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Executive functions and the natural habitat behaviors of children with autism

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ABSTRACT Research suggests that impairments in executive functions play a role in the cognitive deficit in autism. Possible autism-specific impairments include an inability to engage in goal-directed behaviors and adjust behaviors given environmental demands. What has been described as executive functions is based largely on observations of performance in the laboratory rather than in natural settings. An ecological method first described by Barker and Wright and adapted by Scott was used to assess the patterns of goal-directed behaviors of eight children with autism and eight chronological and mental age comparable children with Down syndrome. Quantitative and qualitative features of naturalistic behaviors were collected, and coded using previously described categories of children's behavior. Results indicated that children with autism exhibited shorter and less overlapping goal-directed behaviors. These data suggest a cognitive difference rather than developmental delay, and lend support for impaired executive functions in autism. Practical implications for educators and caregivers are discussed.

KEYWORDS *autism; ecological psychology; executive function; goal-directed behaviors; natural habitat behaviours*

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Autism is a complex disability affecting social and communication development and ability to engage in a wide range of interests and activities (American Psychiatric Association, 1994). These impairments are pervasive and heterogeneous, lasting throughout the lives of people with autism and varying in degree from individual to individual. Even though there is not yet consensus on the nature of the underlying cause(s) of these problems, impairment in executive function (EF) has been implicated (Ozonoff, 1995; Ozonoff and Jensen, 1999; Rumsey and Hamburger, 1990) and linked to characteristics of autism (Hughes, 2001; Ozonoff, 1998; Rogers, 1998; Ruble, 2001). Broadly described as cognitive 'capacities that enable a person to engage successfully in independent, purposeful, self-serving behavior' (Lezak, 1995, p. 42), EFs lack a clear operational definition (Bryson et al., 1997). Barkley (2000) suggests that the term 'executive functions' includes (1) planning of volitional goal-directed intentional action, (2) inhibition and resistance to distraction, (3) problem solving that allows for development, selection, and monitoring of strategies, (4) flexibility in goal-directed actions to meet task demands, (5) persistence in behaviors to attain a goal, and (6) awareness of self over time. Thus, EFs encompass a wide set of self-regulatory behaviors that overlap with one another.

Ozonoff and Jensen (1999) have questioned the specificity of EF impairment in autism because executive deficits are also observed in other neurodevelopmental disorders such as attention deficit hyperactivity disorder (ADHD) and Tourette syndrome (TS). By demonstrating that individuals with autism have more difficulty with two particular components of EFs, Ozonoff and colleagues suggest that different EF profiles may differentiate autism from ADHD or TS. They found that individuals with autism had particular difficulty in planning goal-directed activities and engaging in behaviors that are flexible given task demands.

Research in EF is relatively recent, and no agreement exists on the results of EF as primary or as secondary following a neurological insult in autism. In addition, little information is available on the impact of EF deficits and everyday behaviors of children with autism. Hughes (2001) provides a compelling argument implicating executive dysfunction as a primary causative agent resulting in everyday observable problems in autism, such as joint attention, pretend play, communication, and repetitive behaviors. Rogers (1998) notes clinical descriptions of young children's everyday behaviors. Adaptive classroom behaviors such as working continuously, maintaining attention, and generating novel and creative problem solving strategies are EF problems that must be addressed by educators. Classroom teaching assistants often act as the 'executive' planners for students with autism by providing verbal and physical prompts to help students complete tasks and participate in group learning activities. What has been described, heretofore, as EF is generally based on observations of individuals' micro-level behaviors elicited by laboratory-based neuropsychological tasks rather than molar-level behaviors demonstrated in natural settings. The purpose of this study was to determine whether everyday behaviors in autism, that occur at an observable level and are thought to be mediated by EF, differ in quality and quantity to those of comparable mental and chronological age children.

An ecological psychology approach, originating from the work of Barker and Wright (1955/1971), was chosen to describe the everyday goal-directed behaviors of children with autism. This method allows for the assessment of the interdependent transactions between intentional or goal-directed behaviors and the settings in which these behaviors occur (Wicker, 1979). Ecological methods have been used in numerous studies of childhood goal-directed behavior (e.g. Barker and Wright, 1955/1971; Gump, 1975; Hatfield, 1982; Scott, 2002; Wright, 1967). Intentional goal-directed behavior has been previously defined, independently from EF, as the ability to initiate, engage, and disengage in one activity that consists of a constant and uniform psychological direction across some time period (Barker and Wright, 1955/1971). Depicted as a developmental skill that demonstrates self-organization, the complexity of goal-directed behavior has been shown to relate to age. Barker and Wright (1955/1971), for example, observed children's behavior in a small Midwest town in the USA across a number of settings such as playgrounds, churches, and homes. They found that the age of children positively correlated with the length and complexity of the patterns of their goal-directed behaviors.

