Ecological Assessment of Executive Function in Traumatic Brain Injury

Gerard A. Gioia  
*Pediatric Neuropsychology Program*  
*Children’s National Medical Center*  
*Departments of Pediatrics and Psychiatry and Behavioral Sciences*  
*George Washington University School of Medicine*

Peter K. Isquith  
*Departments of Pediatrics and Psychiatry*  
*Dartmouth Hitchcock Medical Center*  
*Hanover, NH*

Executive dysfunction is a common outcome in children who have sustained traumatic brain injury (TBI). Appropriate assessment of these complex interrelated regulatory functions is critical to plan for the necessary interventions yet present a challenge to our traditional methodologies. Ecological validity has become an increasingly important focus in neuropsychological assessment with particular relevance for the executive functions, which coordinate one’s cognitive and behavioral capacities with real-world demand situations. The Behavior Rating Inventory of Executive Function (BRIEF) was developed to capture the real-world behavioral manifestations of executive dysfunction. Its development and various forms of validity, including ecological validity, are described. Application of the BRIEF’s methodology to the assessment of executive dysfunction in TBI is provided. We advocate a multi-level approach to understanding executive function outcome in TBI, including traditional test-based measures of executive function, real-world behavioral manifestation of executive dysfunction, and the environmental system factors that impact the child. In this model, ecologically valid assessment of executive dysfunction provides an important bridge toward understanding the impact of component-level (i.e., test-based) deficits on the child’s everyday adaptive functioning, which can assist the definition of targets for intervention.

Requests for reprints should be sent to Gerard A. Gioia, Pediatric Neuropsychology Program, Children’s National Medical Center, Departments of Pediatrics and Psychiatry and Behavioral Sciences, George Washington University School of Medicine, 14801 Physicians Lane, Suite 173, Rockville, MD 20850. E-mail: ggioia@cnmc.org.
The executive functions are a critically important area of neuropsychological function in the developing child. These neuropsychological mechanisms of regulatory control play fundamental roles in the child’s cognitive, behavioral, and social-emotional development. The level of executive function, whether intact or impaired, has substantial implications for everyday social and academic function. Individuals with traumatic brain injury (TBI) have documented difficulties with executive function on tests of executive performance, such as inhibition, planning, behavioral regulation (Dennis, Guger, Roncadin, Barnes, & Schachar, 2001; Levin et al., 1996). But the challenge in assessing executive dysfunction is not only to find appropriate performance measures, as Lezak (1995) and others suggested, but also to evaluate the functional, real-world impact of executive dysfunction expressed in everyday activities. In this article, we address the assessment of the executive functions from a perspective that is different from the traditional performance-based test methodology. We approach this problem from an ecological perspective, using the everyday behavior of the child as reported by his or her parents and teachers.

Preparatory to exploring an ecological approach to the assessment of executive function in TBI, we will first review the neuropsychological deficits that result from TBI in children. We then turn our attention to the definition of the complex neuropsychological domain known as the executive functions. Next, we examine the challenges inherent in the assessment of executive functions. A discussion of the ecological validity of neuropsychological assessment, in general, and executive functions, in particular, ensues. We explore various traditional methods that have been used to assess the ability to manage and regulate behavior and cognition. The substance of the article is new work with our Behavior Rating Inventory of Executive Function (BRIEF) (Gioia, Isquith, Guy, & Kenworthy, 2000) as an ecologically valid model to assess children’s executive functions. Finally, we discuss recent work that has applied the use of the BRIEF with children who have sustained TBI.

NEUROPSYCHOLOGICAL DEFICITS IN TBI

A variety of cognitive and behavioral deficits can result from traumatic injury to the developing brain, including deficits in attention, memory, processing speed, and executive functions (e.g., Anderson, Catroppa, Rosenfeld, Haritou & Morse, 2000; Asarnow, Satz, Light, & Neumann, 1991; Dennis, Barnes, Donnelly, Wilkinson, & Humphreys, 1996; Ewing-Cobbs et al., 1998; Fletcher, Ewing-Cobbs, Miner, Levin, & Eisenberg, 1990). Executive function deficits have been tied to a lack of integrity of the frontal lobes of the brain. Magnetic resonance imaging studies of the pathophysiology of TBI suggest particular vulnerability of the frontal (i.e., dorsolateral cortex, orbitofrontal cortex, and frontal white matter) and anterior temporal lobes (Levin et al., 1993). Some data have addressed the relation between frontal lobe damage and executive function
subdomains. Children frequently exhibit neuropsychological difficulties associated with damage to the prefrontal regions with specific deficits in the executive functions such as planning, cognitive flexibility (Ylvisaker, Szekeres, & Hartwick, 1992), behavioral inhibition, and poor organization of learning, memory, and language formulation (Scheibl & Levin, 1997; Ylvisaker, 1998). Severity of TBI is related to specific deficits in executive functioning, such as planning, whereas injury to different regions of the frontal lobes results in different patterns of performance (Levin et al., 1994).

Related observations of real-world function in children with TBI suggest that executive function deficits may be related to functional competence at home and in the classroom, as well as to social cognitive and social affective functioning (Dennis et al., 2001). In real-world settings, children with TBI are at increased risk for experiencing significant difficulties with academic performance, emotional regulation, and social interaction (Eslinger 1998; Eslinger, Biddle, & Grattan, 1997; Eslinger & Grattan, 1991). Among children with TBI, the greatest impact of executive deficits may not be seen at the time of injury, but may emerge later with the dramatic increase in environmental, academic, behavioral, emotional, and social demands on the executive system during adolescence. Problems in social functioning for this group are often the most distinctive features (Ackerly, 1964; Dennis et al., 2001; Eslinger, 1998; Eslinger & Damasio, 1985; Marlowe, 1992). Executive function deficits can result in a demanding, self-centered personality, lack of social tact, impulsive speech and behaviors, disinhibition, apathy and indifference, or a lack of empathy (Eslinger, 1998).

