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Research report

Visual attentional engagement deficits in children with Specific Language Impairment and their role in real-time language processing

Marco Dispaldro [a,*], *Laurence B. Leonard* [b], *Nicola Corradi* [c], *Milena Ruffino* [d], *Tiziana Bronte* [e] and *Andrea Facoetti* [c,d,**]

[a] *Language Acquisition Lab, Dipartimento di Psicologia dello Sviluppo e Socializzazione, Università di Padova, Italy*
[b] *Child Language Research Lab, Speech, Language and Hearing Sciences Department, Purdue University, IN, USA*
[c] *Developmental & Cognitive Neuroscience Lab, Dipartimento di Psicologia Generale, Università di Padova, Italy*
[d] *Unità di Neuropsicologia dello Sviluppo, Istituto Scientifico "E. Medea" di Bosisio Parini, Lecco, Italy*
[e] *Centro Medico di Foniatria, Casa di Cura "Trieste", Padova, Italy*

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ABSTRACT

In order to become a proficient user of language, infants must detect temporal cues embedded within the noisy acoustic spectra of ongoing speech by efficient attentional engagement. According to the neuro-constructivist approach, a multi-sensory dysfunction of attentional engagement – hampering the temporal sampling of stimuli – might be responsible for language deficits typically shown in children with Specific Language Impairment (SLI). In the present study, the efficiency of visual attentional engagement was investigated in 22 children with SLI and 22 typically developing (TD) children by measuring attentional masking (AM). AM refers to impaired identification of the first of two sequentially presented masked objects (O1 and O2) in which the O1–O2 interval was manipulated. Lexical and grammatical comprehension abilities were also tested in both groups. Children with SLI showed a sluggish engagement of temporal attention, and individual differences in AM accounted for a significant percentage of unique variance in grammatical performance. Our results suggest that an attentional engagement deficit – probably linked to a dysfunction of the right fronto-parietal attentional network – might be a contributing factor in these children's language impairments.

1. Introduction

Children with Specific Language Impairment (SLI) show significant deficits in language abilities, without accompanying problems such as hearing impairment, neurological damage, or a deficit in nonverbal intelligence. These children show performance Intelligence Quotients (IQ) that fall within the normal range for their age, pass screening

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* *Corresponding author*. Dipartimento di Psicologia dello Sviluppo e Socializzazione, Università di Padova, Via Venezia 8, Padova 35131, Italy.
** *Corresponding author*. Dipartimento di Psicologia Generale, Università di Padova, Via Venezia 8, Padova 35131, Italy.
E-mail addresses: marco.dispaldro@unipd.it (M. Dispaldro), andreafacoetti@unipd.it (A. Facoetti).

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tests for hearing acuity, present no signs of neurological impairment, and do not display the typical symptoms of autism spectrum disorders (Leonard, 1998). Epidemiological studies suggest that the prevalence of SLI may be as high as 7% among 5-year-olds (Tomblin et al., 1997). In clinically referred studies, males outnumber females, by approximately 3 to 1 (Leonard, 1998). Children with SLI are two or three times more likely than typically developing (TD) children to have siblings with language problems or parents with a history of language problems.

The language impairment is not uniform in children with SLI; different areas within language tend to be more adversely affected than other areas. For many children, grammar is most seriously impaired, with somewhat milder limitations seen in vocabulary and phonology (Leonard, 1998). These children's comprehension of language is often more advanced than their language production abilities.

A central research question is whether this impairment is language-specific (e.g., Eyer and Leonard, 1995; Rice et al., 1995) or whether it derives from a more general deficit. According to general processing limitation approaches (e.g., Kail, 1994; Leonard, 1998; Leonard et al., 2007), children with SLI show difficulties in information processing as exhibited by restricted or inefficient working memory (WM) (Dollaghan and Campbell, 1998; Ellis Weismer et al., 1999; Gathercole and Baddeley, 1990; Marton and Schwartz, 2003; Montgomery, 2000), and sluggish speed of processing (Kail, 1994; Leonard et al., 2007; Miller et al., 2001). This deficit is viewed as general in nature because it is present in non-linguistic as well as linguistic tasks. Furthermore, deficits are seen in visual as well as auditory tasks.

