CHC and DAS-II

Despite large areas of common agreement between CHC theorists, it is evident that the originators of CHC theory do not agree on (a) the number of factors representing independent abilities in the model or (b) the precise nature of each factor (Horn & Blankson, 2005; Carroll, 2005). Moreover, it remains open to debate whether and to what extent subtests from different test batteries that purport to measure a given factor actually do so (Alfonso, Flanagan, & Radwan, 2005).

Seven broad factors are commonly agreed as important in the CHC structure of human cognitive abilities. Each broad factor has a number of contributing first-order narrow factors, which are not shown in order to simplify the figure. Three of the broad factors are more highly related to g than others, and these factors are all represented in the DAS–II core subtests. The broad factors may be described as follows:

- Gc: Variously known as crystallized intelligence/knowledge (McGrew, 2005), crystallized intelligence (Carroll, 2005), and acculturation knowledge (Horn & Blankson, 2005). The DAS–II cluster measuring this factor is the Verbal Ability cluster. The abilities under this factor are all under the domain of language.
- Gf: Known as fluid intelligence (Horn & Blankson, 2005; Carroll, 2005) and fluid intelligence/reasoning (McGrew, 2005). The DAS–II cluster measuring this factor is the Nonverbal Reasoning cluster.
- Gv: Known as visualization and spatial orientation abilities (Horn & Blankson, 2005), broad visual perception (Carroll, 2005), and visual-spatial abilities (McGrew, 2005). The DAS–II cluster measuring this factor is the Spatial Ability cluster.
- Gsm: Known as short-term apprehension and retrieval (Horn & Blankson, 2005), general memory and learning (Carroll, 2005), and short-term memory (McGrew, 2005). There are differences between theorists in their names for this broad factor and in the specification of which narrow abilities underlie it. The DAS–II has a diagnostic Working Memory cluster that measures this broad factor.
- Glr: Known as fluency of retrieval from long-term storage (TSR) or long-term retrieval (Horn & Blankson, 2005), broad retrieval ability (Carroll, 2005), and long-term storage and retrieval (McGrew, 2005). Long-term storage refers here to a period of "minutes, hours, weeks, or longer" (McGrew, 2005, p. 154). Once again, there is some disagreement among theorists as to which primary abilities define this broad ability. The Recall of Objects subtest provides a measure of this factor.
- Gs: Known as processing speed (Horn & Blankson, 2005), broad cognitive speediness (Carroll, 2005), and cognitive processing speed (McGrew, 2005). The DAS–II cluster measuring this factor is the Processing Speed cluster.
- Ga: Known as auditory processing (Horn & Blankson, 2005; McGrew, 2005) and broad auditory perception (Carroll, 2005). The diagnostic subtest measuring this factor is Phonological Processing.

These seven factors appear to be the most robust and replicable broad factors derived from many research studies. There is less agreement between theorists on the importance of others such as reaction time (*Gt*), reading/writing ability (*Grw*) and quantitative knowledge (*Gq*). Regarding the last two, it is debatable whether factors that are so curriculum-dependent should be considered as indicators of cognitive processing.

It is interesting to note that because the development of the BAS and DAS predated the current CHC consensus on the structure of human abilities, the instrument was not developed to model the theory. Also, the inclusion of new subtests in the DAS–II measuring working memory, rapid naming, and phonological processing was primarily based on an evaluation of the importance of these factors from research unrelated to CHC theory. Nevertheless, the factor structure of the DAS–II fits the seven-factor CHC model well. This provides mutual support for the construct validity of the DAS–II and for the robustness of the CHC model.

Ability Constructs and Neurological Structures

Despite the fact that no single theory or model has universal acceptance, there is a common core of theory and research that is supportive of a number of propositions on which the development of the DAS–II was based:

- Human abilities are not explainable solely in terms of a single cognitive factor (*g*) or even in terms of two or three lower-order factors.
- Human abilities form multiple dimensions on which individuals show reliably observable differences, and which are related in complex ways with how children learn, achieve, and solve problems.
- Human abilities are interrelated but not completely overlapping, thus making many of them distinct (Carroll, 1993).
- The wide range of human abilities represents a number of interlinked subsystems of information processing.
- Subsystems of information processing have structural correlates in the central nervous system, in which some functions are distinct and dissociable while others are integrated.