The impact of executive dysfunction may be amplified, rather than attenuated, with increasing time since injury (Dennis, 2000). Prospective case studies (Ackerly, 1964; Grattan & Eslinger, 1991) show the onset of marked behavioral, social, and emotional problems in adolescents who sustained, and appeared to "recover" from, brain injury as children. To the extent that executive dysfunction is expressed both as poor test performance and as real-world dysfunction, it is important to have broad-based assessment tools that measure executive dysfunction in both contexts. As we will explore further, structured performance-based tests may not capture the full spectrum of real-world executive dysfunction, yet an understanding of such deficits and how they impact the child on a daily basis is necessary for developing successful interventions and accommodations. Appropriate intervention thus requires a full ecologically valid assessment of these complex, regulatory functions.

DEFINITION OF THE EXECUTIVE FUNCTIONS

Definitions and models of executive function are plentiful in the literature (e.g., Anderson, 1998; Barkley, 2000; Brown, 1999; Denckla, 1994; Dennis, 1991; Fuster, 1989; Goldman-Rakic, 1987; Levin et al., 1991; Stuss & Benson, 1986;
Welsh & Pennington, 1988), with varying degrees of overlap and consensus as to the overall nature of executive function and specific subdomains. We define the executive functions as a collection of related yet distinct abilities that provide for intentional, goal-directed, problem-solving action. Most would agree that the term is an umbrella construct defined as the control, supervisory, or self-regulatory functions that organize and direct all cognitive activity, emotional response, and overt behavior. Some authors argued, in fact, that it may not be possible to partition the central executive beyond the molar level (Burgess, 1997; Goldman-Rakic 1987), whereas others argued for varying degrees of fractionation (Burgess, Alderman, Evans, Emstie, & Wilson, 1998). Fuster (1985) discussed the critical subfunctions of the prefrontal cortex, that is, the executive functions, necessary for performing long-term goal-directed tasks via the mediation of contingencies across time. Such executive functions are highlighted by delayed tasks, which require the ability to hold information actively in mind in the service of a future goal. Three key components of this system are described, including the following:

- The temporally retrospective function of working memory, the ability to hold old information in mind while actively processing new information.
- The temporally prospective function of anticipatory set.
- Control of interference, which includes the ability to inhibit competing information and action.

Stuss and Benson (1986) described a set of related capacities for intentional problem solving including anticipation, goal selection, planning, monitoring, and use of feedback. Their hierarchical model highlights important aspects of the executive functions that relate to the highest levels of cognition, including anticipation, judgment, self-awareness, and decision making. Welsh and Pennington (1988) provided an early examination of the developmental aspects of the executive functions in children. They characterized the development of the executive functions in terms of “the ability to maintain an appropriate problem-solving set for attainment of a future goal” (p. 201). Finally, Denckla (1994) defined the critical features of the executive functions for active problem solving as follows: providing for delayed responding, future-oriented, strategic action selection, intentionality, anticipatory set, freedom from interference, and the ability to sequence behavioral outputs. Despite the use of different terminology and different emphases in the definitions of these various authors, the common feature among them is the executive system as a set of supervisory functions enabling regulatory control over thought and actions.

Most authors view the executive functions as a set of interrelated capacities rather than as a unitary function. In reviewing the list of domains discussed by others, we have arrived at a basic set of behaviorally referenced areas. Specific subdomains that make up this collection of regulatory or management functions
include the abilities to initiate behavior, inhibit competing actions or stimuli, select relevant task goals, plan and organize a means to solve complex problems, shift problem-solving strategies flexibly when necessary, and monitor and evaluate one's own behavior. The working memory capacity to hold information actively "online" in the service of problem solving is also described within this domain of functioning (Pennington, Bemetto, McAleer, & Roberts, 1996). Finally, we believe the executive functions are not exclusive to cognition; emotional control is also reciprocally related to effective problem-solving activity. That is, goal-oriented problem solving requires not only cognitive control but also the appropriate regulation of one's affective state.

Although we define the executive functions as specific self-regulatory behaviors, it is crucial to understand how these functions operate. In this conceptualization, the executive functions serve as an integrated directive system exerting regulatory control over the basic, domain-specific neuropsychological functions (e.g., language, visuospatial functions, memory, emotional experience, motor skills) in the service of a reaching an intended goal. The executive system makes active, intentional decisions regarding the final behavioral output and recruits the necessary components to reach the goal. As such, the executive functions are defined as the control or self-regulatory functions that organize and direct all cognitive activity, emotional response, and overt behavior. One must approach the assessment process differently depending on whether problem-solving deficits are the result of deficient basic functions (e.g., language) versus a faulty executive control mechanism. The two must work together to produce a coherent, goal-directed product but each has a fundamentally different role toward this end. The unique directive, regulatory nature of the executive functions calls for distinctive methods of assessment.

