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Error and performance feedback processing by children with Specific Language Impairment—An ERP study

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ABSTRACT

The study evaluates error and feedback related processing in children with Specific Language Impairment (SLI), and in age and gender matched controls. Participants performed two tasks which varied in the extent to which feedback was provided following each response. Although no group differences were found in accuracy and response time measures, children with SLI corrected a smaller proportion of their errors in comparison with the control group. Neurophysiological data pointed to error and feedback processing differences between the two groups. Errors committed by the control group elicited error-related ERP components (ERN, Pe), while these components were attenuated in the SLI group. A posterior positivity was elicited in association with incorrect responses in both groups. When a feedback stimulus informed the participants about the accuracy of the response, the feedback, rather than the response, elicited an ERN in the control group, while no ERN was elicited in the SLI group. These results suggest that children with SLI have an impaired ability to self-monitor performance and to take advantage of performance feedback.

1. Introduction

Specific Language Impairment (SLI) is a developmental language disorder affecting about 7% of kindergarten children in the US (Tomblin & Records, 1997). The disorder is considered specific to language, as it cannot be attributed to hearing loss, mental retardation or other known neurological deficits (Benton, 1964). In these children the functionality of the executive control system is reported to be deficient as performance on tasks that are designed to recruit executive functions has been found to be impaired (e.g., Helland & Asbjornsen, 2000; Henry, Messer, & Nash, 2012; Young et al., 2002). Nevertheless, there is considerable controversy regarding the extent to which the disorder is truly specific to the language domain. Some researchers view the disorder as specific to language, particularly to grammar (e.g., Gopnik & Crago, 1991; Rice & Wexler, 1996; Van der Lely, 1993), while others view it as a component of a general deficit in information processing (e.g., *slowing hypothesis*, Kail and Salthouse (1994); *working memory deficit*: Gathercole & Baddeley, 1990; Montgomery, 2003; Weismer, Evans, & Hesketh, 1999; *temporal processing deficit*: Tallal & Piercy, 1973, 1974; Visto, Cranford, & Scudder, 1996). Increasing evidence of impaired performance on different nonverbal tasks by individuals with SLI (e.g., Aram, Ekelman, & Nation, 1984; Bavin, Wilson, Maruff, & Sleeman, 2005; Conti-Ramsden, Botting, Simkin, & Knox, 2001; Gillam, Cowan, & Marler, 1998; Hick, Botting, & Conti-Ramsden, 2005; Hoffman & Gillam, 2004; Ottem, 1999; Stothard, Snowling, Bishop, Chipchase, & Kaplan, 1998; Tomblin et al., 1992) is consistent with the latter view. This view has triggered continuing efforts to elucidate the specific impaired information-processing component(s) of this disorder. Temporal processing deficit, described as a limitation in processing rapidly changing acoustic information, is considered by some researchers to be the core impairment in SLI (Tallal & Piercy, 1973, 1974; Visto et al., 1996). Limitation in working memory has also been proposed as a possible account of language impairments in SLI (Gathercole & Baddeley, 1990; Montgomery, 2003; Weismer et al., 1999). These reported deficits are commonly interpreted to suggest that children with SLI have limited-capacity resources, that they are able to process and/or store only so much incoming information at a given time. An alternative view attributes the language deficit to the manner in which our limited-capacity resources are monitored and managed. In other words, SLI is thus viewed as a consequence of a dysfunctional Executive Control System, a label assigned (Borkowski & Burke, 1996; Eslinger, 1996; Logan, 1985) to a class of high-level cognitive processes that are responsible for allocating resources, evaluating performance and its consequences, and changing strategies to improve future outcomes. The ability to self-monitor performance, to learn from one's own mistakes,

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and to take advantage of performance feedback is an integral component of efficient learning. These skills appear to be under the control of the executive control system in which the Anterior Cingulate Cortex (ACC) plays an important role (e.g., Schall, Stuphorn, & Brown, 2002). Performance monitoring has been extensively studied in children with ADHD (e.g., Groen et al., 2008; Groom et al., 2010; Herrmann et al., 2010; Liotti, Pliszka, Perez, Kothmann, & Woldorff, 2005; Shen, Tsai, & Duann, 2011; Shiels & Hawk, 2010) to a lesser degree in children with Autism (e.g., Larson, South, Krauskopf, Clawson, & Crowley, 2011; Santesso et al., 2010) but, as far as we know, not in children with SLI. As many of the children who at a young age are diagnosed with SLI continue to exhibit learning deficits during the school years and throughout their lives (e.g., Aram and Hall, 1989; Aram et al., 1984; Beitchman, Wilson, Brownlie, Walters, & Lancee, 1996; Conti-Ramsden et al., 2001; Johnson et al., 1999; Stothard et al., 1998), and in light of existing evidence of impairment in other executive functions in these children, it is important to study their ability to monitor performance. Moreover, treatment programs rely heavily on the delivery of performance feedback, yet very little in known about the extent to which children with SLI benefit from these techniques by taking advantage of the external feedback.

Event Related Potentials (ERPs) allow a temporally accurate (in milliseconds) examination of specific processes that are associated with the executive control system. The Error Related Negativity (ERN) is one component of the ERPs which is associated with performance monitoring. The ERN is elicited in association with incorrect responses (e.g., Gehring, Goss, Coles, Meyer, & Donchin, 1993) and with a presentation of an external feedback (e.g., Miltner, Braun, & Coles, 1997) when the accuracy of the response cannot be inferred directly from the response. It is a fronto-central component with a latency of 40–80 ms following error commission and about 250 ms following the presentation of a negative feedback stimulus.

