in a particular situation) to operate in an optimal manner, these processes must interact with properly arranged knowledge stored in memory (including its associative and hierarchical structure). Similarly, in order for people to use the memorization strategy of grouping an unorganized array of to-be-learned items into categories (e.g.,
grouping the items tree, hamburger, car, truck, ice cream, rose bush, bus, tulip, banana into the categories of plants, food, and vehicles), they have to have the categories stored in memory. When readers infer that the text, “She heard the flapping of wings under the porch and saw that the poor creature was injured,” is referring to a bird and that the female character feels sorry for it, they are basing such functional inferences on their structural knowledge base. One cannot infer that the bird is the implicit reference unless one knows that birds have wings.

As one further example of a structural-functional linkage, consider the case of decision-making. When people evaluate their options in a particular situation (e.g., what to wear to work; whether to exercise today; which applicant to hire for a job; etc.), they rely on their causal knowledge to project what will likely happen if a particular option is selected, and on their affective orientations toward these projected outcomes. Although the consequences of some decisions are not terribly serious if causal projections are wrong (e.g., if I choose the wrong tie to wear to work), some decisions are consequential (career decisions; marital decisions, etc.) and it is important that causal inferences are correct. In addition, however, decisions are also based on our assessments related to our values and emotions. Emotions and values pull us toward certain outcomes, and repel us away from others (Byrnes, 2005). For example, I may know that speeding will get me to my destination faster than driving more slowly (a causal inference), but also value my life, my driving record, and would feel guilty if caught by the police. Thus, I usually choose to not speed.

The foregoing analysis suggests that there would be a straightforward developmental relationship between changes in structural aspects of cognition and changes in corresponding functional aspects. For example, as soon as children’s knowledge becomes hierarchically arranged (it does not start out that way), children should start using the organizational memory strategy. Similarly, as soon as they have the requisite knowledge needed to support inference-making while reading, they will make the
appropriate inference. Or, as soon as they have the requisite causal knowledge and values, they will make good decisions.

It turns out that such predictions often turn out to be false. Children have hierarchically arranged knowledge well before (e.g., age 5-6) they use the grouping memory strategy (e.g., age 8-10; Bjorklund, 2011). Similarly, many studies have shown that children have the knowledge needed for inference-making while reading, but nevertheless fail to make the inferences (Paris, Wasik, & Turner, 1991). And studies of adolescent and adult decision-making show that there is often a disconnect between what people know and value, and the decisions they make in the heat of the moment (Byrnes, 2005).

How can these and related findings be explained? In many cases, such developmental delays and situational failures reflect a problem of self-regulation. Self-regulated learning (SRL) has the following attributes (Bernacki, Aguilar, and Byrnes, in press):

- **SRL is Metacognitive**, in the sense that the learner engages in effective forms of planning, organizing, task analysis, goal-setting and monitoring of progress; they understand the task and recognize their own limitations of learners;

- **SRL is Strategic**, in the sense that the learner utilizes effective domain-general (e.g., help-seeking, note-taking) and domain-specific strategies (e.g., reading strategies) that help them overcome processing limitations, overcome emotional distress, and/or promote better comprehension and retention of material;

- **SRL is Adaptive**, in the sense that the learner adjusts appropriately to changes in circumstances and demonstrates an emotional and motivational profile that is associated with achievement (e.g., a calibrated sense of ability, self-efficacy, being concerned about the right kind of things);
• **SRL is Engaged**, in the sense that the learner is focused and remains focused on learning the material and is able to avoid being distracted;

• **SRL is Self-initiating**, in the sense that learners do not need others to urge them to begin tasks, remain focused, organize themselves, use strategies and so on. They engage in self-regulatory behaviors on their own because they want to be successful and understand how these behaviors help them be more successful.

Roger Azevedo and colleagues (e.g., Azevedo & Cromley, 2004; Azevedo, Cromley, Winters, Moos, & Greene, 2005; Azevedo, Moos, Greene, Winters, & Cromley, 2008) have found in a number of studies that college students who demonstrate more of the attributes of SRL than their less self-regulated peers are more likely to locate information when placed in a hypermedia learning environment (e.g., a commercially available computerized encyclopedia). However, these studies also have found that few college students demonstrate appropriate levels of SRL on their own, but can be trained to become more self-regulated using technology-based scaffolds. Those trained in SRL strategies acquire more information and find what they need more efficiently.