Deficits in visual processing have been documented at least since the work of Tallal et al. (1981). These investigators found that children with SLI had difficulty relative to same-age peers in discriminating letter-like visual forms made visible through 75-msec light flashes. As part of evaluating Kail's (1994) generalized slowing hypothesis – that children with SLI are slower in all aspects of processing – several research teams have revealed slower response times (RTs) to visual stimuli of a non-linguistic nature on the part of children with SLI (Miller et al., 2001, 2006; Windsor et al., 2001, 2008). In some studies, the slowing has not been observed in all tasks. However, slower RTs have been seen for visual processing at least as often as for auditory processing. For example, Kohnert and Windsor (2004) found that children with SLI were slower than same-age peers on simple and choice visual detection tasks, but not simple auditory detection tasks.

Recent research has begun to focus on the role of attention during non-linguistic processing, in part because of the assumed importance of attention when performing timed tasks such as those used in speed of processing studies. For example, Schul et al. (2004) found that children with SLI were slower on a visual attention task than a group of TD children matched for age. Finneran et al. (2009) found that children with SLI were less accurate than age controls on a visual task of sustained attention (see Ebert and Kohnert, 2011 for a recent review).

Weaknesses in visual processing are also reflected in tasks of visual WM. Several studies have found deficits in children with SLI in this area of functioning (e.g., Bavin et al., 2005; Hoffman and Gillam, 2004). However, the findings for visual WM may not be independent of those seen for visual attention. Models of WM include attention as an essential process, as seen for example, in the model of Cowan (1999). It appears that brain mechanisms that control selective attention might also be those that refresh representations in WM (Gazzaley and Nobre, 2012; Jonides et al., 2005). In a study employing fMRI, Eliis Weismer et al. (2005) found that children with SLI differed from TD peers in fronto-parietal regions associated with both attention and WM.

One hypothesis, not yet fully explored in SLI, is related to the possibility that the impairment in language might also reflect a multi-sensory limitation associated with temporal engagement of attention, which refers to the ability to process an (auditory or visual) stimulus immediately followed by a second stimulus (see Hari and Renvall, 2001 for a review). In particular, a brief object that is clearly perceptible alone can be rendered invisible by the subsequent presentation of a second object nearby in time: i.e., object substitution masking (see Enns and Di Lollo, 2000 for a review). Despite the great amount of information flooding the scenes, we are able to engage our attentional resources on one object. Thus, attentional engagement can be thought of as a multi-sensory mechanism designed to enhance perception of a complex sensory world, by selecting a specific object to process further. Temporal engagement of attention is crucially involved in object substitution masking (Potter et al., 2002), and it could be specifically impaired not only in children with developmental dyslexia (DD; e.g., Facoetti et al., 2008; Ruffino et al., 2010) but also with SLI, as proposed by the "Sluggish Attentional Shifting" hypothesis of Hari et al. (2001; see Vidyasagar and Pammer, 2010 for a recent review).

According to the neuro-constructivist framework, in which development itself is the key to understanding developmental disorders (Karmiloff-Smith, 1998), a multi-sensory dysfunction of attentional engagement – hampering the temporal sampling of the relevant objects – might be responsible for the typical language deficits shown in children with SLI. Indeed, in order to become a proficient user of language, infants must detect temporal cues embedded within the noisy acoustic spectra of ongoing speech by rapid auditory processing (e.g., Benasich and Tallal, 2002; Goswami, 2011; Tallal, 1980, 2004; Tallal et al., 1993; Wright et al., 1997). A multi-sensory sluggish attentional engagement can mimic a primary rapid signal processing deficit because the inefficient attentional window will expose object perception to major interference from near temporal noisy distracters.

The engagement of temporal attention can be studied by measuring the identification of the first object (O1) when the second object (O2) is presented. O1 accuracy is usually unimpaired at short O1–O2 intervals, (e.g., 180 msec) even when it is measured in elderly normal individuals (Kavcic and Daffy, 2003). If attentional engagement toward O1 is not successfully completed by the time that O2 is presented, then O1 accuracy could be impaired (e.g., Facoetti et al., 2008; Kavcic and Daffy, 2003; Potter et al., 2002; Ruffino et al., 2010). It is known that when two visual stimuli are successively presented, they compete for processing resources (see Keysers and Perrett, 2002 for a review). When the O1–O2 interval is short, O2 is often the first to be identified, but as the O1–O2