Journal of Communication Disorders 55 (2015) 31–43

Contents lists available at ScienceDirect

Journal of Communication Disorders

Learning trajectories for speech motor performance in children with specific language impairment

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ARTICLE INFO

Article history:
Received 7 April 2014
Received in revised form 7 January 2015
Accepted 20 February 2015
Available online 28 February 2015

Keywords:
Specific language impairment
Speech motor learning
Motor skill
Nonword repetition
Speech kinematics

ABSTRACT

Children with specific language impairment (SLI) often perform below expected levels, including on tests of motor skill and in learning tasks, particularly procedural learning. In this experiment we examined the possibility that children with SLI might also have a motor learning deficit. Twelve children with SLI and thirteen children with typical development (TD) produced complex nonwords in an imitation task. Productions were collected across three blocks, with the first and second blocks on the same day and the third block one week later. Children's lip movements while producing the nonwords were recorded using an Optotrak camera system. Movements were then analyzed for production duration and stability. Movement analyses indicated that both groups of children produced shorter productions in later blocks (corroborated by an acoustic analysis), and the rate of change was comparable for the TD and SLI groups. A nonsignificant trend for more stable productions was also observed in both groups. SLI is regularly accompanied by a motor deficit, and this study does not dispute that. However, children with SLI learned to make more efficient productions at a rate similar to their peers with TD, revealing some modification of the motor deficit associated with SLI.

Learning outcomes: The reader will learn about deficits commonly associated with specific language impairment (SLI) that often occur alongside the hallmark language deficit. The authors present an experiment showing that children with SLI improved speech motor performance at a similar rate compared to typically developing children. The implication is that speech motor learning is not impaired in children with SLI.

1. Introduction

While specific language impairment (SLI) was initially defined as the quintessential impairment of language, many cognitive and motor deficits co-occur with the observed language deficit (cf. Leonard, 2014, for a history of the term "specific language impairment"). Concomitant impairments have been observed in the domains of auditory processing (Tallal et al., 1996), short-term phonological memory (Dollaghan & Campbell, 1998; Gathercole, 2006), statistical and procedural learning (Hedenius et al., 2011; Lum, Conti-Ramsden, Morgan, & Ullman, 2014; Plante, Gómez, & Gerken, 2002; Tomblin, Mainela-Arnold,

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http://dx.doi.org/10.1016/j.jcomdis.2015.02.001
0021-9924/

& Zhang, 2007), and motor skill (Bishop & Edmundson, 1987; Hill, 2001; Zelaznik & Goffman, 2010). One notable exception is general intelligence, which by definition, is not implicated in SLI (Lee & Tomblin, 2014; Leonard, 2014; but cf. Gallinat & Spaulding, 2014).

Focusing on motor skill, children with SLI often perform poorly on motor tasks. This performance lag is to such an extent that about one third to one half meet diagnostic criteria for developmental motor coordination disorder (Brumbach & Goffman, 2014; Flapper & Schoemaker, 2013). Not surprisingly, children with SLI score more poorly than their peers with typical development (TD) across many—though not all—movement tasks. Powell and Bishop (1992) found motor impairments in children with SLI in tasks including peg moving, bead threading, rolling a ball with a stick, and balancing on one foot. Zelaznik and Goffman (2010) compared children with SLI and TD on the Bruininks–Oseretsky motor tasks (Bruininks, 1978), including balance, bilateral coordination, and visuo-motor control. Children with SLI performed more poorly than their peers with TD, indicating relative difficulties in fine and gross motor performance. However, in a tapping task assessing timing, Zelaznik and Goffman reported similar performance for the the SLI and TD groups. Tapping tasks are closely related to cerebellar function, and the cerebellum is generally thought to manage movement precision and timing. Based on their findings, Zelaznik and Goffman did not find evidence of cerebellar disfunction in children with SLI. Their conclusions are further supported by recent studies of typical eyeblink conditioning in children with SLI, a task that also relies heavily on the cerebellum (Hardiman, Hsu, & Bishop, 2013; Steinmetz & Rice, 2010).

