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The Carter Neurocognitive Assessment for children with severely compromised expressive language and motor skills

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In this paper, different means of assessing cognitive development in children with severe impairments in *both* their expressive language and their motor skills are reviewed. A range of techniques are considered, including traditional cognitive tests and behavioral and physiological measures, but these techniques are generally impractical and minimally informative when it comes to assessing children with both motor and speech impairments. Electrophysiological measures show some promise for the future, but are currently inadequate for wide-ranging cognitive assessment. Development of the Carter Neurocognitive Assessment (CNA) is described. The CNA is appropriate for use in clinical and research settings and was designed to minimalize the impact of severely impaired motor skills and expressive language on performance. The CNA is intended to itemize and quantify a range of skills reflecting a cognitive level up to approximately 18 to 24 months in four areas: Social Awareness, Visual Attention, Auditory Comprehension and Vocal Communication. The use of the CNA to assess the performance and developmental growth of eight children with Holoprosencephaly (HPE), a midline developmental brain malformation, is described. The CNA is a useful tool for the assessment of children with severely compromised motor and verbal skills and has provided a more positive view of the cognitive potential of children with severe handicaps, such as the sample of children with HPE, than that presented in the past. **Keywords:** Cognitive assessment, language impairment, motor impairment, holoprosencephaly. **Abbreviations:** HPE: holoprosencephaly; BSID–II: Bayley Scales of Infant Development, Second Edition; CNA: Carter Neurocognitive Assessment; ERP: Event Related Brain Potentials; IAR: Item Age Range; IAL: Item Age Level; ANOVA: Analysis of Variance; MIHV: Middle Interhemispheric Variant.

When confronted with the task of assessing the cognitive abilities of children with limited speech, perhaps because of dyspraxia, expressive language delay, or simply because they are still in infancy, the most informative option is often to examine sensorimotor skills. For example, many tests of cognition in infants and toddlers assess object permanence through search, symbolic skills through play, and receptive language through gestures including pointing to pictures. Alternatively, children who have a motor impairment that seriously limits their use of gestures and object play, but who have attained some degree of expressive language, can be tested in a range of areas through their language. It is very difficult, however, to assess children with a serious motor impairment who are also not speaking. There are a number of shortcomings (detailed below) in using traditional cognitive tests, even following adaptation, to test children with both motor and verbal impairments. Techniques not dependent on complex motor responses, including habituation and electrophysiological measures, can be used to assess attention, memory, and sensory processing in nonverbal infants. However, various drawbacks make these techniques impractical for the administration of a wide-ranging cognitive assessment in a typical clinical setting.

In the first section of this paper, the tools and techniques examined in the search for an appropriate assessment for children with both motor and verbal impairments are reviewed. In the second section, the resulting development of the Carter Neurocognitive Assessment (CNA, ©2001– see appendix.[1]) at the Carter Center for Neurocognitive Research at Rutgers University is described. The CNA is an experimental assessment not dependent on sophisticated motor skills or spoken language, but utilizing eye gaze, affect, and social responses as key indicators of performance. It is intended to assess skills up to a developmental level of approximately 18 to 24 months. Above that age level, adaptation of more traditional tests should be used. In the next section, the utility of the CNA is evaluated in the assessment of children with holoprosencephaly (HPE), a rare developmental brain abnormality affecting motor development as well as expressive language. Finally, the efficacy of the CNA is considered.

Review of available assessment instruments

Clinically available tests

A wide range of tests for infants and young children were surveyed in the search for an appropriate

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assessment for children impaired in both speech and motor development, including the Battelle Developmental Inventory (Svinicki, 1984), the Bayley Scales of Infant Development, Second Edition (BSID–II – Mental Scale; Bayley, 1993), the Uzgiris and Hunt Scales of Infant Psychological Development (Dunst, 1980), the Preschool Language Scale – 3 (Zimmerman, Steiner, & Pond, 1992), the Hawaii Early Learning Profile (Furuno et al., 1984), the Rossetti Infant–Toddler Language Scale (Rossetti, 1990), the Bzoch-League Receptive-Expressive Emergent Language Scale, Second Edition (Loretta, 1991), the Vineland Adaptive Behavior Scales (Sparrow, Balla, & Cicchetti, 1984), and the Reynell Developmental Language Scales (Reynell & Gruber, 1990). Although most of these tests have a few items that can be used to assess children with both verbal and motor impairment, the majority of items require motor skills that are in step with chronological age (particularly for younger children) or expressive language (for older children). An additional problem is that some items involve the use of spoken instructions even though those items are not intended to assess receptive language. Thus, any child whose language is less developed as compared to other cognitive areas may be disadvantaged.

To convey the extent to which problems are evident in conventional tests, consider a representative test often used in clinical and research settings: the BSID–II Mental Scale (Bayley, 1993). In the BSID-II Mental Scale, 12 of the 24 items typically presented to a 6-month-old are identified on the scale itself as having a substantial motor requirement; an additional item assesses use of gesture, and 3 other items assess vocalization. This leaves just 8 items that could be used to assess children with seriously impaired motor control and limited vocalizations. At 24 months, 12 of the 36 items on the BSID-II Mental Scale require a spoken response and 9 items are identified as having a significant motor component. Of the remaining 15 items, 8 require a pointing response following spoken instructions and 6 require object manipulation. This leaves just 1 item, attention to the reading of a story, available to assess children with poor motor control and undeveloped spoken language. All of the other tests examined were limited in similar ways, including those with different methodologies, such as the Vineland Adaptive Behavior Scales (Sparrow et al., 1984), which are completed by interviewing caregivers. Two of the four domains assessed in the Vineland Scales would not be appropriate because of their dependence on motor skills: the Motor Skills Domain and Daily Living Skills Domain. The Socialization Domain has 21 items aimed at an age level up to about two years; however, 7 of the items have motor skill requirements and 3 require expressive language. The Communication Domain has 22 items aimed at an age level up to about two years, separated out to obtain receptive and expressive scores. Thus, the only domain that could be fairly assessed for young children with motor and language impairment would be language, an area in which, by definition, such children would be expected to perform poorly. Furthermore, this instrument is subject to all the shortcomings of parent or caregiver report (e.g., a lack of objectivity), as well as the benefits (e.g., the caregivers' extensive periods of observation and sensitivity to their children's idiosyncratic responses).

In all fairness, most of the tests considered above were not designed for testing severely impaired children. Unfortunately, tests that are specifically designed for special populations are often intended for children with delayed motor, perceptual, *or* language skills, but not for children with delays in multiple areas. For instance, the Insite Developmental Checklist (Morgan, 1989), developed to test children with hearing or visual impairments, or both, is heavily dependent on motor skills, as is the Bayley Infant Neurodevelopmental Screener (Aylward, 1995). Furthermore, such tests often assess a limited range of skills. The Nonspeech Test for Receptive/Expressive Language (Huer, 1988) and the test for Evaluating Acquired Skills in Communication (Riley, 1991), for example, only examine language skills. One test was identified that was specifically designed to assess intelligence without requiring speech or motor skills, the Pictorial Test of Intelligence (Dilworth & French, 1990). However, this test was intended for relatively advanced children (with a mental age of 21 to 29 months), and is essentially a vocabulary assessment, requiring children to indicate by pointing or eye-gaze which of four small black and white drawings is the appropriate choice following spoken instructions. This test has several shortcomings, including the limited age-range and scope of assessment, the relatively unengaging stimuli, the requirement of advanced symbolic skills, and the interpretation of an eye-gaze response to stimuli positioned quite close together.