ASSESSMENT OF EXECUTIVE FUNCTION

Though the executive functions may be defined in a relatively straightforward manner, their precise assessment can be very challenging. A clear understanding of the differences between assessment of the "basic" domain-specific content areas of function (e.g., memory, language, visuospatial, social–emotional) and the domain general or "control" aspects of cognition and behavior is essential. What may appear as a problem with the expression of language may be due less (or not at all) to the basic aspects of linguistic functioning (e.g., phonology, syntax, semantics) than to poor "meta-linguistic" functions (e.g., formulating and maintaining an organized, planful approach to the topic of conversation). There is no test or battery that singularly assesses executive function. By necessity, there is always a "domain-specific" content area regulated by the executive control process. Teasing apart executive functions from domain-specific functions is part of
the challenge of the neuropsychological assessment. Efforts to operationalize assessment models of executive function have largely focused on laboratory or clinical performance tests (Kelly, 2000; Welsh & Pennington, 1988; Welsh, Pennington, & Grossier, 1991), with their inherent construct and measurement problems (Pennington et al., 1996; Rabbit, 1997). For example, Burgess (1997) suggested that most neuropsychological tests alone are inadequate in assessing the executive functions because they attempt to separate integrated functions into component parts. Many consider the Wisconsin Card Sorting Task (Heaton, Chelune, Talley, Kay, & Curtiss, 1993) the prototypical test of executive function, despite the inherently limited focus and scope of any single performance measure. Yet, in their comprehensive review of executive function and ADHD studies, Pennington and Ozonoff (1996) cited only a few performance tests that are consistently impaired across studies and note that the Wisconsin Card Sorting Test is not among them. Furthermore, current performance-based tests tap individual components of executive function over a short time frame and not the integrated, multidimensional, relativistic, priority-based decision-making that is often demanded in real-world situations (Goldberg & Podell, 2000; Shallice & Burgess, 1991). As a result, narrow-band, component tests may not be sufficient in capturing more complex, day-to-day, executive problem solving. The need exists for ecologically valid tasks that assess the broader, molar aspects of complex, everyday, problem-solving demands.

**ECOLOGICAL VALIDITY IN NEUROPSYCHOLOGICAL ASSESSMENT**

The shift over time in neuropsychological assessment from identifying brain injury and lesion location to describing functional strengths and weaknesses (Lezak, 1995) and to predicting everyday functioning and needs for intervention and support in the natural environment (Hart & Hayden, 1986; Long, 1996) has necessitated a parallel shift from “traditional” validity considerations (Franzen & Wilhelm, 1996) to ecological validity considerations. Ecological validity in the psychological literature refers in general to the ability to generalize results of controlled experiments to naturally occurring events in the real world (Brunswick, 1955). Regarding neuropsychological assessment, ecological validity may be more narrowly defined as the “functional and predictive relation between the patient’s behavior on a set of neuropsychological tests and the patient’s behavior in a variety of real-world settings” (Sbordone, 1996, p. 16). Thus, an ecologically valid assessment tool is one that has characteristics similar to a naturally occurring behavior and has value in predicting everyday function (Franzen & Wilhelm, 1996).

When neuropsychological tests are developed and applied to identify or quantify deficits, traditional validity (e.g., construct validity) is paramount and ecolog-
cal validity may be of little concern. In practice, however, neuropsychologists are increasingly asked to not only identify functional strengths and weaknesses but to translate such findings into implications and predictions for the individual in his or her everyday milieu. Particularly complex are the demands placed on pediatric neuropsychologists, who are asked what the child’s strengths and weaknesses are, along with questions about academic placement, needed interventions and accommodations, appropriate IEP goals, implications for school and community functioning, and what future behavioral and emotional developments might be expected in the course of that child’s development (Silver, 2000). In this scenario, ecological validity becomes paramount.

Implicit in definitions of ecological validity as the concept is applied to neuropsychological assessment are two requirements: first, that the demands of a test and the testing conditions resemble demands in the everyday world of the child; second, that performance on a test predicts some aspect of the child’s functioning on a day-to-day basis. The first requirement, that of verisimilitude, overlaps with face validity and describes the “topographical similarity” or theoretical relation between the method of data collection and skills or behaviors required in the natural environment of the child (Franzen & Wilhelm, 1996). For example, to what degree does a test that requires scanning a page and crossing out symbols or pictures resemble a child’s activity in school or at home? Some traditional tests have arguably greater verisimilitude in this regard, such as list learning, prose memory, or naming tasks, whereas the relation between copying a complex figure or sorting cards by category and everyday activities is less transparent.

Considerations of verisimilitude include not only the demands of a given test itself but also the conditions in which the test is administered. That is, in evaluating the degree of verisimilitude for a given test, both the required skills and the testing environment and methods need to be considered. For example, though listening to and repeating a list of objects or words bears theoretical resemblance to learning that might be required in school, the controlled rate of presentation, nondistracting assessment setting and environmental structure, guided practice over several trials, and cues to organize the information may not approximate real-world demands. Although such administrative controls and structure are necessary in the assessment setting to ensure reliability and internal validity, they may compromise ecological validity. Indeed, the more likely environment where listening and remembering is required is one in which there are distractions, the presentation rate is varied, there is limited opportunity for rehearsal, and there may be additional demands such as taking notes. Tests administered within the confines and controls of the laboratory setting may thus underestimate the implications of a child’s difficulties or deficits in the classroom. On the other hand, such tests may overestimate functional difficulties, as the child may apply compensatory strategies in their everyday world or exhibit behavior patterns that increase functionality (Ylvisaker & Gioia, 1998).
The second requirement of ecological validity in neuropsychological assessment is veridicality, or the degree to which test performance predicts some aspect of the child’s everyday functioning. This aspect is both theoretical and empirical: Theoretically, is there reason to believe the test might predict real-world behavior; and empirically, does test performance correlate with some measure of real-world functioning (Franzen & Wilhelm, 1996; Rabin, 2001)? Though this has been the focus of increasing attention, very little is known about prediction of everyday behavior from neuropsychological tests. Methodologically, such an analysis is complicated by the difficulties inherent in capturing an individual’s functioning in a reliable and valid numerical fashion. In the adult literature, several studies have focused on the correlation of neuropsychological test data with patients’ vocational status (e.g., Bayless, Varney, & Roberts, 1989), or, more commonly, with rating scales that assess aspects of daily functioning (Dunn, Searight, Grisso, Margolis, & Gibbons, 1990) or vocational functioning (e.g., Lysaker, Bell, & Beam-Goulet, 1995).