Although few developmental studies of SRL have been conducted in which adults, adolescents, and children are placed in the same complex learning situation, the following trends are likely to emerge given the results of studies of individual aspects of SRL: with age, children are more likely to demonstrate higher levels of metacognition, engage in more adaptive use of strategies, initiate tasks without prodding, and resist distraction during learning (Bernacki et al, in press; Bjorklund, 2011; Byrnes, 2008). However, the differences between children, adolescents, and adults are relative rather than large per se. As noted above, many college students fail to demonstrate the kinds of SRL behaviors they need to appropriately find and make sense of information required to complete school-related tasks.
The literature documenting problems of metacognition, adaptive strategy use, self-initiation, and resistance to distraction is considerably more extensive than the literature explaining why it is that the level of SRL is not very impressive even in adults. In other words, we know that SRL increases with age and that certain kinds of technology can elicit it (Bernacki et al., in press), but we do not have definitive answers regarding why it increases, why it increases so modestly, and why individual differences exist in adult learners (why some demonstrate high levels of SRL but some do not).

We can, however, appeal to Vygotsky’s theory (1978) for clues as to likely developmental mechanisms that could promote increases in SRL. Vygotsky argued that successful development consists of the progressive internalization of skills within collaborative learning opportunities between a child who lacks the skills and someone who already has the skills (e.g., a parent, teacher, or more capable peer). Because the child starts out as a novice in a skill such as using a search engine to locate information, it is necessary for the more capable individual to be rather heavy handed in providing advice and feedback. However, as the child gains skill, it is important for the more capable individual to be less and less directive, and provide less and less structure and feedback over time. If this “fading” is implemented appropriately, the child eventually learns how to perform the skill on his or her own. In other words, the skill progresses from being completely “other regulated” at the beginning to being completely “self-regulated” at the end.

Vygotsky’s theory would predict that college students do not demonstrate a high level of SRL because their parents and teachers failed to promote SRL in the manner described. For example, parents may operate in a heavy handed way, reminding their children of deadlines, essentially doing the task for the child. Teachers may likewise walk students through the task, monitor them, and remain heavy handed. If this is the case, the removal of parent or teacher input would lead to students
floundering on their own because they never internalized the skills and never relied on their own metacognition and strategies to figure out how to proceed effectively.

Conclusions and Implications

In this chapter, I have relied on findings regarding age changes in the structural and functional aspects of cognition to speculate about the likely consequences of these age changes for IB. Although these findings on cognitive development are well-established, it would be premature to draw firm conclusions from them regarding the implications for practitioners on what to expect when children, adolescents, and adults are asked to seek information, make sense of it, or use it in particular situations. I think the predictions expressed in this chapter are certainly reasonable and many are likely to be born out, but part of the fun of conducting research is discovering that predictions can sometimes be wrong (at least for me). Thus, I would encourage researchers interested in IB to conduct the following kinds of studies:

• Create or administer credible measures of existing knowledge to groups of information-seekers who vary along the expertise continuum for some domain; correlate the level of knowledge with the IB of these groups; more expert individuals should show more facility with keywords, should rely on the hierarchical structure of knowledge in the domain to facilitate their searches, and find the information they need more efficiently than those with less knowledge; It would also be interesting to contrast true experts, experienced non-experts, novices, and expert searchers who are not expert in the domain (e.g., librarians) to see who locates and makes sense of the information fastest; given the extreme domain-specificity of expertise, it is important to conduct such studies in multiple domains to identify common patterns;

• In follow up studies, add measures of information processing capacity to determine the extent to which information overload affects IB, over and above the effects of knowledge;
• Add measures that assess the extent to which searchers consider the topic of the search interesting and important to them (and the importance of doing well on the assignment or completing it with accurate information); there are reasons to expect that knowledge, processing capacity, and affective orientations would all make independent contributions to performance; if age differences exist in knowledge, processing capacity, and affective orientations, these differences should lead to age differences in IB;

• Finally, it would be important to assess the level of self-regulation of participants since SRL has been clearly related to search behavior in college students; SRL could help to explain why searchers who have the requisite knowledge nevertheless do not engage in optimal forms of search behavior.
References