In this present study, written records of behaviors of comparable children with autism and Down syndrome (DS) were collected and analyzed. Records comprised descriptions of behavior directly observable by a layperson (Scott, 1980) and made by recording the behavior of the child, the people around the child, and ongoing events onto a portable tape recorder. The tapes were transcribed as narrative records called *chronologs*, which were used for data analysis (see Figure 1 for a sample chronolog). To allow for coding of real-time behavior, time notations were made in the margin of the chronologs. Next, the ongoing description of real-time behavior was divided into its naturally occurring structural units (Scott, 1980) via the activity unit (AU). Defined as a 'chunk' of an individual's ongoing, goal-directed behavior, an AU depicts intentional action comprising a continuous psychological direction from the perspective of the actor (Scott, 1980). These behavioral units are common to a layman's description of behavior, and at home might include 'eating dinner', 'watching TV', or 'playing with toys'. When the child engaged in a different activity, a new AU was marked (see Figure 1 for unitized chronologs). Each AU was labeled from the intention of the child, describing what the AU was about, what was happening, or what the child was trying to do. Examination of children's intentions advanced understanding of communication and social behaviors of children with autism (e.g. Mundy and Sheinkopf, 1998; Mundy et al., 1986; Wetherby et al., 1998). This study is the first to use children's intentions to assess EF.

A word may be in order concerning the 'behavioral intent' in AUs and its relationship to EF. Behavioral evidence is required to judge 'intent' in an AU. For example, the child must be emitting some behavior, at some level, toward a goal or end state. When all behavior toward that end state ends, the AU ends. For example, a boy may be talking to mother. Father enters and the boy turns to him and begins talking but keeps his hand on mother's knee and his body is still mainly pointed in mother's direction. In ecological research this is considered to be evidence of at least some intent to continue talking to mother. When the boy leaves mother and climbs into father's lap, all behavioral evidence of 'talking to mother' has ended. The boy may very well talk to mother again, from father's lap, but there is a different character or quality to that behavior than the previous ones. In this case, again, behavioral evidence is sought as to whether the boy thinks he is continuing to talk to mother or whether he is having a new conversation. The judgment is made from the perspective of the boy. One advantage of ecological research is that analyses are done based on the actual behavior at the time and not on some *a priori* categories that are always coded one way regardless of the naturally occurring, ongoing context of the behavior at the time it occurs. This has been done quite reliably in previous studies (Barker and Wright, 1955/1971; Dumke, 1986; Gump, 1969; 1974; 1975; 1978; 1987; Hatfield, 1982; Rager, 1986; Ruble, 1997; 1998; Scott and Hatfield, 1985; Wright, 1967). It is a matter of looking at behavior at the molar level (molecular behaviors do not have this level of reliability in ecological research), having enough familiarity with the overall behavior patterns of the boy (from reading the entire record before beginning the segmenting of AUs), and looking astutely for actual behavioral cues of the boy's intent. This is somewhat different than laboratory-experimental

Chronolog A
Name: Richie, child with autism eating dinner with his Mother, Father, and Brother, Bobby
Age: 6 years, 11 months old

Eating Dinner[49]

Richie continues to eat, not responding in any way to mom's comment to dad.

31:26 Dad begins to talk to mom about dad hurting his ankle.

Richie continues to eat with a blank facial expression.

Mom asks Bobby how his day was at school.

Dad immediately asks Bobby whether he has homework.

Bobby explains to dad how much homework he has.

Dad then asks Bobby whether he does any homework in school.

Richie continues to eat, looking around the room and at his plate of food, not appearing to be attending to the family conversation.

32:23 Richie continues to eat while his parents talk to Bobby about how much Bobby doesn't get done at school.

Getting up to drink[51]

Suddenly, Richie gets out of his seat and walks in a deliberate manner to his mom and says, "My baby, my baby."

He stands by her and looks at the turkey sitting on the table.

Mom asks him whether he wants some turkey and tells him to "Go ahead" indicating that he could eat some.

Not responding to mom, Richie turns away, begins walking, and then stops.

He turns around, points toward mom, and looks at mom and says, "Mommy, drink."

He picks up her drink.

Mom tells him to put the drink down.