Assessment of veridicality in pediatric neuropsychology is further complicated by confounds unique to children. Silver (2000) cogently articulated four primary challenges to assessing the ecological validity of child-focused assessment instruments: methodology of neuropsychological assessment, methodology of assessing everyday functioning, developmental factors, and intervening variables. Whereas the first two issues are inherently problematic in both adult and child assessment, the latter two are unique to, or more complex in, pediatric populations. Developmental considerations introduce variability, dampening the predictive power of neuropsychological tests (Silver, 2000). At one level, we are simply unable to perform detailed assessment of the full spectrum of typical neuropsychological domains in very young children, and even if we could, it is not clear that tests developed for adults or older children tap similar functions in younger children. Because executive functions are tied to emergent development, the status of executive function in children with perturbations of development need to be tied to the developmental stage of the child at perturbation or brain insult. At another level, children are still developing and functions are emerging into early adulthood. Thus, it may not be possible to detect or evaluate functional difficulties or to assess their impact on everyday functioning until the child matures. In the case of children with TBI or other acquired insult, deficits may not become apparent until the environment places demands on a particular function.

Finally, intervening variables may influence the ability to assess ecological validity to a greater extent with children. The child’s environment is such a mediator: Family environment is affected by a child’s functional difficulties, and the family environment in turn affects the child (Taylor et al., 1999). Further, a child with neuropsychological deficits may receive additional supports, either through developmental or rehabilitation services or through the school. Indeed, Silver (2000) noted a paradox in ecological validity determination with child instruments: Once weaknesses are identified via neuropsychological assessment, recommendations
are generally proffered for interventions with a goal of ameliorating the functional deficits to enhance everyday functioning, thus modifying the statistical relation between the original tests and future measures of everyday functioning.

ECOLOGICAL VALIDITY AND ASSESSMENT OF EXECUTIVE FUNCTION

The methodology of neuropsychological assessment places particular constraints on assessment of executive function. The structured and interactive nature of the typical assessment situation may relieve the demands on the executive functions, and thereby reduce the opportunity to observe critical behaviors associated with the executive functions (Bernstein & Waber, 1990). That is, in many testing situations, the examiner provides the structure, organization, guidance, plan, cueing, and monitoring necessary for optimal performance by the child, thereby serving as that child’s external executive control (Kaplan, 1988; Stuss & Benson, 1986). A child with significant executive dysfunction can perform appropriately on well-structured tasks of knowledge in which the examiner is allowed to cue and probe for more information, thus relieving the child of the need to be strategic and goal directed, or to exercise their executive functions more generally.

Recognizing the different stimulus conditions that are provided within the comfort of the controlled setting of testing (which may be necessary to identify the child’s knowledge and abilities) versus those existing within the child’s everyday world is critically important. Frequently, the more novel or complex the task, the greater the demand for the executive functions. The more familiar, automatic, and simple the task, the less the child needs to recruit his or her executive functions. What may be a complex, novel task for one child may be a relatively familiar and automatic task for another, requiring that such children recruit vastly different degrees of executive control functions toward solving that particular problem. The ultimate application of assessment data to formulating credible practical recommendations and intervention strategies demands a clear understanding of this issue. Assessing the child’s behavior and responses under greater and lesser degrees of examiner-determined control and structure can help clarify the child’s executive control competence.

A paradox in the assessment of the executive functions is that some individuals with significant deficits in specific executive function subdomains may, in fact, perform appropriately on many purported “tests of executive function,” yet have significant problems making simple real-life decisions (Stuss & Buckle, 1992). All tests are multifactorial, requiring for any particular individual greater or lesser degrees of domain-specific content knowledge and experience (the novelty-familiarity issue), and thereby demanding varying degrees of organization, planning, inhibitory control, and flexibility. For example, a child may be able to perform
appropriately on the Wisconsin Card Sorting Test (Heaton et al., 1993), which requires flexibility in problem solving, yet fail miserably in strategically modifying his or her approach to completing a set of math problems in the classroom. Goldberg and Podell (2000) argued that many existing neuropsychological tests assess more narrow veridical than real-world adaptive decision-making; as a result, one may not be collecting the relevant data to document the full essence of strengths and weaknesses in the array of executive functions.

The past decade has seen attention to ecological validity in assessment of executive function and the development of new assessment devices with verisimilitude in mind (Lezak, 1982; Roberts, Franzen, Furuseth, & Fuller, 1995; Shallice & Burgess, 1991; Wilson, Evans, Emslie, Alderman, & Burgess, 1998). Whereas increased attention to verisimilitude in test development and to demonstrating the veridicality of these newer measures and existing tests of executive function is reported in the adult assessment-focused literature (e.g., Bayless, Varney, & Roberts, 1989; Burgess, Alderman, Wilson, Evans, & Emslie, 1996; Kibby, Schmitter-Edgecombe, & Long, 1998; Lysaker, Bell, & Beam-Goulet, 1995), less attention has been paid to similar issues in the pediatric assessment literature. In her comprehensive review of ecological validity in neuropsychological assessment of children with TBI, Silver (2000) noted the multiple challenges to establishing ecological validity in this context. The majority of studies reviewed predict neuropsychological test variables from injury characteristics (e.g., Glasgow Coma Scale), rather than postinjury functioning from neuropsychological test variables, as though performance on neuropsychological tests is an outcome in and of itself. Several more recent studies, however, examine the relations between test performance and functioning in the everyday context via rating scales or structured interviews such as the Vineland Adaptive Behavior Scales (Sparrow, Balla, & Cicchetti, 1984) or via academic achievement testing as a proxy for school functioning (Hartlage & Templar, 1996). Regarding measures of executive function, there is precedent for the use of rating scales designed to tap executive functions in the everyday environment and promise in their use for demonstrating veridicality (Goulden, Silver, Harward, & Levin, 1997; Isquith & Gioia, 1999; Molho & Silver, 1997). Silver concluded that, despite the current limitations to ecological validity, neuropsychological tests are necessary to inform the clinician as to strengths and weaknesses under the best of circumstances to “illuminate the individual ability profile upon which interventions should be based” (p. 986).