The lack of success in the search for an appropriate test raised the question of how children with both verbal and motor impairments are normally assessed. The combined experience of the authors, of over 50 years of clinical work in the field of speech and language pathology and neurodevelopmental assessment, as well as extensive consultation with specialists working with children with multiple disabilities, suggests that clinicians tend to use standardized tests, sometimes adapting their administration to better meet a child's abilities. Clinicians also rely heavily on caregiver reports and informal observations to describe abilities that are missed. Whether the tests are administered as intended or following adaptation various considerations arise, as outlined below.

If tests are administered in a standardized manner, children can be scored for their performance in comparison to a control group. Caution must be exercised, however, before drawing conclusions from comparisons among different groups of children, as their environmental learning experiences differ greatly. For example, early emerging vocabulary, often targeted in assessments, may differ among groups. In addition, it is very important that the scores or age-equivalents generated are not interpreted as representing children's actual levels of achievement, as impaired children may only have the potential to score on a limited number of items. Furthermore, many tests generate a single overall score and this is inappropriate for children whose performance levels vary considerably across different cognitive domains. If a child with a large scatter in performance is tested on a general test, he or she will rarely be tested to the lower threshold of skills in areas of weakness, or to the full extent of skills in areas of strength. Finally, children, caregivers, and testers often have to endure a testing session in which children are repeatedly presented with items requiring responses that the children have little hope of achieving. The negative psychological impact of such an experience for all concerned, both during the testing session and thereafter, should be avoided if possible. Nevertheless, it is sometimes necessary to assess a severely impaired child with a standardized test, for example, in order to qualify for therapeutic or educational services.

The adaptation of a standardized test can be advantageous and often results in a more positive experience for all involved. Tasks can be more flexibly administered to yield information about the child's cognitive abilities. In addition, spontaneously observed behaviors can provide important information, and caregiver report of behaviors can be considered (Dunst, 1980). Variability in item presentation invalidates any standardized scoring (Bayley, 1993; Zimmerman et al., 1992), although approximate skill levels for individual items can be generated. Note that modifying the presentation or required response of a task may significantly change the cognitive demands of the task. For instance, modifying a task from a reaching to a looking response might eliminate the need to inhibit alternative physical responses or reduce the degree of attention or compliance required (Monahan, Leevers, & Benasich, 2000). Although it may be the most promising approach, adaptation of any of the individual tests reviewed in this paper still results in few items appropriate for children with multiple disabilities. Nevertheless, the clinical and research communities tend to use this approach, with considerable duplication in the large amount of time and resources involved in preparing for an assessment.

Behavioral, physiological, and electrophysiological techniques

Children exhibiting both language and motor impairment can be viewed as having difficulty interfacing with the outside world. They are impaired in their ability to communicate their cognitive abilities through language and sensorimotor skills. Assessment techniques that bypass or minimize these impaired channels of communication can better assess cognitive abilities. These techniques, some of which are reviewed below, include the use of measures of 'looking time' to indicate processing skills, and the examination of other physiological and electrophysiological measures for evidence of discrimination and memory.

The extent of impairment across many different cognitive domains is considered by some to be relatively consistent in many severely delayed populations (e.g., Pennington & Bennetto, 1998), suggesting that a fundamental underlying skill or process critical in many domains is impaired. Candidate processes include efficiency of information processing (forming representations), memory (maintaining and retrieving representations), and attention and inhibition. These skills are thought to be reflected in infant information processing paradigms by measures of looking times to familiar and novel stimuli (e.g., rate of habituation, recognition memory, and novelty preference). Such infant information processing skills are relatively good predictors of cognitive and language outcomes in different groups of children, particularly children at high risk for delay as a result of premature birth or low socioeconomic circumstances (McCall & Carriger, 1993). Furthermore, measures of information processing can identify those infants likely to score below the normal range on intelligence tests in early childhood and are also sensitive to the presence of neurological impairment (for review see Fagan & Haiken-Vasen, 1997). However, research in this area has been most successful in identifying how processing variables relate to concurrent or future cognitive skills rather than examining indicators of individual skills in individual children. There is also a great deal of variability in how assessments are administered.

Physiological measures, such as heart rate parameters, have been examined for their potential to reflect cognitive function in children with disabilities. Roussounis and Gaussen (1987) found that heart rate measures varied in response to different stimuli, and thus demonstrated cognitive function (discrimination) in a group of motor-impaired infants typically labeled as 'hard to test'. Moreover, cardiac reactivity has been reported to relate to adaptive competence in developmentally disabled children (Tuber, Ronca, Berntson, Boysen, & Leland, 1985). Zelazo and colleagues developed the use of heart rate responses, in addition to other behavioral and physiological measures, in an information processing protocol (Zelazo, Kearsley, & Stack, 1995; Zelazo, 1997). This protocol was developed as a nonverbal clinical assessment of representational skills appropriate for children with motor limitations, low compliance, or both. Experimenters take measures of children's responses to a range of novel and familiar sequences and children are scored for their representational level by comparing their responses to those of normally developing children at a range of ages. Representational level, as assessed in this procedure, may determine the extent to which developmentally delayed children respond to intervention (Zelazo & Stack, 1997). However, this particular protocol is costly, time-consuming, and gives only an estimate of representational ability with little information concerning other skills that children may or may not possess.

The direct measurement of brain responses to different stimuli bypasses the need for external communication and therefore has good potential for assessing cognitive skills in the impaired child. Event-related brain potentials (ERPs) can be used to identify which stimuli children's brains can discriminate, and techniques can be developed to assess more sophisticated skills such as vocabulary (Byrne, Dywan, & Connolly, 1995). Many studies find ERP differences between groups of children, such as children with Down syndrome, developmental dysphasia, fetal alcohol syndrome, or mental retardation (Díaz & Zurrón, 1998; Kaneko, Ehlers, Philips, & Riley, 1996; Karrer, Karrer, Bloom, Chaney, & Davis, 1998). However, it is important to appreciate the difficulty involved in relating these brain responses directly to behavioral differences. For instance, ERPs revealed processing differences between normally developing infants and infants with Down syndrome in a visual habituation task, even though their looking behaviors appeared to be the same (Karrer et al., 1998). These techniques show great promise for the future with anticipated reduction in many factors, including cost, the need for highly specialized technicians and data analysis, and the repetitive (and therefore time-consuming) nature of administration. Much basic research still needs to be done to establish the norms of development and allow us to interpret what different ERP profiles might reflect in terms of concurrent and future cognitive and processing skills. Nevertheless, techniques that can be used to analyze performance for individual children and for individual skills are under development (e.g., Byrne et al., 1995).

All of the techniques discussed above are useful in providing evidence of cognitive skills in children otherwise difficult to assess. A disadvantage of all these techniques is that little detail is generated on the precise skills that children have and what areas might be considered their strengths and weaknesses. Work at the Carter Center for Neurocognitive Research has investigated the possibility of using a range of these techniques, including multiple habituation, associative learning, and ERP procedures, to assess individual children's performance with a wide range of stimuli (Leevers, Kinsman, Flax, Roesler, & Benasich, 2000; Monahan et al., 2000; Roesler, Flax, Leevers, & Benasich, 2001). These techniques are still evolving and, given the intensive and repetitive nature of the assessments, they are reserved for research laboratories and highly specialized clinical settings. These limitations underscore the need for a practical, informative, and easily interpreted clinical assessment for children with both speech and motor impairments.