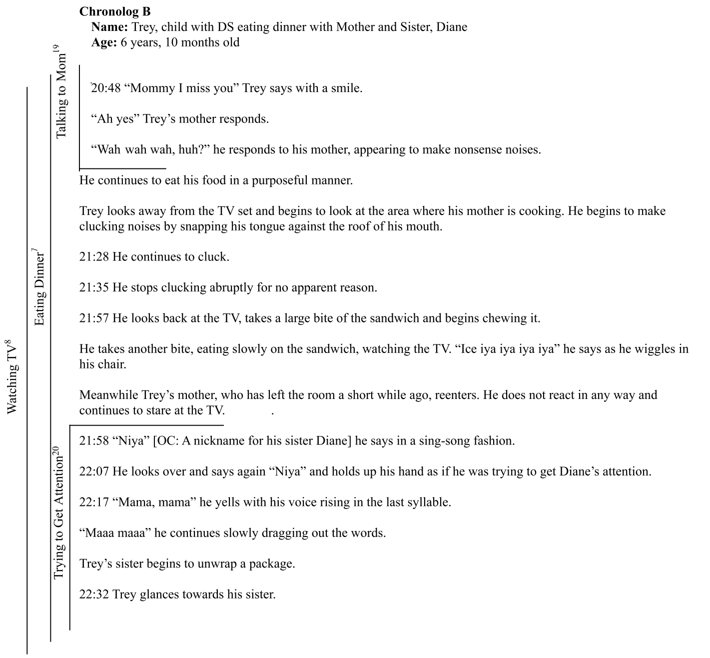

Figure 1 **The first excerpt, chronolog A, illustrates dinnertime behavior of a child with autism, Richie. Chronolog B demonstrates dinnertime behavior of a child with Down's syndrome, Trey. Both children exhibited overlapping units of behavior. Trey, however, demonstrated more complex patterns of behavior with more overlap and of longer duration. Notice that each unit of behavior is labeled and numbered for purposes of coding and data analysis (times in minutes and seconds)**

definitions of intention, which tend to be more internal, and more non-continuous, than AUs.

There are several similarities between EF (as it has been described by Barkley, 2000) and AUs, and there are also some differences. An activity unit is thought to be a reasonable analog for three aspects of EF: (1) planning of volitional goal-directed intentional action, (2) inhibition and resistance to distraction, and (3) persistence in behaviors to attain a goal. The nature of intent in the AU is similar in both. In the AU the child is proceeding toward a goal and is also sufficiently persistent and resistant to distraction to keep the AU in progress. These are thought to be direct behavioral evidences of intent at the molar level in the natural habitat.

There are also several dissimilarities between an AU and EF. An AU does not deal with 'awareness of self over time' (Barkley, 2000). Further, it is not clear whether an AU deals with 'problem solving that allows for the development, selection, and monitoring of strategies' or 'flexibility in goal-directed actions to meet task demands'. There appear to be elements of both of these in an AU, but these aspects need further study.

In summary, the AU was considered a sufficiently similar analytic unit to that of EF to provide a reasonable analog. In addition, it occurs within the child's natural habitat, thus increasing its ecological validity.

After the AUs were identified, the patterns of goal-directed behaviors were coded for each AU. Pattern dimensions that have been applied in previous ecological studies (Barker and Wright, 1955/1971; Scott, 1980; Wright, 1967) were selected for the present study and included the length of goal-directed behavior or AU, the number of overlapping AUs, and the type of AU overlap. The length of AUs was calculated to the nearest .25 minutes. Wright (1967) found that older children had longer AUs. The number of overlapping AUs is a measure of the simultaneity or co-occurrence of goal-directed behaviors (Wright, 1967) at one point in time and represents ability to self-organize behavior. Thus, ability to perform multiple behaviors that reflect varying intentions is assessed by number of overlapping AUs. Wright (1967) also found older children to have more overlapping behaviors.

The third dimension, type of AU overlap, reflects the complexity of the structure of behavior as children engaged in one or more different AUs at a time. Five types of AU overlap were coded (see Figure 2). When an AU was non-overlapping or isolated, the child's intention was to accomplish one goal. When an AU overlapped with another AU, the child's intentions were to perform two different actions simultaneously. An example is a child playing with a toy and watching TV. The structure of these overlapping patterns is captured by AU overlap. An AU that encompasses one entire other AU is called enclosing. The AU that is entirely within another AU, on the other hand, is called enclosed. A child, for example, may try to get his/her mother's attention momentarily (enclosed AU) while watching TV, which occurs over the course of several minutes (enclosing AU). Wright found that most units of behavior are enclosed as people more often produce short goal-directed behaviors within the context of fewer longer goal-directed activities. As children age, Wright concluded, behavior occurs in longer segments (featured by enclosing units), emphasizing maintenance of goal-directed behaviors in the presence of potentially interrupting action units (featured by enclosed AUs). All three dimensions of AUs – length, amount of overlap, and type of AU overlap – reflect developmental patterns of behavior that correlate with age (Wright, 1967). The purpose of this study was to describe the patterns of goal-directed behaviors of children with autism.