In sum, as neuropsychologists are increasingly asked to make predictions about a child’s functioning in the everyday environment and to recommend interventions and accommodations, demonstrating, or increasing, the ecological validity of our testing repertoire becomes essential. One consideration involves developing new measures from an ecological perspective, with particular attention to verisimilitude or similarity to real-world tasks. Given the challenges inherent in such novel
test development, an alternative or parallel course is to examine the ability of our existing tool kit to predict children’s functioning in the everyday environment, or it’s veridicality. This is not without impediments, including the very methodology of neuropsychological tests and testing, the methodology of functional assessment, the developmental course of the subjects, and the likelihood of intervening variables. Despite the challenges, there are potential, if not promising, avenues of research and development in the service of ecologically valid assessment of executive function, and more broadly, of pediatric neuropsychological assessment in general. One avenue is to develop future tests with an emphasis on verisimilitude, such as the Test of Everyday Attention for Children (Manly, Robertson, Anderson, & Nimmo-Smith, 1999). Another avenue is to develop better methods to reliably capture aspects of children’s everyday functioning in specific domains, such as the executive functions, that enable assessment of veridicality. A third avenue that may balance the conflicting validity demands of performance tests with the ecological validity demands of assessment applications is to develop both avenues concomitantly; traditional tests of discrete neuropsychological functions administered in well-controlled settings to preserve construct validity and identify a child’s profile along with reliable measures of these functions through ratings of everyday behaviors in the natural environment to enable greater confidence in predictions from neuropsychological assessment.

**BRIEF**

The BRIEF was developed with ecological validity in mind. The impetus for the BRIEF came from our own clinical need to more efficiently and systematically capture information about manifestations of executive function difficulties in children’s everyday behaviors at home, in school, and in their communities. Parents and teachers possess a wealth of information about children’s behavior in these settings that is directly relevant to an understanding of executive function. Historically, we gathered this information via lengthy interviews with parents, and often could not elicit similar input from teachers due to time constraints. A well-established tradition exists, however, in utilizing structured behavior rating systems in the assessment of psychological and neuropsychological functions (Achenbach, 1991; Conners, 1989; Reynolds & Kamphaus, 1994). Given the difficulties and complexities involved in performance assessment of executive function and a need for greater ecological validity in evaluating executive function, we developed BRIEF to assess the behavioral manifestations of executive functions in children aged 5 to 18 years (Gioia et al., 2000). The BRIEF was designed as a means of culling and standardizing the rich information provided by parents and teachers in a more reliable and efficient manner with known psychometric properties. Such an ecologically valid system of assessing the everyday self-regulatory behaviors of
children serves as an integral component in the clinical evaluation of executive dysfunction.

The BRIEF assesses eight interrelated subdomains of executive function: Inhibit, Shift (Flexibility), Emotional Control, Initiate, Working Memory, Plan–Organize, Organization of Materials, and Monitor. These descriptors were selected from domains commonly discussed in the literature (e.g., Denckla, 1989; Stuss & Benson, 1986; Welsh, Pennington, & Grossier, 1991; Ylvisaker, Szekeres, & Hartwick, 1992) and from discussions with colleagues. More general domains of executive function (e.g., self-regulation, anticipation) for which specific behaviors could not be generated were not included. Other possible domains (e.g., goal-setting, strategic problem solving) were incorporated within the eight existing domains (e.g., planning, shift). The eight domains and examples of their everyday behavioral manifestation are described as follows:

1. Inhibit is the ability to resist or delay an impulse, to appropriately stop one’s own activity at the proper time, or both. The ability to inhibit is readily observed in daily activities such as acting without thinking, being easily distracted, and being unable to sit still.

2. Shift captures the ability to alter problem-solving strategy during complex tasks, the ability to think flexibly, and the ability to switch or alternate attention. In their day-to-day lives, children may exhibit problems with transitioning from one situation, activity, or aspect of a problem to another as the situation demands. Caregivers often describe these children as “getting stuck” on a topic, or as being highly perseverative.

3. Emotional control is the manifestation of executive function within the emotional realm. It is closely associated with the ability to inhibit and modulate responses. Emotional control is a characteristic that is not easily assessed in the laboratory, but can be readily observed at home and school. An inability to modulate emotional responses may manifest as overblown emotional reactions to seemingly minor events or as a general affective reactivity.

4. Initiate is described as the ability to begin a task or activity, or the process of generating ideas or problem-solving strategies. Caregivers often report that children with initiation difficulties have trouble getting started on homework or chores and that they require prompts or cues to begin. Problems with initiation are not the result of noncompliance or disinterest in the task: The child typically has an interest in the task or activity and wants to succeed but cannot get started.