The relationship between cognitive abilities and neurological systems has long engaged the discipline of psychology. It has been known for many years that there are cause-and-effect relationships; however, the nature of these relationships has not been clear. There is now much evidence that the factors measured by psychometric tests are robust across instruments and samples. It appears that these factors reflect the operation of information processing systems of the brain, and it is this reality that underlies the factors we measure. Whatever the precise location of such systems may be in the brain (and most systems probably have multiple, linked locations), the existence of these systems gives us confidence that there is a structural reality underlying the latent variables we measure.

The following section of this chapter outlines some links between the factor structure of abilities and neuropsychological systems in the areas of verbal and spatial abilities, fluid reasoning abilities, and some aspects of memory. DAS–II measures (subtests, clusters, and composites) are mapped onto this structure.

Broad verbal and visual-spatial abilities

Two of the major ability clusters in the DAS–II and other cognitive batteries reflect two major systems through which we receive, perceive, process, and remember information. These systems are linked to the auditory and visual modalities. Factorially, the systems are represented by verbal and visualization (or spatial) factors—*Gc* and *Gv* in CHC theory.

Neuropsychologically, there is strong evidence for the existence of these systems. They tend to be localized in the left and right cerebral hemispheres, respectively, although there are individual differences in areas of localization of function. Moreover, the systems are doubly dissociated—that is, they represent two distinct, independent systems of information processing (McCarthy & Warrington, 1990; Springer & Deutsch, 1989). In the DAS–II, the two factors (verbal and spatial) are measured by the Verbal and Spatial clusters in both the Early Years and School-Age batteries.

Horn and Carroll both consider that there is a separate factor of auditory processing (*Ga*) that is concerned with the analysis of sound patterns such as in speech sounds, rhythm, and sequences of sounds (Horn & Blankson, 2005; Carroll, 2005). Although such abilities certainly are related to the development of higher-order language skills such as those defined by *Gc*, they are more closely linked to the auditory system than *Gc*. It seems reasonable to suppose that they are mediated by a separate processing system that handles auditory input, and they are clearly vulnerable in cases of hearing impairment.

Integration of complex information processing

For normal cognitive functioning, the auditory-verbal and visual-spatial systems operate in an integrated fashion. Integration of the visual and auditory information-processing systems (and information from all subsystems) is probably a necessary underpinning for complex mental activity. Factorially, this integrative system is represented by the fluid reasoning (*Gf*) factor in CHC theory. It seems likely that the best measures of *Gf* require integrated analysis of both verbal and visual information. This is achieved through the presentation of visual problems that, for most efficient solution, require the individual to encode the components of the visual stimulus, and to use internal language to generate hypotheses, to test them, and to identify the correct solution.

Neuropsychologically, it seems that the integrative function of frontal lobe systems is central to executive function which is involved in planning and other complex mental processes (Luria, 1973; discussed by McCarthy

& Warrington, 1990, pp. 343–364), and it is therefore reasonable to hypothesize that it may provide a structural correlate for Gf. Similarly, it is clear that the corpus callosum has a major role in connecting the right and left cerebral hemispheres, and limitations in callosal transmission may be implicated in cases of poor visual-verbal integration. Whatever the localization of specific mechanisms may be, the fact that our brains have an integrative function seems incontrovertible. The best tests of *Gf* require that integrative process.

In the DAS–II, the *Gf* factor is measured by the Nonverbal Reasoning cluster in both the Early Years and the School-Age batteries. The subtests measuring this ability require integrated analysis and complex transformation of both visual and verbal information, and verbal mediation is critical for the solution of these visually presented problems for most individuals.

There is evidence that Gf is highly correlated with g, the higher-order general factor (Carroll, 2003; Gustafsson, 1988, 1989, 2001; Härnqvist, Gustafsson, Muthén, & Nelson, 1994). Although there are many factors at a lower order of generality that are also related to *g*, the three that have the greatest contribution to defining g are the *Gf, Gv,* and *Gc* factors. For example, Carroll states: "There is abundant evidence for a factor of general intelligence...that dominates factors or variables that can be mastered in performing induction, reasoning, visualization, and language comprehension tasks" (1993, p. 624).

The hierarchical factor analyses of the DAS standardization data by Keith (1990) provided further support for this position: at the school-age level, the subtests with the highest loadings on g were those forming the Verbal (*Gc*), Nonverbal Reasoning (*Gf*) and Spatial (*Gv*) clusters. In the DAS–II, g is measured by an overall composite, General Conceptual Ability (so named because it provides a brief description of g). Because it is estimated from only those subtests that are the best estimators of *g* (i.e., those that measure *Gf, Gc,* and *Gv*), the GCA is a purer measure of *g* than the composites of most other batteries that include all cognitive subtests in the composite, regardless of their *g* loading.