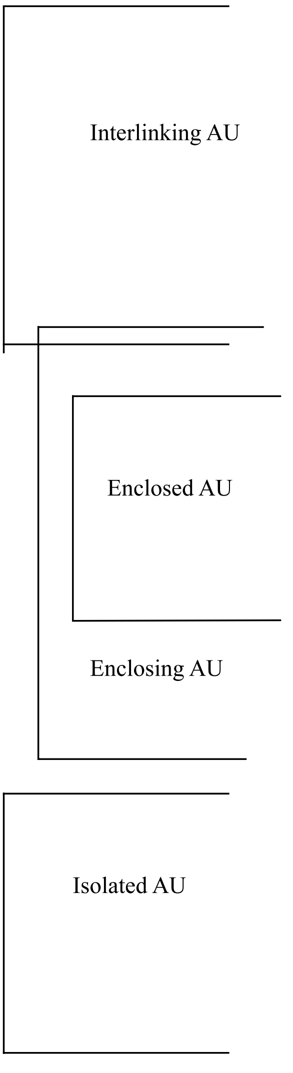

Figure 2 **Types of AU overlap**

Methods

Participants

Participants included eight children with autism and eight with Down syndrome (DS) and their families. Boys between the ages of 6 and 10 years and who participated primarily in local educational programs for students with mild to moderate mental impairments were recruited. Special education directors were asked to identify teachers of children with autism or DS. Teachers were asked to forward two letters to parents: one describing the study and one for informed consent. Parents willing to participate contacted the researcher directly or provided permission for the teacher to share their phone number with the researcher. For participation, parents received a small stipend of $25.00. Children were previously diagnosed by other professionals not connected to this study. Children with autism met DSM-IV criteria for autistic disorder.

The Vineland Adaptive Behavior Scales – Interview Edition (VABS) (Sparrow et al., 1984) was administered to the child's parent or caregiver. *T*-test analyses of domain standard scores are reported in Table 1. No differences in communication (t = –0.54, n.s.) or daily living skills (t = –1.8, n.s.) were found. Socialization skills were significantly lower for boys with autism (t = –2.3, $p < 0.05$). VABS standard scores were significantly below average and consistent with reported cognitive level for both groups of children. School personnel, with parents' permission, released previous psychological assessments of cognitive levels.

While 16 participants might be considered a relatively small number for a typical laboratory-experimental design, it is consistent with ecological and naturalistic designs. In the latter, more weight is given to the amount of behavior examined, e.g. total hours of observation time, or numbers of behavioral units. In the present study, for example, a total of 31 hours 33 minutes of observation was collected which contained a total of 1182 units of behavior. This is not to say that numbers of participants do not play a role in understanding the findings, but to note that there are other measures of depth of sample than just number of participants. Of course, the ultimate criterion for both strategies is to sample to redundancy, i.e. until no new

Table 1 **Characteristics of participants**

Measure	*Autism*		*Down syndrome*		*t*
	M	*SD*	*M*	*SD*	
Age (years)	8.5	1.6	8.7	1.1	0.28
Cognitive level	2.1	1.1	2.3	0.5	–0.57
	Moderate[a]		Moderate		
VABS:					
Communication SS[b]	39.0	15.2	42.8	12.4	–0.54
Socialization SS	48.4	9.6	66.4	20.1	–2.3*
Daily living SS	32.9	17.0	49.4	19.1	–1.8

[a] Overall level of retardation: 0 = borderline (70–84); 1 = mild (55–69); 2 = moderate (40–54); 3 = severe/profound (< 39).
[b] Standard score.
* $p < 0.05$.

data or findings emerge. Even very large sample sizes do not guarantee this. Therefore, a variety of types of depth of sample should be considered in any well founded overall program of research.

Setting

Participants were observed for about 2 hours in their natural environment at home, during two behavior settings, dinner and free and open activities (before dinner and after dinner). Observations were started at the natural beginning of an activity (e.g. when the child started playing after eating snack) and terminated at the natural end of an activity (e.g. when the child finished watching TV and began to get ready for bed). Natural start and end points were determined beforehand during the phases of orientation and adaptation described next.

Observations

Before observations were initiated, participants completed two steps. They were first oriented to the study and then adapted to the procedures and equipment. Orientation consisted of informing families of the study and the procedures. The VABS and a semi-structured interview were completed at this time. The interview identified family members who would be present during adaptation and the actual observation. The children were allowed to look at and examine the stenomask (described in the apparatus section). In the second step, the family was *adapted* to the observer's presence and the equipment. During this step, the experimenter followed the child, spoke into the stenomask, and recorded the behavior until the child and all other people in the environment adapted to the equipment and the presence of the observer. Scott's (1980) criteria for adaptation were applied. Detailed descriptions of these steps are provided in Ruble (1998). Essentially, adaptation occurred when the observer acted as a non-responding piece of the environment and resulted when the child and the people in the environment stopped noticing the observer (Scott, 1980). It took approximately two 2 hour visits to gain adaptation. Each visit occurred within 1 to 2 days. Wright's (1967) finding that children under the age of 10 easily adapted to the observer's presence was confirmed in the present study.