The Carter Neurocognitive Assessment (CNA)

Goals of the Assessment

The CNA was originally developed for use with children with holoprosencephaly (HPE), a rare developmental brain malformation. Most children with HPE have severe motor impairment and little expressive language. Review of existing assessments revealed that few were practical or useful for such a group of children. Accordingly, the need was identified for a flexible assessment specifically intended for assessing children with both language and motor impairment. Although development of the CNA arose from work with children with HPE, its use could benefit any child with both language and motor impairment, for example children with cerebral palsy.

The CNA was developed with three main goals in mind: (1) to provide caregivers and professionals with information on the developmental abilities of their children; (2) to monitor changes in an individual child's abilities over time; and (3) to facilitate communication among caregivers, medical professionals, clinicians, and educators about the developmental range and abilities of different groups of children.

Design of the Carter Neurocognitive Assessment (CNA)

The CNA is reproduced in full in the appendix. It consists of 97 items that assess a wide range of cognitive skills that normally emerge from 0 to 18 months of age, with a few items at the 18- to 24-month levels of development. The items are grouped into the four scales described below.

Social Awareness (including Nonverbal Communication) includes items such as attention and response to voices (but not the content of what is said), making eye contact, smiling, joint attention, imitation, and anticipation. Included in this area are nonverbal communication skills such as making needs known or indicating 'yes' and 'no'.

Visual Attention assesses basic visual skills, including tracking and scanning, as well as more interpretive skills such as knowledge of object permanence. Such skills are often underestimated in other tests because motor responses are required, such as reaching, grasping, or pointing; in this scale many items are adapted for the use of an eye gaze response.

Auditory Comprehension (including Attention) includes all items assessing receptive language, as well as simple sound discrimination and localization. The ability to maintain attention is also assessed.

Vocal Communication is separated out from other forms of communication, which are included in the Social Awareness scale. On other tests, children often receive a low overall test score due to limited verbal skills, even though their caregivers have managed to interpret their children's nonverbal messages well. The isolation of vocal skills in this scale should prevent children with expressive language delay from scoring low in other areas. Items include the production of: communicative sounds, vowels and consonants, babbling, turn-taking vocalizations, single word approximations, and some early language forms.

A non-trivial advantage of using the CNA is that it requires minimal motor sophistication, thus, caregivers, children, and testers do not have the demoralizing experience of a testing session in which inappropriate items are repeatedly attempted and failed. There is a wide range of acceptable responses for many of the items in all four scales, and because children may not have a wide repertoire of responses, attention is paid to the context in which observed behaviors are performed. It is essential to be aware of the subtle motor movements that children are capable of performing spontaneously. Many items can be observed from spontaneous behaviors at any point during a visit or these behaviors can be directly elicited. In addition, caregiver report of responses is noted.

The CNA is designed for use with children with intact visual and auditory acuity. Further adaptations and innovations would have to be implemented to appropriately assess children with more severe sensory problems. Children who are higher functioning and require more demanding items might be able to communicate their responses through augmented communication devices or with yes and no responses to complete adaptations of traditional tests.

Administration and scoring

To administer each scale of the CNA, the examiner chooses a starting point based on information obtained from caregiver questionnaires, medical or educational records, and a brief 'warm-up' and discussion at the start of the session. Within each scale, items are listed in approximate order of sophistication. The age estimates for each item were generated by drawing from a wide range of research and standardization samples that converged on appropriate developmental milestones for normally developing children (e.g., Berk, 1997; Cole & Cole, 1993; Owens, 2001) and should only be taken as approximations. Directions for administering each CNA item are provided on the score sheet. For some items, specific requirements are listed, whereas for others there is much more flexibility.

Children receive credit or no-credit for each item and caregiver report of items is also noted. The CNA can be used as an ordinal scale to document a child's individual skills. In addition, a quantitative score can be derived for each scale. The order of administration of items is flexible; however, a child must receive credit for three consecutive items in each scale in order to achieve a basal. If a double basal score occurs (e.g., if a child receives three consecutive credits then a no-credit then three consecutive credits), consider the basal at the higher level to be the true basal. A ceiling score is achieved on each scale when five consecutive no-credits are obtained. Any incidentally observed items above or below these limits may be entered into the score sheets for additional information and it is acceptable to administer additional items, if required, to fully assess a child's limits; however, they should not be included in the raw score. Scores (and therefore basals and ceilings) can be calculated with or without credit for 'caregiver report' depending on the goals of the assessment. The number of items below the ceiling that receive credit within each scale is totaled to generate a *raw score*; all items below the basal (or any second basal) are counted as receiving credit. It is possible to convert the raw score for each scale into an *Item Age Range* (IAR) using the scoring table included on the CNA score sheet. This provides an estimate of the age range of the items for which the child received credits. It is stressed that this does *not* provide an upper age equivalence of performance for individual children. The age ranges provide a guide to the typical developmental level, in months, of skills that a particular child is demonstrating, within each scale. When reporting age ranges, care should also be taken to describe children's individual skills. Any items for which credit is received above the ceiling level can be discussed and it may be appropriate to comment on the consistency or scatter of a child's performance.

In addition to the age ranges, the table provides a discrete number, called the *Item Age Level* (IAL). The IAL is intended for use in research analyses and should not be interpreted as a score for individual children. The IAL approximates the age at which a raw score would typically be attained in normally developing children.

It should be noted that the sensitivity of each scale fluctuates depending on the number of items available at each level. Specifically, the sensitivity of the scale decreases as the age level of the items increases, with fewer items at higher age levels in all scales (although this is less marked in the Vocal Communication scale). In addition, there are few items at the 1- to 4-month level in the Auditory Comprehension scale. This is a function of the type of items that can be completed by children with both expressive language and motor impairments.

Inter-rater reliability

Because of the nature of the assessment, some level of subjectivity is involved in the scoring. Inter-rater reliability was determined by re-scoring eight testing sessions from videotape; four of these sessions were re-scored by two different scorers. All of the children whose sessions were re-scored were diagnosed with HPE and had impaired speech and motor skills (six children were classified as having semilobar HPE, one was classified as having alobar HPE, and one was classified as having lobar HPE – see below for clarification of classifications). The children were aged from 5 to 71 months, and averaged 41 months (SD = 19 months).

An average of 30.1 items were compared in the 12 sessions between the original experimenter and off-line coders: 86% of items were agreed upon (SD = 14%). An average of 20.8 items were compared in the 4 sessions between the two off-line coders: 87% of items were agreed upon (SD = 5%). The reliabilities of raw scores and IALs were also assessed for each scale in each session. Note that a subset of items could not be scored by off-line coders because they were either scored at a different point in a child's visit or because they were out of the view of the camera. This may have influenced inter-rater reliability. Nevertheless, the reliabilities were high. For the raw scores, there was a mean difference of 1.57 points (SD = 2.1) for on-line to off-line scoring ($r = .96$, $p < .0001$), and a mean difference of .88 points (SD = 1.4) for off-line to off-line scoring ($r = .98$, $p < .0001$). For the IALs, there was a mean difference of 1.23 points (SD = 1.4) for on-line to off-line scoring, ($r = .95$, $p < .0001$), and a mean difference of .59 points (SD = 1.1) for off-line to off-line scoring ($r = .98$, $p < .0001$).