Separate verbal and visual short-term memory systems

Some cognitive tests, such as the Woodcock-Johnson III Tests of Cognitive Abilities (WJ III; Woodcock, McGrew, & Mather, 2001) represent memory by a single factor. Supporting this position, CHC theory does not distinguish at the second-order, group factor level between separate, modality-related memory systems. Proponents of the theory, however, admit uncertainty. On the one hand, Carroll (1993) included the first-order visual memory factor (*MV*) in a primarily auditory-verbal second-order short-term memory (*Gsm*) factor. On the other hand, Flanagan, McGrew, and Ortiz (2000) place MV under the second-order factor of visual processing (*Gv*). Evidence from the fields of cognitive psychology and neuropsychology shows clearly, however, that verbal and visual short-term memory systems are distinct and are doubly dissociated (Hitch, Halliday, Schaafstal, & Schraagen, 1988; McCarthy & Warrington, 1990).

The DAS–II therefore keeps visual and auditory short-term memory tasks as distinct measures and does not treat short-term memory as unitary. Visual short-term memory is represented at the Early Years level by Recognition of Pictures and at the School-Age level by Recall of Designs and Recognition of Pictures (out-of-level for ages 13:6 and older; a reliable and valid measure for older children of average to below-average ability). Auditory short-term memory is represented across the entire age range by Recall of Digits, a subtest that is a purer measure of this function than the digit span subtests of a number of other batteries. Additionally, a working memory cluster also measures the *Gsm* factor, and again this is kept separate both from the visual STM subtests and from Recall of Digits, to make interpretation clearer.

An integrative visual-verbal memory system

The long-term storage and retrieval factor (*Glr*) in the CHC model is typically measured by tests that have both visual and verbal components. McCarthy and Warrington (1990) call this visual-verbal short-term memory and conclude that it is underpinned by another distinct, dissociable information-processing system. While its relationship with other processes is relatively small, it may be an important type of gateway process underlying some types of working memory. Holding information in visual-verbal short-term memory may be necessary in order to solve a problem that requires the manipulation and transformation of an array of visual information that has verbal associations.

In the DAS–II Recall of Objects subtest, for example, an array of pictures is presented, but they have to be recalled verbally. Sequential order is not important, and the child is able to organize and associate pictures in any way that helps in remembering them.

Gc: Crystallized Intelligence

Gf: Fluid Intelligence

Gv: Visual-Spatial Processing

Gsm: Short-Term Memory

Glr: Long-Term Storage and Retrieval

Gs: Cognitive Processing Speed

Ga: Auditory Processing

Figure 2.5 Narrow and Broad Factors in Cattell-Horn-Carroll Theory

Processing speed

The CHC processing speed factor (*Gs*) is typically measured by tests that require relatively simple operations that must be performed quickly—speed of decision, speed of naming, clerical speed, and so on. These types of timed activities are more complex than those involved in reaction-time paradigms, which seem to form their own factor (*Gt*).

While individual differences in neural speed may be one of the determinants of performance on processing speed tasks, it is clear that because all *Gs* tasks require some form of additional processing, other determinants are involved. Most such tasks require visual analysis of patterns, pictures or symbols, and verbal encoding of the stimuli (either silent or spoken). Some tasks then require comparisons to be made between stimuli before a response is made. Although such tasks are not cognitively as complex as, say, reasoning problems, there is clearly some degree of processing required. Speed of response may therefore reflect not only neural speed but perhaps efficiency in accessing information, efficiency in holding information in short-term memory, and efficiency in visual-verbal integration. It seems clear that *Gs* tasks reflect underlying brain function. Performance on them is not easily improved with practice (although this is not to say that coaching on specific items would not improve performance). Prior experience on similar tasks is unlikely to be helpful. So measures on such tasks do reflect some function of the underlying speed and efficiency of processing systems.

In the DAS–II, the Gs factor is measured by the diagnostic Processing Speed cluster in children ages 5 years and older. The Rapid Naming subtest reflects speed of access to the lexicon of words in the child's long-term verbal memory. The Speed of Information Processing subtest reflects speed in making quantitative comparisons, either with numbers or non-numerically.

Theoretical developments and controversies in the area of human abilities continue. CHC theory continues to be debated. Other theories, such as the Naglieri and Das Planning, Attention, Simultaneous, and Successive (PASS) theory, Gardner's theory of multiple intelligences, and Sternberg's theory of intelligence continue to be promoted and no doubt have some devotees (Naglieri & Das, 2005; Chen & Gardner, 2005; Sternberg, 2005).