Bishop and Edmundson (1987) analyzed longitudinal performance on language and motor tasks in children with SLI and their peers with TD, beginning at age four. They found that children with SLI were slower in a peg-moving task and were more likely to move pegs to the wrong locations. Over the course of three sessions spanning 18 months, however, children with SLI improved at a rate comparable to the improvement rate of their peers with TD.

Motor impairments accompanying SLI can also be seen in tasks focusing on speech movements (hereafter *speech motor* tasks). Goffman (1999) asked children with TD and SLI to produce multiple tokens of CVCVC nonwords with either trochaic stress (e.g., /pʌpəp/, compare to 'BA-by') or iambic stress (e.g., /pəpʌp/, compare to 'bal-LOON'). Lip and jaw movements during these productions were then overlaid and compared to one another to derive a measure of articulatory stability. Children with SLI showed less stable lip and jaw movements compared to their peers with TD across words and across stress patterns. Similarly, Goffman (2004) found that children with SLI were less stable when producing iambic sequences composed of a function word followed by a novel content word (e.g., "a babb", compare to "a cow"). Overall, children with SLI are poorer at implementing the articulatory movements associated with prosodic sequences than their typically developing peers.

In addition to motor deficits, learning deficits are commonly observed alongside SLI, particularly in procedural and statistical learning tasks. Plante et al. (2002) compared language/learning disabled young adults to typical peers in a statistical word-order-learning paradigm. Both groups listened to strings of syllables that were arranged according to word-order rules. For example, the rule might allow the syllable *jed* to be followed by *fim* and then *tup*, or *jed fim tup*. However, *jed* could not be followed by *tup* and then *fim*. Participants then had to distinguish between new strings that were either consistent with the word-order rules or violated them. The language/learning disabled group performed more poorly on the task than their peers with TD, primarily because they rated rule-breaking strings like *jed tup fim* as acceptable.

Evans, Saffran, and Robe-Torres (2009) used a speech segmentation task (cf. Saffran, Aslin, & Newport, 1996) to examine statistical learning in children with TD and SLI. Both groups listened to a stream of syllables like *dutabatutibupidabupatubibupadababupudutaba*, in which groups of three syllables tended to occur together. For example, the syllable *pi* was always followed by *dabu*, although what followed *bu* varied. Thus, *pidabu* acted like a word in the syllable stream but *dabupa* did not. Across two experiments, children with SLI struggled to learn the consistent syllable combinations compared to their peers with TD.

Regarding procedural learning in serial reaction time tasks, a veritable explosion of studies have been conducted in the last few years. There are a few reports of typical performance in children with SLI (Gabriel, Maillart, Guillaume, Stefaniak, & Meulemans, 2011), but more often children with SLI perform poorly relative to their peers with TD (cf. Lum et al., 2014 for a meta-analysis). For example, Lee and Tomblin (2014) had young adults (age range 19–25) with and without language difficulties complete several procedural learning tasks, including a serial reaction time task, a pursuit rotor task, a weather prediction task, and a nonword repetition priming task. Participants with language difficulties performed significantly more poorly than their typical peers on all tasks but the first, suggesting that language impairment correlates with procedural learning impairment across a variety of tasks.

A similar study with younger children (age range 7–11) was recently completed by Hsu and Bishop (2014). Those authors observed impaired performance in children with SLI relative to same-age peers on a serial reaction time task and a word learning task. In contrast to Lee and Tomblin (2014), they observed a non-significant difference between the groups in a pursuit rotor task. The two groups even performed similarly after a two-week hiatus. Given the apparent strengths and weaknesses of their participants with SLI, Hsu and Bishop conclude that the procedural deficit may be most striking in tasks with sequential patterns.

Many studies have reported procedural learning impairments in children with SLI during immediate learning, but Hedenius et al. (2011) tested procedural learning over time. In that study, children with SLI and TD completed an Alternating Serial Reaction Time task in which participants pressed a key corresponding to the location of a picture on a screen. A repeating sequence occurred across trials, but was interspersed by trials where the location was random. The results revealed similar performance across the two groups on the first day, but children with language impairments—and children