Performance of children with holoprosencephaly

Development of the CNA was prompted by the need to assess children with HPE, a developmental malformation of the brain, uncommon in live births (estimated at 5–12 per 100,000) but more frequent among spontaneous abortions (1:250; Muenke & Beachy, 2001). HPE results from an incomplete cleavage of the embryonic forebrain (Cohen, 1989; Golden, 1998) that, in turn, produces incomplete separation of the cerebral hemispheres. A continuum of mild to severe brain agenesis has been observed, corresponding to the following structural classifications: lobar, semilobar, and alobar. HPE diagnoses reflect the extent to which separation has occurred, although using these categorizations is not always straightforward (Barkovich, Simon, Clegg, Kinsman, & Hahn, 2002; Cohen, 2001). Deep brain structures, such as the basal ganglia, thalamic nuclei, hypothalamic nuclei, and mesencephalon, are often involved in HPE, and thus endocrine dysfunction, temperature dysregulation, microcephaly, and cranio-facial malformations can be associated with HPE (Plawner et al., 2002). Middle interhemispheric variant (MIHV) of HPE is also diagnosed and often produces less severe symptoms (Simon et al., 2002). Children with HPE have a high mortality rate. However, approximately one-half survives beyond their first year, depending on diagnosis and the presence of cytogenic abnormalities (Croen, Shaw, & Lammer, 1996; Olsen, Hughes, Youngblood, & Sharpe-Stimac, 1997). Children typically have severe motor impairment and few develop spoken language.

The performance of eight children is described: six children were classified as having semilobar HPE, one as having alobar HPE, and one as having MIHV. Each child was assessed twice. All of the children were referred by the Carter Center for Research into HPE and Related Brain Malformations at the Kennedy Krieger Institute. They may not be representative of all children with HPE, as children judged to be too impaired to gain from the assessment may not have been referred. Nevertheless, assessment of the children described here provides unique information on what a subset of children with multiple severe impairments can achieve. It also demonstrates the usefulness of the CNA in assessing children with multiple handicaps.

Table 1 details the gender and diagnosis of each child along with the age of each visit and IALs for each scale of the CNA. Recall that the IALs are intended for research purposes and statistical comparisons. Caregivers and those working with the children would be presented with an IAR (an age range for the items credited in each scale) to aid their interpretation of performance. Children were between 9 and 63 months of age at Visit 1 (average = 36 months), and between 16 and 93 months of age at Visit 2 (average = 52 months). The range of time between visits was 7 to 29 months with a mean 16 months.

Inspection of Table 1 reveals that chronological age is not a strong guide to IAL. As expected, all of the children achieved IALs well below their chronological ages, and this was particularly pronounced in the Vocal Communication Scale. Most children improved their scores between Visits 1 and 2, although these improvements were often small. It was not possible to examine the effect of classification upon performance in this small sample, but other analyses are presented below.

Figure 1 depicts the average IAL for each scale in each visit. These data were examined by a 4×2 analysis of variance (ANOVA) with a between factor of Scale and repeated measures on Visit. The ANOVA produced main effects of Scale, $F\,(3, 28) = 13.49$, $p < .0001$, and Visit, $F(1, 28) = 14.72$, $p < .001$, and no interaction between the two. The main effect of Visit reflects the overall increase in IAL from 9.85 in Visit 1 to 12.0 in Visit 2 and the lack of interaction

Table 1 Participant details and performance shown by visit and scale

	Gender	Classification	Visit	Age	CNA Item Age Level (IAL)			
					Social	Visual	Auditory	Vocal
1	Male	Semilobar	1	9.1	6	6	8	4.5
			2	16.7	12	9	13	1.67
2	Female	Semilobar	1	19.0	12	7.5	13	6
			2	37.1	18*	13*	19*	9
3	Female	MIHV	1	23.7	10.7	9	12	14
			2	41.7	18*	13*	19*	13.3
4	Male	Semilobar	1	36.0	11.3	12	14	5
			2	62.9	11.3	18*	14	10
5	Male	Semilobar	1	36.3	10.7	13*	15	7
			2	48.4	11.3	12	17	4.5
6	Female	Semilobar	1	39.0	12	9	13	2.5
			2	47.0	11.3	11	19*	5
7	Female	Semilobar	1	60.3	12	9	12	3.3
			2	69.7	12	9	13	4
8	Female	Alobar	1	63.2	9.3	18*	14	4.5
			2	92.6	12	13*	14	4.5

Ages and IALs reported in months.
MIHV = Middle Interhemispheric Variant.
* = Score at or one item below ceiling.

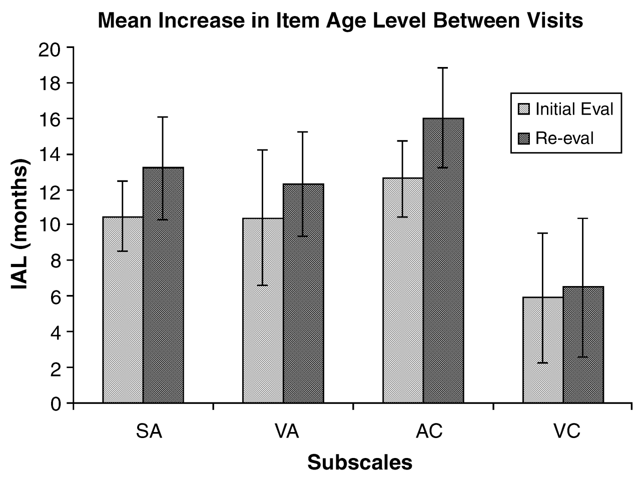

Figure 1 IAL = Item age level; SA = Social awareness; VA = Visual attention; AC = Auditory comprehension; VC = Vocal communication

shows that performance increased relatively evenly across the scales. The main effect of Scale was examined by Newman-Keuls post-hoc tests. Over both visits, the IAL for the Vocal Communication Scale (6.2) was significantly lower than that of the Social Awareness Scale (11.9), the Visual Attention Scale (11.3), and the Auditory Comprehension Scale (14.3), all $p < .001$. The higher-scoring scales did not differ from each other. The pattern of performance across the four scales was further examined by intercorrelating the IALs. Only one of the six correlations examined was significant: Auditory Comprehension and Social Awareness, $r = .74$, $p < .001$.

Every administration of the CNA was scored in two ways: (1) from performance observed in the session and (2) by also crediting caregiver report of additional items. These data were compared, averaged across visits, by a 4 × 2 ANOVA with a between factor of Scale and repeated measures on Caregiver Report (IALs calculated with or without caregiver report). The ANOVA produced main effects of Scale, F (3, 60) = 14.87, $p < .0001$, and Caregiver Report, F (1, 60) = 17.77, $p < .001$, and an interaction between the two, F (3, 60) = 3.23, $p < .05$. The main effects should be interpreted in the light of the interaction between them. This interaction was examined by Newman-Keuls post-hoc tests – with our main interest being the impact of caregiver report within each scale. In fact, inclusion of reported items significantly raised the IAL in the Vocal Communication scale only, from 6.2 to 7.8, $p < .05$. Caregivers probably reported more productive language than was observed because of the limited period of observation in the laboratory and also because the caregivers were more attuned to their individual child's way of communicating. In addition, further inquiries revealed that many of the reported vocalizations (and gestures) were situation-specific (e.g., they only occurred at bath time or with a certain family member). Note that even with the inclusion of reported items, performance on the vocal communication scale was lower than that of all the other scales, $p < .01$.

Finally, some important developmental skills that were observed are described. These specific skills are itemized on the CNA and have not been characterized in previous publications on children with HPE. All eight of the children had developed some key social skills, achieving credit for joint attention, anticipation, and social referencing. All children also used eye-gaze to successfully communicate by, for example, looking at an adult and then a toy, as a request to be given the toy. All of the children looked at pictures and showed some evidence of knowledge of object permanence, such as appreciating the persistence of objects or locating hidden objects. All of the children appeared to interpret the emotional content of what was said to them, and had developed some receptive language. Finally, all of the children were heard to produce vowel sounds and consonants, but just one child was heard to produce canonical babbling. While vocalizations were infrequent, seven children were judged to vocalize with communicative intent and three children used conversational intonation. As might be expected, only one child (diagnosed with MIHV) was observed to produce conventional words, although three additional children were reported by their caregivers to use words.