Despite this activity, or perhaps because of it, no single theory or model has or is likely to have universal acceptance. Therefore, it is probably a mistake to base a cognitive test battery on any single theory. Rather, the tasks and score interpretations of a battery should reflect a wide range of theories to accommodate users who have varying theoretical views. Applied psychologists tend to be eclectic in their theoretical stances, drawing upon various theories that appear to have relevance to the particular problems they encounter. Consistent with such a deliberately eclectic approach, the DAS–II represents to varying degrees many of the theoretical developments reviewed. However, because of the consensus on the nature of the seven CHC factors shown in Figure 2.5, and the likely demand by users of the DAS–II, subtests and composites are identified according to the narrow and broad CHC factors that they measure.

CHC Abilities Measured by DAS-II

Differential Ability Scales Second Edition

Subtest Summary

Subtest	Abbreviation	CHC Abilities		Abilities Measured
		Broad	Narrow	
Copying	Copy	*Gv*	*Vz*	Visual-perceptual matching and fine-motor coordination in copying line drawings
Early Number Concepts	ENC	*Gc/Gf*	*LD/KO/RP*	Knowledge of prenumerical and numerical concepts
Matching Letter-Like Forms	MLLF	*Gv*	*Vz*	Visual discrimination among similar shapes
Matrices	Mat	*Gf*	*I*	Nonverbal reasoning: perception and application of relationships among abstract figures
Naming Vocabulary	NVoc	*Gc*	*VL*	Expressive language; knowledge of names
Pattern Construction	PCon	*Gv/Gf*	*SR*	Visual-perceptual matching, especially of spatial orientation, in copying block patterns. Nonverbal reasoning and spatial visualization in reproducing designs with colored blocks
Pattern Construction (Alt.)	PCon(A)	*Gv/Gf*	*SR*	The same abilities for Pattern Construction without a time constraint
Phonological Processing	PhP	*Ga*	*Pc*	Knowledge of sound structure of the English language and the ability to manipulate sound
Picture Similarities	PSim	*Gf*	*I*	Nonverbal reasoning shown by matching pictures that have a common element or concept
Rapid Naming	RNam	*Gs*	*Pc*	Automaticity of integration of visual symbols with phonologically referenced naming
Recall of Designs	RDes	*Gv*	*MV*	Short-term recall of visual and spatial relationships through reproduction of abstract figures
Recall of Digits Forward	DigF	*Gsm*	*MS*	Short-term auditory memory and oral recall of sequences of numbers
Recall of Digits Backward	DigB	*Gsm*	*MW*	Short-term auditory memory and oral recall of sequences of numbers
Recall of Objects–Immediate	RObI	*Glr*	*M6*	Short-term recall of verbal and pictorial information
Recall of Objects–Delayed	RObD	*Glr*	*M6*	Intermediate-term recall of verbal and pictorial information
Recall of Sequential Order	SeqO	*Gsm*	*MW*	Short-term recall of verbal and pictorial information
Recognition of Pictures	RPic	*Gv*	*MV*	Short-term, nonverbal visual memory measure through recognition of familiar objects
Sequential and Quantitative Reasoning	SQR	*Gf*	*I/RQ*	Detection of sequential patterns in figures or numbers
Speed of Information Processing	SIP	*Gs*	*Ps*	Quickness in performing simple mental operations
Verbal Comprehension	VCom	*Gc*	*LS*	Receptive language: understanding of oral instructions involving basic language concepts
Verbal Similarities	VSim	*Gc*	*LD*	Verbal reasoning and verbal knowledge
Word Definitions	WDef	*Gc*	*LD/VL*	Knowledge of word meanings as demonstrated through spoken language

CHC ABILITIES **Broad:** ***Gv*** = Visual processing; ***Gf*** = Fluid reasoning; ***Gc*** = Comprehension knowledge; ***Ga*** = Auditory processing; ***Gs*** = Processing speed; ***Gsm*** = Short-term memory; ***Glr*** = Long-term storage and retrieval; **Narrow:** ***Vz*** = Visualization; ***LD*** = Language development; ***RP*** = Piagetian reasoning; ***KO*** = General (verbal) information; ***I*** = Induction; ***VL*** = Lexical knowledge; ***SR*** = Spatial relations; ***Pc*** = Perceptual speed, complex; ***MV*** = Visual memory; ***MS*** = Memory span; ***MW*** = Working memory; ***M6*** = Free-recall memory; ***RQ*** = Quantitative reasoning; ***Ps*** = Perceptual speed, scanning; ***LS*** = Listening ability