Abnormal ERN patterns are apparent in children with different disorders, particularly those involving impaired executive functions. The reports regarding ADHD are mixed; some report an abnormal pattern in the form of a reduction in ERN amplitude (e.g., Groen et al., 2008; Liotti et al., 2005), while others find a typical ERN and a reduction in Pe amplitude (e.g., Groom et al., 2010; Shen et al., 2011). Children with anxiety disorder are reported to exhibit increased ERN amplitude compared to typically developing peers (e.g., Ladouceur, Dahl, Birmaher, Axelson, & Ryan, 2006). This pattern is similar to that observed in adults with anxiety disorders.

We report here a study designed to examine the extent to which children with SLI are impaired in their ability to self-monitor their performance, and to examine whether these children rely on external feedback to monitor their performance. Two tasks were employed to address these questions. The first was a two-choice speeded reaction time task, while in the second task a feedback was presented after each response. Three scenarios were considered. In one, children with SLI will not differ from their peers in error and feedback processing. These findings will indicate that the monitoring system of children with SLI is intact. The second scenario was that children with SLI will exhibit impairment in self-monitoring their errors but not in processing feedback. These results will suggest that children with SLI rely on the external feedback to monitor their performance as a compensation strategy for their deficient self-monitoring skills. The third possible outcome is that children with SLI will exhibit impairment in self-monitoring and are not compensating for this deficit by processing external feedback. In this case, children with SLI will show a more general deficit in performance monitoring regardless of the source of the error signal (internal or external).

A spatio-temporal Principal Component Analysis (PCA), as described by Spencer, Dien, and Donchin (2001), was utilized to analyze our data. This analysis reduces the dimensionality of a large dataset, and parses the complex waveforms, separating the overlapping ERP components. This analysis allowed us to avoid making presumptions about the spatial and temporal distribution of the error related components in children.

Table 1
Descriptive and mean data for the NL and SLI groups (*SD* in parentheses).

	NL	SLI
N	10	10
Male/female	7/3	7/3
Age in months	99 (11.5)	99.3 (14)
Nonverbal IQ Standard Scores (K-Bit)	114 (10.53)	95.8 (9.85)**
Language composite scores (TOLD P-3; TOLD I-3)	112 (7.97)	72.4 (11.01)**
Language – receptive	116.8 (8.39)	74.7 (12.44)**
Language – expressive	107.1 (11.13)	79.4 (9.76)**

** Significant group difference, $p < .001$ (Albeit within normal limits, the nonverbal IQ scores of children with SLI (see data in Table 1) in our sample were significantly lower than those of the children in the NL group. The relatively low nonverbal IQ scores in the SLI group were not surprising in light of ample evidence of low IQ scores of children with SLI (e.g., Aram et al., 1984; Conti-Ramsden et al., 2001; Stothard et al., 1998>; Tomblin, Freese, & Records, 1992), especially in those who show consistent language impairment after the age of five. In the present study we consider the relatively low nonverbal IQ scores as a common characteristic of children with SLI who continue to exhibit language deficit after the age of five).

2. Methods

2.1. Participants

The experimental group comprised 10 children (7 boys, 3 girls), aged 7–10 years (mean age 8 years 3 months), with a diagnosis of SLI. These children were recruited from schools and clinics in the Tampa Bay area. The inclusion criteria for the SLI group were as follows: (a) Previously diagnosed with language impairment by a speech-language pathologist, (b) Language composite score on the Test of Language Development-Primary-Third edition (TOLD P-3) for ages 7 and 8; 11, and the Test of Language Development Intermediate–third edition (TOLD I-3) for ages 9 and 10 at least 1 SD below the mean (<85), and (c) Nonverbal IQ scores on the Kaufman Brief Intelligence Test (K-Bit) within normal limits (85–125).

Children with nonverbal IQ scores below 85, as well as those with ADHD as indicated by the NICHQ Vanderbilt Assessment Scale—Parent Informant, were excluded from the study.

The control group comprised 10 age- and gender-matched children with normal language development. Children in both groups were right-handed, with no history of neurological deficits. A diagnosis of ADHD and the use of medications made up the exclusion criteria. Data collection began after parents signed a consent form. A summary of the participants' age, gender, and scores on a language test and an IQ screening test are provided in Table 1.

2.2. Experimental procedure

All tests were performed in the Cognitive Psychophysiology Laboratory in the Psychology Department at the University of South Florida. Participants completed two Flanker tasks while their electroencephalogram (EEG) was recorded. The session began with a practice trial designed to acclimate participants to the experimental conditions and to ascertain that participants are able to master the task and to maintain high accuracy levels. During the EEG recording, the experimenter was present in the subject's room as an observer to record any adverse behavior. Instructions were repeated during breaks between blocks.

2.3. Tasks

Participants performed two variations of the *Eriksen Flanker task* (Eriksen & Eriksen, 1974). This task requires the inhibition of response tendencies in the face of interfering stimuli. Participants are asked to respond to a centrally presented target stimulus, which is sometimes flanked by distractor stimuli that activate conflicting response channels. A congruent/compatible trial is one in which all stimuli activate the same response, whereas an incongruent/incompatible trial is one in which the flankers are associated with a competing response. It is well established that individuals are prone to make errors when presented with incompatible arrays (Flankers effect). Participants were instructed to respond by pressing a left or right button on a response box according to the identity of a stimulus at the center of a five-stimulus array. In two arrays, all five stimuli were identical (*SSSSS*, *HHHHH*). In the other two arrays, the central stimulus was different from the other four (*SSHSS*, *HHSHH*). Prior to the presentation of the task, participants were asked to identify the test stimuli (i.e., the letters H and S). They were then asked to point to the target stimulus that