Apparatus

Chronologs were collected with a stenomask (Schoggen, 1964). The stenomask covers the lower half of the face, quieting the observer's comments and allowing the observer to quietly record all ongoing events in the environment onto an audiotape. The stenomask was connected to a portable tape recorder and had a switch that allowed the recorder to be turned on and off unobtrusively. A stopwatch was used for time notations.

Observer training

The observers consisted of six graduate students: all but one (LR) were unaware of the purposes of the study and collected 82 percent of the chronologs. Practice records from each observer were recorded, transcribed, and critiqued until criteria established by Barker and Wright (1955/1971) were met. Criteria included chronolog records that provided: (1) an acceptable level of behavioral descriptions at the molar level, (2) an acceptable level of low inference descriptions, and (3) a time-line reference.

Reliability of unitization

Each chronolog was partitioned into its naturally occurring structural units via the AU (Scott, 1980). Two reliability analyses were conducted, after approximately one-third and then after about two-thirds of the data had been analyzed. Using the Scott and Hatfield (1985) method, the percentage of agreement was determined by adding the total number of units agreed by both judges and dividing this number by the total number of units. Also, the duration of behavior was part of the analysis, increasing the ecological validity. About 45 minutes of data were analyzed for each interrater reliability analysis. Two independent raters demonstrated acceptable reliabilities of 95 and 89 percent agreement.

Categorization and reliability of categorization

Following unitization, each AU was then categorized. Three categories were selected because they had been applied in previous ecological research (Barker and Wright, 1955/1971; Scott, 1980) and were thought to be related to EF. Two independent raters coded the AUs, and two separate reliability analyses were obtained, after about one-third and after about two-thirds of the data had been analyzed. About 60 minutes of chronolog data were analyzed per reliability analysis. The reliabilities met an acceptable level, ranging from 92 to 100 percent agreement for analysis 1 and analysis 2, again using the Scott and Hatfield (1985) method.

Data transformation

In order to generate the proportional data, data transformation was applied using a time-weighted formula (Scott and Hatfield, 1985), creating proportional or percentage scores. Time-weighted percentages are proportions of total AU time. The time-weighted formula was used to transform data for two purposes: (1) to describe behavior that occurred *throughout* a particular unit; and (2) to answer the question of duration of goal-directed behaviors. Because multiple individual pairwise comparisons were conducted, the Bonferroni procedure was applied by category in order to protect against the risk of type I error and to minimize experiment-wise error rate (Kazdin, 1992).

Results

Behavioral output

Table 2 shows the behavioral output data. No significant difference for observational time was found between groups ($t = 0.30$, $p = 0.77$). A total of 1182 AUs were emitted by the children during the observations. The mean number of AUs per group was compared and although boys with autism had more AUs than boys with Down syndrome, the difference was not significant ($t = 2.1$, $p = 0.07$).

Because it was possible for the children to be involved in more than one AU at a time, in overlapping patterns (e.g. a child could be watching TV and eating dinner simultaneously), AU time exceeded observational time (see Table 2). No significant difference was found between groups for AU time ($t = –0.54$, $p = 0.59$). Because observational time and AU time revealed no differences, group differences in the content or patterns of AUs were not likely to be an artifact of varying amounts of observation or AU time between groups of children.

Table 2 **Behavioral output data**

Diagnosis	*Observation time* (min:s)	*Number of Activity Units*	*Activity Unit time* (min:s)
Autism			
Total	15:50	710	20:01
Mean	1:58	89	2:30
Down syndrome			
Total	15:43	472	24:07
Mean	1:58	59	3:01
Overall total	31:33	1182	44:08
Overall range	1:46–2:07	43–139	1:58–3:47
Overall mean	1:58	74	2:45

Note: Activity Units are behaviors that occur along a constant psychological direction from the perspective of the child (Scott, 1980).

Length of activity units

The length of AUs by diagnosis was examined descriptively and statistically. The mean length of the AUs was 2 minutes 35 seconds, the median length was 30 seconds, and the modal length was 15 seconds. Of the total 1182 AUs examined, 542 units of 15 seconds duration occurred, indicating a high percentage of very short AUs, similar to findings from previous studies of ecological data (Barker and Wright, 1955/1971; Dumke, 1986; Wright, 1967). The mean length of the AUs was 2 minutes 16 seconds for the children with autism and 3 minutes 24 seconds for the children with Down syndrome ($t = –2.4$, $p = 0.03$). Children with autism exhibited significantly shorter AUs that were approximately 1 minute less in duration.

Number of overlapping activity units

Of the total AUs, 20 percent did not overlap at any point with any other AU, about 50 percent overlapped with one other AU, and approximately 19 percent had two overlaps. Approximately 12 percent had more than two overlaps. A *t*-test of proportional scores indicated that the children with Down syndrome had significantly more overlapping units (mean of 2.0) than the children with autism (mean of 1.3) ($t = –2.85$, $p = 0.01$).