In sum, the children with HPE demonstrated a wide range of developmental skills. Although these particular children may not be representative of all children with severe developmental handicaps, they do demonstrate the potential for development in such populations. Despite their acquisition of wide-ranging skills, the children's performance was impaired in all areas assessed, particularly in vocal communication. Even if additional vocal skills reported by caregivers are taken into account, children's vocal communication lagged behind skills in other areas. In contrast to typically developing children, chronological age was not greatly predictive of children's performance. Nevertheless, most children improved their performance over time.

Discussion

The CNA provided accurate descriptions of individual children's skills in a sample of children with severe speech and motor impairment. Although the children with HPE may not be representative of all children with severe motor and speech handicaps, their performance demonstrates the potential for using a more systematic approach to assessing the neurocognitive skills in such a special needs population.

The assessment of children with HPE has provided a unique opportunity to evaluate the usefulness of the CNA by considering the extent to which it has fulfilled, to date, the three goals for which it was developed. First, the CNA provided useful documentation of individual children's performance. The ability to evaluate performance separately in each of the four different scales was especially beneficial given that performance in any one area was not generally related to performance in the other areas. In particular, low performance on items assessing vocal communication did not limit children's performance in other areas, including their non-vocal communicative abilities. Information on the performance of individuals has been shared with caregivers, therapists, and clinicians, often providing the first positive documentation of their children's skills.

Second, the monitoring of development of individuals over time was enhanced using the CNA. Eight children were evaluated twice, with an average of 16 months between assessments. Despite the relatively slow progress made in this group of children, the CNA was sufficiently sensitive to document gains across time. In the future, it is hoped that the CNA may be used as a reiterative tool to set intervention goals as a function of performance profiles in each area and then to assess the efficacy of that intervention. This is particularly important for multiply handicapped children who are not now being adequately assessed as it is difficult to set goals for intervention when a starting point cannot be defined.

Finally, the information gathered on the skills of children with HPE has already provided a wealth of new information on the potential cognitive development of children with severe multiple handicaps. In fact, the data suggest that the cognitive outcome of children with HPE can be more positive than previously envisaged. As children with other types of severe motor and speech impairments are assessed, their profiles can be compared to see whether their developmental trajectories are similar or different. It is hoped that the CNA will facilitate communication among medical professionals, clinicians, educators, and caregivers about the developmental range and abilities of different groups of children.

While performance of the children with HPE was impaired in all areas assessed, particularly in vocal communication (even when vocal skills reported by caregivers are taken into account), most children improved their performance over time. Skills that have not been observed when administering adaptations of standardized tests at this age level can be measured and monitored with the CNA, providing positive feedback and guidance to caregivers and clinicians. Thus the CNA represents a significant addition to the clinical tools available to assess young children with severe handicap. However, some caveats and methodological limitations must also be noted.

Limitations

While the CNA is useful in describing early developing neurocognitive skills observed in children with severe motor and expressive language deficits, there are specific methodological limitations to be considered. First is the issue of age approximations. The authors are aware that the lack of a standardization sample for this specific test creates some speculation regarding the validity of the actual test scores. The age estimates were generated from a wide range of research and standardization samples that converged on appropriate developmental milestones for normally developing children. It was beyond the scope of this research to test a standardization sample. Furthermore, it was not clear whether a sample of normally developing children would be appropriate for standardization, given the differing task requirements, developmental pattern and order of skill acquisition between groups of children. Thus, the CNA is useful as an ordinal scale to itemize children's skills, the age ranges are intended to aid interpretation of children's performance, and the IALs are intended to help analyze performance rather than provide actual age levels of individual children's skills.

Test–retest reliability is also a concern. The standard method for obtaining such reliabilities is not practical with the population of medically fragile children for which the test was developed. It was not possible to arrange two visits, close enough together so that children's performance would not have changed. Many of the children traveled long distances with overnight stays, accompanied by one or more family members and sometimes with therapists. An alternative would be to test children twice in the space of one extended visit, but that could result in practice effects. In either case, differences in performance may result from variability in state and fatigue common in these children. As an alternative to test–retest reliabilities, the data provided on inter-rater reliabilities were very positive. A child's best performance was obtained by administering the CNA only once when the child was in a good, alert state during their visit. Testers re-scored the same session rather than separate performances that might be influenced by other external factors, such as fatigue or irritability, causing differences in scoring that are a result of the child's state rather than the test itself.

The authors are aware that the varying density of items from scale to scale might cause fluctuations in the sensitivity. Unfortunately, this is one of the difficulties in testing such special needs populations, as there are a limited number of items that can be fairly administered. Additionally, while it may appear that a 'ceiling effect' occurred for some of the scales in the sample reported (see Table 1), recall that the intent was not to quantify an actual rate of increase but to document improvement. Scores at ceiling might signal the clinician to move to an adaptation of a conventional standardized assessment in that area.

One must keep in mind the difficulties encountered when assessing special needs populations such as the group for which this assessment was designed. The emphasis should be placed on the actual behaviors observed rather than the score itself. Further fine-tuning and refinement will occur as the CNA is used across other severely impaired populations.

Conclusions

Design of the CNA arose from the need to assess a group of children impaired in both their motor and expressive language skills. A review of existing assessments and behavioral or neurophysiological techniques revealed no appropriate instruments and thus the need to develop a new assessment tool. Use of the CNA provided a more positive view of the cognitive potential of a group of children with HPE than that described in the past. Although a recent paper has recognized the potential for more positive outcomes, reporting that some children with HPE survive into the teenage years with mild cognitive impairment and reporting the ability of a few children to use multi-word utterances (Plawner et al., 2002), none provide detail on the children's specific developmental skills. The majority of clinical and medical personnel first encountering children with multiple handicaps as severe as HPE have extremely low expectations for their performance. These low expectations may well be confirmed if the children are tested by conventional means. As more appropriate assessments are used, including the CNA, and information reaches the medical, clinical, and research communities, a more accurate perception of the potential of children with severe developmental delay should emerge.

As more experience is gathered in using the CNA to assess specific populations with severe motor impairment and expressive language delays, its usefulness, reliability, and validity will continue to be monitored. In the meantime, the CNA is provided in the appendix[2] in the hope that other clinicians and researchers will find it of real practical value in the assessment of children with severely compromised motor and verbal skill development.

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[2] Permission is granted by the authors and Rutgers University to reproduce the test protocol for clinical and educational purposes.

Medical Center, and The Kennedy Krieger Institute, Baltimore.

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Appendix: The Carter Neurocognitive Assessment

The Carter Neurocognitive Assessment

Name: ______________________ Examiner: ______________________

Caregiver: ______________________ Relationship to Child: ____________

	Year	Month	Day	History/Diagnosis: ____________
Date of Evaluation				______________________
Date of Birth				______________________
Chronological Age				______________________

Positioning	Position the child for best performance. Items might need to be presented on angled or colored surface, ask parents what works best.			
Compromising Difficulties	Describe any difficulties that might compromise performance (e.g., auditory or visual problems, side preferences, head control etc.)			
Scale	Raw Score	Item Age Range (IAR)	Item Age Level (IAL)	Comments (note range of credits, scatter, strengths/weaknesses)
Social Awareness				
Visual Attention				
Auditory Comprehension				
Vocal Communication				

General Guidelines for Presentation and Scoring

There is a wide range of acceptable responses. The examiner should be attuned to the subtle and idiosyncratic behaviors exhibited by children with physical disabilities. Because children may not have a wide repertoire of responses, attention must be paid to the context in which observed behaviors are performed. It is essential to be aware of the subtle motor movements that the child is capable of performing spontaneously.