5. Working memory is the process of holding information in mind for the purpose of completing a related task. Working memory is essential to follow complex instructions, complete mental arithmetic, or perform tasks with more than one step. A common observation is that a child with working memory difficulties has trouble remembering things for even a few minutes, or when sent to get something, forgets what she or he was supposed to get.
6. The ability to plan involves anticipating future events, setting goals, and developing appropriate steps ahead of time to carry out an associated task or action. Planning involves imagining or developing a goal or end state, and then strategically determining the most effective method or steps to attain that goal. This often involves the sequencing and stringing together of steps to most efficiently move toward an end state. Parents and teachers may complain about the child's lack of planning ability, tendency to start assignments at the last minute, or not thinking ahead about possible problems.

7. The ability to organize complex information becomes increasingly important as demands for independent functioning increase (Bernstein, the natural history of LD). Organization involves establishing and maintaining order within an activity or carrying out a task in a systematic manner. Caregivers may report observing a scattered approach to solving problems, that the child is easily overwhelmed by large tasks or assignments, or has difficulties organizing personal belongings.

8. The ability to self-monitor includes checking on one's own actions during or shortly after finishing a task to assure appropriate attainment of a goal. Children who do not self-monitor often rush through assignments without checking their work for mistakes. Additionally, such children may be unaware of how their actions affect others in a social context.

Specific items for the BRIEF scales were generated primarily from behavioral descriptions of executive difficulties during clinical interviews with parents and teachers, ensuring good face and content validity. Item-category membership was determined by the sorting decisions of 12 clinical neuropsychologists, as well as statistical analyses (item–total correlation analyses, principal factor analyses, and interrater agreement). Table 1 presents sample items within each subdomain along with item–total correlations, percentage of agreement amongst expert ratings as to item–scale fit, and Cronbach's (1951) alpha as an indicator of internal consistency for the parent and teacher forms of the BRIEF.

The resulting instrument demonstrates appropriate psychometric integrity. Internal consistency is high, with values ranging from .80 to .98. Test–retest reliability is adequate, with average correlations of .81 for parent clinical scales (.84–.88 for the index scores) in the normative sample over a two week period. Similarly, average teacher test–retest correlations for the clinical scales were .87 (.90–.92 for the index scores) over a 3.5-week period. Correlations between parent and teacher informants are moderate, with an overall mean of .32 for the normative sample, which is similar to the literature on consistency among parent–teacher informants (Achenbach, McConaughy, & Howell, 1987).

The construct validity of the BRIEF was examined using common factor analysis while exploring uni- versus multidimensional solutions. Parent ratings of 852 clinically referred and 1,419 children in the normative sample, and teacher ratings
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<th>Scale</th>
<th>Sample Item Content</th>
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<th>Teacher Form</th>
<th>Expert Ratings (%)</th>
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<td>Item–Total Correlations</td>
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<td>Inhibit</td>
<td>Interrupts others</td>
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<td>Gets out of seat at the wrong times</td>
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<td>Gets out of control more than friends</td>
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<td>Shift</td>
<td>Resists accepting a different way to solve a problem with schoolwork, friends, chores, and so on</td>
<td>.52</td>
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<td>Becomes upset with new situations</td>
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<td>Acts upset by a change in plans</td>
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<td>.59</td>
<td>.75</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Mood changes frequently</td>
<td>.62</td>
<td>.79</td>
<td>100</td>
</tr>
<tr>
<td>Initiate</td>
<td>Is not a self-starter</td>
<td>.51</td>
<td>.73</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Needs to be told to begin a task even when willing</td>
<td>.48</td>
<td>.68</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Has trouble getting started on homework or chores</td>
<td>.54</td>
<td>.69</td>
<td>100</td>
</tr>
<tr>
<td>Working memory</td>
<td>When given three things to do, remembers only the first or last</td>
<td>.60</td>
<td>.72</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td>Has trouble concentrating on chores, schoolwork</td>
<td>.68</td>
<td>.77</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td>Needs help from adult to stay on task</td>
<td>.67</td>
<td>.78</td>
<td>100</td>
</tr>
<tr>
<td>Plan–organize</td>
<td>Does not bring home homework, assignment sheets, materials, and so on</td>
<td>.55</td>
<td>.67</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Has good ideas but cannot get them on paper</td>
<td>.57</td>
<td>.72</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>Gets caught up in details and misses the big picture</td>
<td>.54</td>
<td>.58</td>
<td>100</td>
</tr>
<tr>
<td>Organization of materials</td>
<td>Cannot find things in room or school desk</td>
<td>.60</td>
<td>.82</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Leaves a trail of belongings wherever they go</td>
<td>.71</td>
<td>.77</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Leaves messes that others have to clean up</td>
<td>.69</td>
<td>.78</td>
<td>100</td>
</tr>
<tr>
<td>Monitor</td>
<td>Does not check work for mistakes</td>
<td>.49</td>
<td>.60</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Makes careless errors</td>
<td>.58</td>
<td>.61</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Is unaware of how his or her behavior affects or bothers others</td>
<td>.56</td>
<td>.57</td>
<td>100</td>
</tr>
</tbody>
</table>

Note. BRIEF = Behavior Rating Inventory of Executive Function.
of 475 clinically referred and 720 students in the normative sample were examined. The eight scales were submitted to a principal factor analysis with oblique rotation. Examination of one-, two-, three-, and four-factor solutions yielded a similar factor structure for the parent and teacher clinical and normative groups. The two-factor solution was the most theoretically and statistically sound. Across parent and teacher groups, Factor 1, a metacognitive problem-solving factor, was defined by the subdomains Initiate, Working Memory, Plan–Organize, Organization of Materials, and Monitor. Factor 2, a behavior regulation factor, was defined by Inhibit, Shift, and Emotional Control. Correlations between the two factors ranged from .56 to .71. The overall stability of the two-factor solutions across clinical and normative samples for the parent and teacher scales provided strong support for the underlying factor structure of the BRIEF. This analysis also provided support for a limited multidimensional model of executive function.