Type of overlap

Of the total 1182 AUs, 20 percent were non-overlapping (a unit that did not overlap with any other unit), 11 percent were enclosing (a larger unit that had at least one other entire unit within itself), 55 percent were enclosed (a smaller unit that was entirely within a larger unit), and 13 percent were interlinking (a unit that partially overlapped with another unit). These findings are consistent with Wright's (1967) findings that the majority of units are enclosed. Although two analyses (enclosing and enclosed) reached a value of $p < 0.05$ (see Table 3), the group differences were non-significant when the Bonferroni correction was employed (p required for significance = 0.0125).

Discussion

Executive functions, such as carrying out volitional, planned, goal-directed behaviors and adjusting those behaviors with flexibility to environmental demands, have been characterized as a primary cognitive impairment in autism (Ozonoff and Jensen, 1999) and implicated in everyday problems experienced by persons with autism (Hughes, 2001). This study investigated whether there was an observable difference in the EFs of everyday actions of children with autism and children with Down syndrome. Using ecological psychology methods, a systematic examination of naturalistic patterns of

Table 3 **Mean percentages of AUs in type of categories by diagnosis[a]**

Type of overlap	*Diagnosis*				*T-test**
	Autism		*Down syndrome*		
	M	*SD*	*M*	*SD*	
Isolated: AU occurred without any overlap	0.23	0.09	0.13	0.09	2.03
Enclosing: AU contained at least one entire other AU within it	0.13	0.04	0.08	0.04	2.74
Interlinking: AU occurred at least partially during the course of another AU	0.10	0.06	0.13	0.09	–0.83
Enclosed: AU itself is completely contained within at least one entire other AU	0.51	0.10	0.64	0.08	–2.71
Interrupted: AU is discontinuous	0.00	0.01	0.01	0.01	–1.27

[a] Calculated as a % of each child's total *N* of AUs.
* No differences significant.

behavior was conducted. The patterns of goal-directed behaviors called activity units (AUs) were examined in terms of three criteria: length, amount of overlap, and type of overlap. These are all developmental indicators of complexity and maturity of goal-directed behaviors. Children with autism exhibited AUs that were about half the length and half the amount of overlap compared to those of children with Down syndrome. In Wright's (1967) ecological study of children who were typically developing and physically disabled (of average cognitive ability), he found a significant direct correlation between age and mean length of duration of units, showing that shorter AUs are more frequent in younger children and longer AUs in older children.

Fewer overlapping AUs observed in autism reflect children's relative difficulty engaging in more than one activity at a time. Similar to the data on developmental course of AU length, behavior that reflects varying intentions is judged as related to developmental maturity. Wright (1967) reported an increased connectedness among the behavioral units (i.e. more overlapping units) of older children. Older children were more adept in generating simultaneous goal-directed activities. Pierce et al. (1997) demonstrated that children with autism have particular difficulty processing simultaneous cues. In this study, children with autism were also less able to produce behaviors of multiple intentions simultaneously, perhaps emphasizing the relationship in simultaneous information processing and flexibility in meeting task demands and problem solving.

A third indicator of AU complexity was the type of AU overlap. Children with autism tended to have more enclosing AUs (the AU contained within it at least one other entire AU) and fewer enclosed AUs (the AU itself is completely contained within at least one other entire AU) than their counterparts with Down syndrome. Wright (1967) found a negative correlation between the number of enclosing units (larger units made up of smaller units) and age. That is, 'the behavior of the older children occurred in fewer but longer segments [represented by enclosing units], which means that older children managed to maintain goal-directed actions with greater persistence in the face of potentially interrupting action units' (1967, p. 12). He also found a positive correlation between enclosed units and age. When older children engaged in a second (although simultaneous) activity, they were able to do so while still maintaining in progress at least some behaviors toward the first goal. The behavioral patterns of the children with autism in this study were less complex. Compared to the results from Wright's (1967) study that younger children behave in a more sequential manner, engage in one activity at a time, shift frequently from one activity to another, and persist in a given activity for a relatively short time, findings from the present study suggest that the children with autism behave structurally as if they were more developmentally immature than would be expected, based on their chronological and mental age.

These structural differences shed new information on subtle aspects of disordered development in autism and may reflect quantitative and qualitative differences in behavior mediated by EFs. The inabilities to have flexible control of attention, to inhibit competing stimuli in order to complete goal-directed behavior, and to keep a plan in mind and carry out the plan, reflect the patterns of behavior described by parents and teachers (Rogers, 1998) and found in this study. The findings of shorter and fewer overlapping AUs suggest that children with autism have difficulty persisting in goal-directed behaviors and engaging in more than one activity at a time, a skill requiring flexibility in attention, working memory, and ability to persist in goal-directed behaviors. A word of caution is that the AUs do not directly test underlying cognitive functions such as attention and working memory and should be viewed as inferences.