Skills can be observed during spontaneous interactions at any point during a visit or they can be directly elicited. In addition, caregiver report of responses should be noted. Caregivers have a unique competence in understanding their children's communication patterns. A brief description of specific behaviors is helpful when reporting results (e.g., vocalizations, gestures, mannerisms, movements).

Responses often require appropriate looking behaviors/facial expressions

Other responses may include:

Eye widening or eye blink,
Change in facial expression,
Body movement or stilling,
Change in respiration, skin color or muscle tone.

Scoring:

+ = Credit
– –= No-Credit
CR= Caregiver Report
NA= Not Administered

Note that the M column on each scale provides an *estimate* of the age (in months) at which each item would be credited in typically developing children.

The starting point of each scale should be chosen based on information obtained from caregiver questionnaires, medical or educational records, and a brief 'warm-up' and discussion at the start of the session. The order of administration of items is flexible, but items should be administered until a basal and ceiling have been scored. Additional items above or below these limits may be scored for additional information, but they should not be included in the raw score.

Basal: 3 consecutive credits (if a double basal score occurs, e.g., if a child receives 3 consecutive credits then a no-credit then 3 consecutive credits, consider the basal at the higher level to be the true basal).

Ceiling: 5 consecutive no-credits.

Raw score: Tally the number of items below the ceiling for which the child received credit within each scale (all items below the basal, or any second basal, are counted as receiving credit).

Item Age Range (IAR, months): Convert raw scores to IAR by referring to table at end of protocol. IAR is an estimate of the age range of the items for which a child receives credits. This is *not* an age equivalence of performance for individual children. The age ranges provide a guide to the typical developmental level, in months, of skills that a particular child is demonstrating, within each scale.

Item Age Level (IAL, months). Convert raw scores to IAL by referring to table at end of protocol. IAL is intended for use in research analyses and should not be interpreted as a score for individual children.

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Social Awareness (Including Nonverbal Communication)

M	Score	Item, elicitation, and scoring
1		**S1. Responds in anticipation of lifting** (e.g., may increase or decrease bodily movement as adult's arms reach down)
1		**S2. Differentiates people from surroundings** (e.g., stops environmental looking and looks longer at person, or changes facial expression when looking at person)
1		**S3. Enjoys physical contact** (e.g., child calms, vocalizes contentedly, smiles, or stops crying, in response to frolic play, tickling, rocking, cuddling, or stroking)
1		**S4. Comforted by being held** (quiets or stills when upset, if picked up)
1		**S5. Responds to voice** (call or speak to child when child is not looking directly at examiner, child may look or make other response)
1		**S6. Makes eye contact** with adult (e.g., during feeding, when being rocked or held)
1		**S7. Smiles reflexively** (i.e., smiles are fleeting, not consistent)
2		**S8. Smiles or vocalizes in response to adult** attention, smile, or voice (Also credit S7)
2		**S9. Looks at a speaker's face** for at least 3 seconds
2		**S10. Discriminates strangers from familiar** caregivers (e.g., shows desire to be picked up or held by familiar persons, becomes more lively with familiar people)
3		**S11. Searches for speakers out of visual field** (e.g., have someone off to side of child call his/her name and observe if child turns to look for speaker)
3		**S12. Reacts to new situations** (e.g., quiets, cries, change in muscle tone, breathing pattern or any change in behavior following a change in environment)
4		**S13. Responds to mirror image** (e.g., smiles, vocalizes, makes eye contact)
5		**S14. Responds to still face** (approach child with still face or do not respond to child's gaze or interaction – child should look away or become upset)
6		**S15. Anticipates** an event (e.g., approach, pause and lightly tickle child with a stuffed toy or your fingers to elicit a pleasurable reaction. Repeat this sequence four (4) times. Note the child's reaction, as he/she is approached but not yet in contact with you or the toy. There should be a response to the pause in the activity, not a general increase in excitability due to the sequence.)
6		**S16. Enjoys social play** (e.g., peek-a-boo with experimenter hiding; child laughs, smiles, becomes excited)
8		**S17**. Makes **social reference** (child directs gaze from an object or environmental event, to an adult, and maybe, but not necessarily, back to object or event, as if to make a comment. Also credit S2)
8		**S18. Signals notion of acceptance, rejection or makes a request** (E.g.), Acceptance – smiles or shows excitement to indicate pleasure, enjoyment or contentment. Rejection – frowns, pouts, averts eye gaze, becomes passive, and increases body tension or rate of respiration to indicate displeasure or annoyance. Request – attention seeking signals such as looking at or reaching toward a desired object and making a social reference to request object/action. Credit if child vocalizes with intention to communicate - see C17. Do not credit if child only indicates acceptance/rejection of food when being fed.)
9		**S19. Attempts to imitate** any gesture or bodily movement within child's repertoire (e.g., hand opening, waving – not facial expressions or vocalization)
10		**S20. Makes joint attention following point**, head direction, gaze, and verbal cue (look and point to a place about 15° to left of child's midline and verbally direct gaze, "look, over there", if child does not look, repeat to the right of midline. Credit if child follows direction once. Can be observed incidentally when presenting pictures.)
10		**S21. Shows emerging control** over interactional situations - behavior ceases when goal accomplished (manipulative crying; indicates a desire for a change in activities through vocalization or actions, such as closing eyes, turning away; resists removal of a toy)
10		**S22. Participates in a turn-taking routine** (e.g., peek-a-boo or knocking down block tower, reciprocal vocal play, would need to anticipate caregiver response and repeat, i.e., both adult and child must take two turns each. Also credit S16)
12		**S23. Repeats action** if laughed at or praised (The action should be one that occurs spontaneously or incidentally and when the caregiver reacts, the child should repeat the initial action.)
12		**S24. Makes joint attention following head direction**, gaze, and verbal cue (look but do not point to a place about 15° to left of child's midline and verbally direct gaze, "look, over there", if child does not look, repeat to the right of midline. Credit if child follows direction once, can be observed incidentally. Also credit S20)
12		**S25. Indicates no** (ask caregiver for response, can try to elicit by presenting something and asking if child wants it. e.g., turns head away, closes eyes)
14		**S26. Indicates yes** (ask caregiver for response, can try to elicit by presenting something and asking if child wants it. e.g., nods head, looks up)
18		**S27. Attends to nursery rhyme**, nonsense rhyme, or poetry (e.g., Humpty Dumpty, Baa Baa Black Sheep, Jack & Jill; voice can be rhythmic, but not singing, should not use actions or finger play; examiner can read from book, but child should not be allowed to look at pictures.)