To establish a measure of convergent and discriminant validity, the BRIEF was examined in relation to general measures of behavior in children [Child Behavior Checklist (CBCL)-Teacher Report Form (TRF), Achenbach, 1991; Behavior Assessment System for Children (BASC); Reynolds & Kamphaus, 1992]. Principal factor analyses (PFA) of the BRIEF and general behavioral measures resulted in similar four-factor structures, with most of the BRIEF scales separating from the TRF–CBCL and BASC scales (Gioia, Isquith, & Guy, 1998). The BRIEF structure was again defined by a “metacognitive problem-solving” factor (BRIEF Initiate, Working Memory, Plan–Organize, Organization of Materials, Monitor scales (with Attention scale of CBCL–TRF and BASC)), a “behavior regulation” factor (BRIEF Inhibit, Shift, Emotional Control along with BASC Aggression scale), a CBCL–TRF or BASC externalizing factor, and a CBCL–TRF or BASC “internalizing” factor.

Overall, the BRIEF has strong psychometric integrity. The instrument as a whole and the individual scales are face valid with good content validity, are internally consistent, and have appropriate reliability properties. Factor analyses provide support for a consistent two-factor structure of the BRIEF, for convergent validity, and for discriminant validity.

In examining the ecological validity of the BRIEF, recall that there are two considerations, verisimilitude and veridicality. To achieve verisimilitude, the demands of a test are to be similar to demands in the everyday world of the child; to achieve veridicality, the test performance must predict some aspect of the child’s daily functioning. Regarding verisimilitude, the BRIEF was explicitly designed to capture everyday executive behaviors while balancing the demands for reliability and construct validity. Examples of items within the BRIEF clinical scales that attempt to capture the everyday manifestations of executive dysfunction include “Tries the same approach to a problem over and over even when it does not work” tapping problem-solving inflexibility or “When sent to get something, forgets what he or she is supposed to get” tapping working memory. Such items were selected to be a
direct reflection of real-world difficulties encountered by dysexecutive children and thus address verisimilitude.

The BRIEF also shows promise for veridicality, that is, predicting behavior in the natural environment. The correlational analyses with the BRIEF scales and broad behavioral measures suggest strong, logical relations (e.g., the BRIEF Inhibit scale with the Aggressive Behavior scale on the CBCL and the Aggression scale on the BASC). There is some suggestion that BRIEF scores correlate with scholastic achievement (Mahone, Koth, Cutting, Singer, & Denckla, 2001), an indication of “real-world” functioning (Hartlage & Templer, 1996). Preliminary work by our group has also found significant and selective correlations between the BRIEF and children’s everyday adaptive behavior functioning (Janusz, Ahluvalia, & Gioia, 2001). Finally, given that executive functions are the underlying neuropsychological constructs reflected in the diagnostic symptoms of ADHD (Barkley, 1997, 2000; Brown, 1999; Denckla, 1996; Isquith & Gioia 1999; Pennington & Ozonooff, 1996; Welsh & Pennington, 1988), the BRIEF should predicting ADHD subtype diagnosis. Indeed, two BRIEF scales that are theoretically related to ADHD symptoms—Working Memory and Inhibit—are strongly predictive of ADHD subtypes (Gioia & Isquith, in press; Isquith & Gioia, 2000).

ECOLOGICAL ASSESSMENT OF EXECUTIVE FUNCTION IN TBI

As previously noted, various types of executive dysfunction characterize the functional deficits seen in children with TBI (Ylvisaker, 1998). Problem-solving rigidity (Ylvisaker, Szekeres, & Hartwick, 1992), disinhibition, and planning deficits (Levin et al., 1994; Scheibel & Levin, 1997) have all been described. Most of the TBI literature has used performance-based tests in their identification of executive dysfunction. Few have examined the short-term recovery and long-term outcome from a broader ecologically relevant perspective (Silver, 2000). Notable exceptions exist, however. Taylor and Yeates have conducted a program of research (e.g., Taylor et al., 2001; Taylor et al., 1999; Yeates et al., 1997; Wade et al., 2001) in which family context variables are integrally examined regarding their relation to neuropsychological outcome. They report the influence of the preinjury family as a moderator variable on the outcome of TBI. The family environment and burden are discussed as critical factors to consider in understanding neuropsychological outcome with significant implications for interventions. Ylvisaker and Feeney (1998) have also championed a contextualized approach to the everyday manifestations of TBI, with a particular focus on the executive functions. In this model, the important caretakers (parents, teachers) take an active role in the assessment of the child’s functional strengths and weaknesses and also play a critical role in the
tervention programming. Recently, Dennis et al. (2001) examined parent ratings of attentional–inhibitory control and social–behavioral regulation in children with TBI in addition to neuropsychological performance testing. They report selective relations between testing and everyday behavior ratings.