Educational implications

The types of EF problems described above are often reflective of everyday challenges described by parents, educators, and clinicians working with individuals with autism. Although little research on interventions of EFs and autism is available, Ozonoff (1998) provides detailed descriptions of treatment approaches largely based on other disabilities. Interventions include medication and external structuring, as well as cognitive-behavioral and flexibility training approaches. One particular approach, external structuring, has been theoretically linked to EF and autism (Mesibov et al., 1994; Rogers, 1998). Such an approach includes the use of activity schedules (McClannahan and Krantz, 1997). Although activity schedules were designed to promote independence by decreasing the likelihood of children's prompt dependency on adults, activity schedules also promote maintenance of goal-directed behavior by supporting working memory and organization. In a multiple baseline study of four boys with autism, MacDuff et al. (1993) applied a graduated guidance approach to teach the use of a photographic activity schedule which resulted in sustained activity engagement. The picture stimuli appeared to serve as an 'executive' planner by helping the boys persist in goal-directed activities. More research, however, is needed on the use and outcomes of various types of external structuring procedures that may help compensate problems of EF.

Children with autism and intellectual impairment, who are often excluded from laboratory research studies owing to the cognitive and language requirements of neuropsychological tests, were represented in the present study. The generalizability, however, of these findings is unknown as children with autism who have typical language or cognitive skills were not included. Further research on the specificity of these findings is needed in order to increase understanding of specific EF patterns in autism as reflected in everyday behaviors.

Conclusion

Executive function is thought to be an important concept in examining the regulation of an individual's behavior, particularly with individuals with autism. Ecological methods called chronologs were used to examine some aspects of EF within a child's natural habitat. The chronologs were analyzed via activity units – goal-directed, naturally occurring segments of behavior – which provided a useful analog for three aspects of EF described by Barkley (2000). Children with autism, when compared with those with Down syndrome, showed shorter AUs, fewer overlapping AUs, and less complex AUs. Together, these findings were interpreted as suggesting that children with autism demonstrate, in their natural habitats, some of the deficits in EF that have also been seen in laboratory-experimental studies, e.g. less ability than their age peers to carry out goal-directed behavior over time, less resistance to distraction, and less complex behavior. There are significant educational implications of these findings. Next research steps would be to map ecological natural behaviors onto neuropsychological test results.

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References

AMERICAN PSYCHIATRIC ASSOCIATION (1994) *Diagnostic and Statistical Manual of Mental Disorders*, 4th edn (DSM-IV). Washington, DC: APA.

BARKER, R. & WRIGHT, H. (1955/1971) *Midwest and its Children* (original work published 1955). Hamden, CT: Archon.

BARKLEY, R.A. (2000) 'Genetics of Childhood Disorders: XVII. ADHD, Part 1: The EFs and ADHD', *Journal of the American Academy of Child and Adolescent Psychiatry* 39: 1064–8.

BRYSON, S., LANDRY, R. & WAINWRIGHT, J. (1997) 'A Componential View of Executive Dysfunction in Autism', in J. BURACK & J. ENNS (eds) *Childhood, Attention, and Psychopathology*, pp. 232–59. New York: Guilford.

DUMKE, R. (1986) 'Participation of Academically Marginal and Nonmarginal Students across Classroom Subsettings', doctoral dissertation, Indiana University.

GUMP, P. (1969) 'Intra-Setting Analysis: The Third Grade Classroom as a Special but Instructive Case', in E.P. WILLEMS & H.L. RAUSH (eds) *Naturalistic Viewpoints in Psychological Research*, pp. 200–20. New York: Holt.

GUMP, P. (1974) 'Operating Environments in Schools of Open and Traditional Design', *School Review* 82: 575–93.

GUMP, P. (1975) 'Ecological Psychology and Children', in E.M. HETHERINGTON (ed.) *Review of Child Development*, vol. 5, pp. 75–126. Chicago, IL: University of Chicago Press.

GUMP, P. (1978) 'School Environments', in I. ALTMAN & J.F. WOHLWILL (eds) *Children and the Environment*, pp. 131–73. New York: Plenum.

GUMP, P. (1987) 'School and Classroom Environments', in D. STOKOLS & I. ALTMAN (eds) *Handbook of Environmental Psychology*, pp. 691–732. New York: Wiley.

HATFIELD, J. (1982) 'The Behavior of Hyperactive Children and Unlabeled Peers across Classroom Subsettings: An Ecological Analysis', *Dissertation Abstracts International* 43: 272B.

HUGHES, C. (2001) 'Executive Dysfunction in Autism: Its Nature and Implications for the Everyday Problems Experienced by Individuals with Autism', in J. BURACK & T. CHARMAN (eds) *The Development of Autism: Perspectives from Theory and Research*, pp. 255–75. New York: Erlbaum.

KAZDIN, A. (1992) *Research Design in Clinical Psychology*, 2nd edn. Needham, MA: Allyn & Bacon.