Visual Attention

M	Score	Item, elicitation, and scoring
1		**V1. Turns eyes toward light** source (flash or turn on penlight within child's field of vision)
1		**V2. Visually explores environment** – looks around new room
1		**V3. Looks at object** (suspend an object, such as a tennis ball or small toy, 8 inches in front of child while standing out of view, can jiggle it to get attention, see if child sustains gaze)
1		**V4. Tracks moving person or object** (use any object that interests the child, e.g., toy, light, face)
1		**V5. Horizontal tracking** (suspend object, such as a tennis ball or small toy, in front of child while standing to the side, can jiggle it to get attention, slowly move to left then right, then back to mid-line. Credit if child's eyes follow object in both directions - can attract child's attention back to object. Can repeat twice if necessary. Also credit V3, V4)
1		**V6. Vertical tracking** (as above, but moving from middle of chest, up to forehead, and back. Also credit V3, V4)
2		**V7. Circular tracking** (as above, but moving object in vertical circle about a foot wide. Also credit V3, V4)
2		**V8. Looks at** 1 inch **block** (attract attention to cube on table and see if child sustains gaze)
2		**V9. Reacts when face** (can be caregiver) quickly **moves out of view** (when child had been looking at it)
3		**V10. Alternates glance between 2 objects** (present 2 objects in child's field of vision simultaneously, credit if child alternates glance between objects. Can score from picture presentations.)
4		**V11. Attends to small visual detail** (e.g., looks at small object (about 1 mm in size) such as a grain of rice or piece of fluff. Can try to attract child's gaze)
4		**V12. Reacts to disappearance of object** (hold small, bright object in front of child, move around so that child tracks it and then move it behind a plain screen. Repeat on other side if necessary. Credit if child fixates on point of disappearance)
5		**V13. Looks at drawing** (credit if child watches you doodle)
5		**V14. Anticipates location of fallen object with auditory cue** (attract attention to keys and then knock off edge of table onto a hard surface so that they make a noise, credit if child looks for fallen object, do not cue child by looking or pointing)
6		**V15. Maintains attention** to a person or an object for **1 minute** (using toy or book engage child in simple play activity, or child can play independently, not watching video)
6		**V16. Vocalizes or shows excitement in response to animated toys** (e.g., activate a wind-up mobile, busy box, pull toy, wind-up toys or spin top and observe child's reaction. Keep your verbalizations and vocalizations to a minimum. Child should not just be watching but show signs of excitement, such as flushed cheeks, vocalization, and smiling)
6		**V17. Looks at pictures** (hold open picture book for child and watch line of gaze)
9		**V18. Looks for object** (place a small toy under a cup, call child so that he or she shifts gaze from cup, ask, "Where is it?" if child does not look, reveal toy and repeat item. Can use food like goldfish or cheerios)
9		**V19. Looks for object in 1 of 2 places** (hide object under 1 of 2 cups, call child so that he or she shifts gaze from cup, ask, "Where is it?" look in cup which child looks at, show correct place if necessary, repeat twice. Child must look correctly to left and right. Can use food like goldfish or cheerios. Also credit V18) Left______ Right_______
11		**V20. Visually anticipates path** (slowly move suspended object in circle around head up to 3 times; child needs to disengage gaze and move it to where object will reappear. Also credit S15, V3 & V4)
12		**V21. Looks for object** under **reversed** cups (as with V18, but after hiding object reverse cups, making sure child observes reversal. Child must successfully look when object is reversed on the left and the right. Also credit V18) Left______ Right_______
13		**V22. Looks for object** after **visible displacement** (as with V18, but after hiding object, reveal it and hide it again under other cup, making sure child observes switch. Child must successfully look when object is switched to the left and the right. Also credit V18). Left______ Right_______
18		**V23. Maintains attention** to a person or an object for **3 minutes** (using toy or book engage child in simple play activity, or child can play independently, not watching video. Also credit V15, V23)

Auditory Comprehension (Including Attention)

M	Score	Item, elicitation, and scoring
1		**A1. Responds to sounds** (e.g., startles to loud noise, activity arrested when approached by sound, quiets to sound or voice, looks around)
1		**A2. Discriminates** between sounds (after getting used to and ignoring one sound reacts to another sound, e.g., rustling plastic bag, shaking keys, whistling, rattle etc.)
4		**A3. Looks to source of sound** via eye gaze
5		**A4. Distinguishes general meanings** of warning, anger, or friendly voice patterns (e.g., child may look very serious or uncertain when hearing an angry voice; child smiles, brightens and becomes livelier when hearing a friendly voice. Do not accentuate facial expression)
6		**A5. Recognizes 2 words**: **emphasized** (e.g., "daddy," "bye-bye," "mama," or child's own name; child responds when own name is called or specific object or person is named, child may perk up and look for object or person when named, can be a similar reaction to similar sounding words)
7		**A6. Recognizes 2 words: not emphasized** in speech (e.g., ask caregiver if there are any words which child recognizes and watch child as caregiver says words to you in normal conversation, or as you repeat them back in normal speech to caregiver, e.g., "I see, she recognizes 'mama' and 'bottle' ", do not give credit for child's own name)
8		**A7. Follows any direction** with **no gestural cue** (e.g., "Where's mama/light/bottle?", "Wave bye bye", "Look up" etc., ask caregiver for appropriate request or routine, caregiver can elicit)
12		**A8. Follows direction to look at object** when named (similar to A6 & A7, but child needs to look at an object. Also credit A7.)
14		**A9. Identifies 2 body parts** on self (e.g., ask child to "Show me your eyes" and look for blink or widening; open mouth, wave or flex hand or foot, ask caregiver for suggestions. Also credit A5, A7)
14		**A10. Looks at 3 pictures** (present a pair of pictures, showing each picture to the child as you do so and, if child is reported to verbalize, ask what it is to score items C23. Then instruct child to look at each picture, saying, e.g., "Ball, look at ball". **Do not point to pictures**. If no response, then repeat directions. Take child's first response. Present each pair once, asking for one item, then present pairs again, asking for the other item. Be sure to randomly ask for items on left and right. Child must identify 3 items for credit. Also credit A5, A7, A8, V17) Ball (L)____ & Cup (R)____ Shoe (L)____ & Book (R)____ Car (L)____ & Flower (R)____
15		**A11. Looks at 2 verb**s (lay out a pair of pictures, showing each picture to the child as you do so. Then instruct child to look at one picture, saying, e.g., "Hugging, look at Hugging". Do not point to pictures. If no response, then repeat directions. Take child's first response. Present both pairs once asking for one action, then present again asking for the other action. Be sure to randomly ask for items on left and right Child must identify 2 items for credit. Also credit A5, A7, A8, V17) Crying (L)____ & Hugging (R)____ Kissing (L)____ & Sleeping (R)____
19		**A12. Looks at 3/3 objects** (lay out all three objects, showing each object to child before putting it down. Instruct child to look at each object, e.g., "Book, look at book." **Do not point to objects**. If no response, then repeat directions. Take child's first response. Also credit A5, A7, A8) Book (L)____ Brush (C)____ Bunch of keys (R)____
19		**A13. Maintains attention while adult reads short story** (read short picture storybook, taking about 30 sec., with child and see if child maintains attention throughout. Child can look at pictures. Credit V17 if child looks at pictures in book.)
21		**A14. Looks at 3 body parts on another person or doll when named** (e.g., hand, foot, hair, ask caregiver which body parts child can identify).

Vocal Communication

Vocalization is an umbrella term including any voiced sounds such as: babbling, gurgles, giggles, squeals, chuckles, raspberries, screams, fussing, growls, humming, vowel sounds etc.

Verbalizations and first true words are speech skills used with communicative intent. They include some approximation to the sound patterns of recognizable real words. They can be idiosyncratic word-like utterances used consistently and functionally to signify specific things, which are not the usual recognized words in a language system.