The structure of the BRIEF has significant promise in the assessment of ecologically relevant aspects of executive dysfunction in TBI. The three subdomains of the Behavioral Regulation factor—Inhibit, Shift, and Emotional Control—are commonly reported problems following injury to the prefrontal regions of the brain. In addition, difficulties in executive function tapped by the five subdomains of the Metacognition factor—Initiate, Working Memory, Plan–Organize, Organization of Materials, and Monitor—can also result from TBI. One such study of executive functioning using the BRIEF in children who have sustained TBI was conducted by Armstrong, Mangeot, Colvin, Yeates, and Taylor (2001). The authors report on the long-term prevalence and correlates of executive dysfunction following childhood traumatic brain injuries. The children in their sample were approximately 5 years postinjury, including severe and moderate TBI, as compared with orthopedic injuries (OI). BRIEF ratings, measures of family functioning—including the Family Burden of Injury Interview (FBII) and Family Assessment Device (FAD)—and the Brief Symptom Inventory (BSI) were completed by the parents. Neuropsychological testing included several measures of executive function. Scores on the BRIEF displayed a significant linear trend across groups, most with the largest deficits in executive functions reported in the severe TBI group. The BRIEF Behavioral Regulation and Metacognition Index scores were related consistently across all groups to the Consonant Trigrams test, a test of working memory. The BRIEF Index scores also predicted parent psychological distress (BSI) and perceived family burden (FBII), in the TBI and OI groups. In contrast, general family functioning as measured by the FAD was related to BRIEF scores only in the TBI groups. These findings demonstrate the relation between executive function, as measured by the BRIEF, as well as parent and family stress. Among families of children with TBI, general family functioning may be particularly stressed by the injured child’s executive dysfunction. An ecologically valid measure of executive function, such as the BRIEF, reveals this relation in ways that performance-based tests do not.

Several points regarding the ecological validity of executive function are highlighted by Armstrong et al.’s study. First, injury severity was associated with everyday manifestations of executive function. This finding extends the findings of other authors who have used only performance-based tests (e.g., Levin et al., 1994) in relating injury severity to neuropsychological outcome. It also differs from the findings of Dennis et al. (2001), who did not find injury severity to be related to parent ratings of attentional control or social–behavioral regulation. Second, a traditional performance-based test of working memory (i.e., Conso-
nant Trigrams) was associated with an everyday manifestation of executive dys-
function in the BRIEF.

Studies such as Armstrong et al. (2001) with the BRIEF and Dennis et al.
(2001) with specific behavior ratings highlight the utility of real-world behavioral
anchors with which traditional neuropsychological test performances and injury
variables can be related. Test-based and behavior rating-based outcomes provide
not only information on the specific components of executive function but also
seeks to identify their real-world functional manifestations. Neuropsychological
dysfunction on a test should not be the end goal in itself but instead highlight spe-
cific ways in which the child manifests problems with executive function. Finally,
Armstrong et al. highlight the role of the family context in terms of its importance in
the child’s executive function. Ecologically valid measurement of executive func-
tion, as provided by the BRIEF, allows examination of critical, family-contextual
determinants. Such an assessment model ties the everyday executive function out-
come of the child with TBI into a broader systemic context and begins to define the
foci for active intervention within the child and the caretaking system.

SUMMARY

Executive dysfunction is a common outcome in children who have sustained TBI.
Appropriate assessment of executive functions is critical to plan necessary inter-
ventions. Because executive functions are a complex, environmentally sensitive
set of interrelated processes, their assessment challenges our traditional testing
methodologies. Ecological validity has become an increasingly important focus in
neuropsychological assessment with a number of authors articulating the critical
issues (Cripe, 1996; Silver, 2000). This article highlights two important is-
issues—veridicality and verisimilitude—that neuropsychological measures must
consider. Tests can vary in the degree to which they are highly structured and con-
trolled, such as in a laboratory or clinical setting versus a less-structured real-world
setting. They can also vary in terms of their face and content validity, as well as in
their ability to predict real-world behavior. Given the nature of the executive func-
tions with their inherent focus on managing and coordinating cognitive and behav-
ioral activities in response to real-world demands, ecological validity is particu-
larly important in their assessment. The BRIEF was explicitly developed with an
eye to these issues of ecological validity. Within the various theoretical domains
described by others, items tapping specific, everyday behaviors were generated to
capture the real-world behavioral manifestations of executive dysfunction. In addi-
tion to meeting traditional standards of reliability and validity, the BRIEF also
demonstrates ecological validity with its inherent focus on the actual, everyday beh-
aviors of children.
Returning to TBI, or for that matter any complex disorder involving the executive functions, we submit that an ecologically valid approach to the assessment of these self-control functions is critical to provide appropriate intervention. The work by Armstrong et al. (2001) and Dennis et al. (2001) provide an instructive example toward this end. These studies highlight a multilevel approach to understanding neuropsychological outcome in TBI. Traditional test-based measures of executive function are given to tap specific components of executive function such as working memory, inhibition, and organization. One might describe this level as the component or molecular level. Armstrong et al. defined the child’s real-world behavioral manifestation of executive dysfunction via the BRIEF. This characterizes the molar level of function in the child, describing the ways that the specific components might play out in terms of everyday behaviors. Finally, the environmental system factors are revealed including the family structure and resources and parent-coping skills. These are key, facilitating factors necessary for full ecologically sensitive interventions directed at the molar and molecular levels of the child’s behaviors. In this model, the ecologically valid assessment of executive dysfunction provides an important bridge toward understanding how the component-level (i.e., test-based) deficits impact on the child’s everyday adaptive functioning. The definition of real-world behaviors also provides actual behaviors, situations, or both, toward which interventions may be directed.

We advocate for an ecologically valid model of neuropsychological assessment that explicitly incorporates at least three levels of information—(a) specific process components typically defined by clinical tests, (b) real-world behavioral manifestations of the specific cognitive processes, and (c) the environmental systems factors that impact on the child’s function. An assessment approach that balances these three elements would incorporate the traditional psychometric qualities of reliability and validity while also providing strong ecological validity. Such a comprehensive approach would better guide intervention planning and monitoring—the ultimate goal of good neuropsychological assessment.

REFERENCES