LEZAK, M. (1995) *Neuropsychological Assessment*. New York: Oxford University Press.

MACDUFF, G., KRANTZ, P. & MCCLANNAHAN, L. (1993) 'Teaching Children with Autism to Use Photographic Activity Schedules: Maintenance and Generalization of Complex Response Chains', *Journal of Applied Behavior Analysis* 26: 89–97.

MCCLANNAHAN, L. & KRANTZ, P. (1997) 'In Search of Solutions to Prompt Dependence: Teaching Children with Autism to Use Photographic Activity Schedules', in D. BAER & E. PINKSTON (eds) *Environment and Behavior*, pp. 271–8. Boulder, CO: Westview.

MESIBOV, G., SCHOPLER, E. & HEARSEY, K. (1994) 'Structured Teaching', in E. SCHOPLER & G. MESIBOV (eds) *Behavioral Issues in Autism*, pp. 195–207. New York: Plenum.

MUNDY, P. & SHEINKOPF, S. (1998) 'Early Communication Skill Acquisition and

Developmental Disorders', in J. BURACK (ed.) *Handbook of Mental Retardation and Development*, vol. xviii: 183–207. New York: Cambridge.

MUNDY, P., SIGMAN, M., UNGERER, J. & SHERMAN, T. (1986) 'Defining the Social Deficits of Autism: The Contribution of Nonverbal Communication Measures', *Journal of Child Psychology and Psychiatry and Allied Disciplines* 27: 657–69.

OZONOFF, S. (1995) 'EFs in Autism', in E. SCHOPLER & G. MESIBOV (eds) *Learning and Cognition in Autism*, pp. 199–219. New York: Plenum.

OZONOFF, S. (1998) 'Assessment and Remediation of EF in Autism and Asperger Syndrome', in E. SCHOPLER, G. MESIBOV & L. KUNCE (eds) *Asperger Syndrome or High Functioning Autism?*, pp. 263–92. New York: Plenum.

OZONOFF, S. & JENSEN, J. (1999) 'Specific EF Profiles in Three Neurodevelopmental Disorders', *Journal of Autism and Developmental Disorders* 29: 171–7.

PIERCE, K., GLAD, K. & SCHREIBMAN, L. (1997) 'Social Perception in Children with Autism: An Attentional Deficit', *Journal of Autism and Developmental Disorders* 27: 265–82.

RAGER, T. (1986) 'An ecological comparison of the effects of mainstreamed and nonmainstreamed settings on the behavior of EMR children', doctoral dissertation, Indiana University.

ROGERS, S. (1998) 'Neuropsychology of Autism in Young Children and its Implications for Early Intervention', *Mental Retardation and Developmental Disabilities* 4: 104–12.

RUBLE, L. (1997) 'A Comparative Study of Natural Habitat Behaviors of Children with Autism and Children with Down Syndrome: An Ecological Approach', *American Psychological Association*, Chicago, IL.

RUBLE, L. (1998) 'Comparative Study of the Natural Habitat Behaviors of Children with Autism and Children with Down Syndrome: An Ecological Approach', *Dissertation Abstracts International* 59 (5-B): 2459 (University Microfilms no. AAM98–34558).

RUBLE, L. (2001) 'Analysis of Social Interactions as Goal-Directed Behaviours in Children with Autism', *Journal of Autism and Developmental Disorders* 31 (5): 471–82.

RUMSEY, J. & HAMBURGER, S. (1990) 'Neuropsychological Divergence of High-Level Autism and Severe Dyslexia', *Journal of Autism and Developmental Disorders* 20: 155–68.

SCHOGGEN, P. (1964) 'Mechanical Aids for Making Specimen Records of Behavior', *Child Development* 35: 985–8.

SCOTT, M. (1980) 'Ecological Theory and Methods for Research in Special Education', *Journal of Special Education* 14: 279–94.

SCOTT, M. (2002) 'Children's Problems and Solution Strategies in the Natural Habitat', manuscript submitted for publication.

SCOTT, M. & HATFIELD, S. (1985) 'Problems of Analyst and Observer Agreement in Naturalistic Narrative Data', *Journal of Educational Measurement* 22: 207–18.

SPARROW, S., BALLA, D. & CICCHETTI, D. (1984) *Vineland Adaptive Behavior Scales (Survey Form).* Circle Pines, MN: American Guidance Service.

WETHERBY, A., PRIZANT, B. & HUTCHINSON, T. (1998) 'Communicative, Social-Affective, and Symbolic Profiles of Young Children with Autism and Pervasive Developmental Disorder', *American Journal of Speech-Language Pathology* 7: 19–91.

WICKER, A. (1979) *An Introduction to Ecological Psychology*. Belmont, CA: Wadsworth:

WRIGHT, H. (1967) *Recording and Analyzing Child Behavior with Ecological Data from an American Town*. New York: Harper & Row.