M	Score	Item, elicitation, and scoring
1		**C1. Cry is unattenuated**, nasal, one breath long
1		**C2. Makes reflexive sucking or comfort sounds**
1		**C3. Makes random vocalizations** (not crying or reflexive sounds, often accompanying physical activities and do not appear to be communicative)
2		**C4. Vocalizes when adult smiles or speaks**
2		**C5. Uses intonation to express feelings** (e.g., hunger, pain, social attention)
2		**C6. Produces two different vowel sounds**
3		**C7. Vocalizes to singing** (e.g., softly sing "Rock-a-Bye Baby or have caregiver sing a favorite song to child and observe response. Also credit C4)
3		**C8. Vocalizes to cooing** sounds (Also credit C4)
4		**C9. Laughs** (e.g., when played with, during play with objects, when head is covered with a cloth, during sensory stimulation, such as tickling or brushing with soft toy: high-pitched speech sounds are acceptable. Also credit C5)
4		**C10. Produces solitary vocal play** apparently playing with sounds rather than responding to environment (e.g., cooing vowel or consonant-vowel sounds in repetitive fashion; credit is not given if only single, random sounds are produced)
4		**C11. Vocalizes 1 consonant** (can try to elicit through imitation - ask caregiver for suggestions)
5		**C12. Takes turns vocalizing** (vocalize to child in playful manner, pausing occasionally to give child a chance to respond. If child vocalizes, vocalize again and pause to see if child responds again, child should vocalize appropriately two times. Also credit C4)
5		**C13. Imitates vocalization** (e.g., mama, bye bye. Approximation is sufficient, need not use consonants, ask caregiver for suggestions and caregiver can elicit. Also credit C4)
6		**C14. Vocalizes to own name** (Also credit C4)
8		**C15. Reduplicative babbling** (credit for any chain containing at least two consonants and two vowels, e.g., "baba", "baga". Also credit C11)
8		**C16. Produces 4 different consonant-vowel** syllables (Also credit C11)
9		**C17. Vocalizes with communicative intent** (e.g., uses vocalization or intonation to convey meaning, such as labeling, using a rising intonation to signal a request, using a squeal, cry or whine in combination with eye contact to gain attention. Also credit C5 & S18)
9		**C18. Produces multiple speech sounds with conversational intonation** (need not use consonants)
10		**C19. Participates in speech routine games or vocalizes along with song** (e.g., in sneezing game, adult says "ah, ah, ah, ah, ah", child says "choo" – ask caregivers if there are any routines like this and have them initiate routine with child. Also credit S16, C17) (Credit S22 if vocalizations are in a turn-taking manner, e.g., parent sings "eeiieeii" and child responds "oh" for Old MacDonald song)
11		**C20. Imitates word** (approximation is sufficient, need not use consonants, ask caregiver for suggestions and caregiver can elicit) (Also credit C13, C4)
12		**C21. Uses "jargon"** (produces at least 3 different syllables in one breath with varying intonation, includes consonants. Also credit C18, C15, C11, C6)
12		**C22. Produces 2 words** (can be idiosyncratic word-like utterances, must be used consistently and selectively to signify specific things, can ask caregiver and try to elicit specific items, not imitations. Also credit C11, C17)
14		**C23. Labels 1 picture** (See A10. Ball – Cup, Shoe – Book, Car – Flower. Also credit C11, C17)
14		**C24. Labels 1 object** (show each object once and ask, "What is it?" Take first response, ask again if no response: ball, book, keys, comb, and cup. Also credit C11, C17)
14		**C25. Uses 1 word to convey desires** (e.g., "more", "no", word for bottle used as a request not just label or comment. Also credit C11, C17)
16		**C26.** Has a **vocabulary of 8 words** (Also credit C25, C22, C17, C16, C11, C6)
16		**C27. Names self in mirror image** (says, "baby", "me", or name. Can prompt by asking, "who's that? Etc. Also credit S13, C17, C11)
17		**C28. Produces 2 word utterance** (e.g., "more juice", "no book", do not give credit for 2 words consistently used together to convey 1 concept, such as, "all done", "gimme", nor for imitation. Also credit C22, C17, C11, C6)
18		**C29. Imitates 2 word utterance** (approximation is sufficient, ask caregiver for suggestions and try elicit, e.g., "good job". Also credit C20, C13, C11, C6)
19		**C30. Produces 1 pronoun** (me, my, mine, you, I, it, he, she, can elicit by pointing to or taking child's object and saying, "Who's is this?" Also credit C17, C11)
20		**C31. Labels 3 objects** (show each object once and ask "What is it?" take first response, ask again if no response: ball, book, keys, comb, and cup. Also credit C24, C17, C11, C6)
20		**C32. Produces 3-word sentence** (not imitation. Also credit C28, C22, C21, C17, C11, C6)
24		**C33. Asks question** (credit for any "wh- " question or word approximation with rising intonation that is interpreted by an adult as a request, not imitation or label. Also credit C25, C17, C11, C5)

Additional Notes:

Scoring Table

	Social Awareness		Visual Attention		Auditory Comprehension		Vocal Communication	
Raw Score	IAR	IAL	IAR	IAL	IAR	IAL	IAR	IAL
1	0–1	0.14	0–1	0.17	0–1	0.50	0–1	0.33
2	0–1	0.29	0–1	0.33	0–1	1.0	0–1	0.67
3	0–1	0.43	0–1	0.50	1–4	4.0	0–1	1.0
4	0–1	0.57	0–1	0.67	4–5	5.0	1–2	1.33
5	0–1	0.71	0–1	0.83	5–6	6.0	1–2	1.67
6	0–1	0.86	0–1	1.0	6–7	7.0	1–2	2.0
7	0–1	1.0	1–2	1.33	7–8	8.0	2–3	2.5
8	1–2	1.33	1–2	1.67	8–12	12.0	2–3	3.0
9	1–2	1.67	1–2	2.0	12–14	13.0	3–4	3.33
10	1–2	2.0	2–3	3.0	12–14	14.0	3–4	3.67
11	2–3	2.5	3–4	3.5	14–15	15.0	3–4	4.0
12	2–3	3.0	3–4	4.0	15–19	17.0	4–5	4.5
13	3–4	4.0	4–5	4.5	15–19	19.0	4–5	5.0
14	4–5	5.0	4–5	5.0	19–21	21.0	5–6	6.0
15	5–6	5.5	5–6	5.33			6–8	7.0
16	5–6	6.0	5–6	5.67			6–8	8.0
17	6–8	7.0	5–6	6.0			8–9	8.5
18	6–8	8.0	6–9	7.5			8–9	9.0
19	8–9	9.0	6–9	9.0			9–10	10.0
20	9–10	9.33	9–11	11.0			10–11	11.0
21	9–10	9.67	11–12	12.0			11–12	11.5
22	9–10	10.0	12–13	13.0			11–12	12.0
23	10–12	10.67	13–18	18.0			12–14	12.67
24	10–12	11.33					12–14	13.33
25	10–12	12.0					12–14	14.0
26	12–14	14.0					14–16	15.0
27	14–18	18.0					14–16	16.0
28							16–17	17.0
29							17–18	18.0
30							18–19	19.0
31							19–20	19.5
32							19–20	20.0
33							20–24	24.0

Raw score: Tally the number of items below the ceiling for which the child received credit within each scale (all items below the basal, or any second basal, are counted as receiving credit).

IAR (Item Age Range, months): Convert raw scores to IAR by referring to table above. IAR is an estimate of the age range of the items for which a child receives credits. This is *not* an age equivalence of performance for individual children. The age ranges provide a guide to the typical developmental level, in months, of skills that a particular child is demonstrating, within each scale.

IAL (Item Age Level, months): Convert raw scores to IAL by referring to table above. IAL is intended for use in research analyses and should not be interpreted as a score for individual children.