CORTEX 45 (2009) 119–130

available at www.sciencedirect.com

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journal homepage: www.elsevier.com/locate/cortex

Special issue: Research report

Rhythmic motor entrainment in children with speech and language impairments: Tapping to the beat

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ARTICLE INFO

Article history:
Received 12 January 2007
Reviewed 1 May 2007
Revised 4 July 2007
Accepted 24 September 2007
Published online 31 October 2008

Keywords:
Entrainment
Language
Auditory
Rhythm
Literacy

ABSTRACT

In prior work (Corriveau et al., 2007), we showed that children with speech and language impairments (SLI) were significantly less sensitive than controls to two auditory cues to rhythmic timing, amplitude envelope rise time and duration. Here we explore whether rhythmic problems extend to rhythmic motor entrainment. Tapping in synchrony with a beat has been described as the simplest rhythmic act that humans perform. We explored whether tapping to a beat would be impaired in children for whom auditory rhythmic timing is impaired. Children with SLI were indeed found to be impaired in a range of measures of paced rhythmic tapping, but were not equally impaired in tapping in an unpaced control condition requiring an internally-generated rhythm. The severity of impairment in paced tapping was linked to language and literacy outcomes.

There is considerable evidence that children with speech and language difficulties (Specific Language Impairment or SLI) have co-occurring motor problems. Although SLI is defined on the basis of expressive and receptive language deficits that interfere with the educational achievement and communication ability of the child, many studies report co-morbidity with motor co-ordination deficits. For example, Robinson (1991) found that 90 per cent of his sample of children with speech and language difficulties had motor impairments. There are reports of difficulties with both gross motor skills such as balance (Hill, 1998) and with fine motor skills such as bead-threading and speeded tapping (Bishop, 2002; Bishop and Edmundson, 1987; Dewey et al., 1988; Owen and McKinlay, 1997; Preis et al., 1997; see Hill, 2001 for a review). In a review of the literature, Hill (2001) found that most children with SLI also have a diagnosis of developmental coordination disorder (DCD). DCD is defined in terms of movement difficulties out of proportion with general development and intelligence.

Despite the variety of motor tasks that have been given to children with language difficulties, the literature is very inconsistent. For example, the peg-moving task is frequently employed to examine fine motor abilities in children with SLI. In this task, children are required to move pegs from one end of a board to the other and are timed while (1) using their dominant hand only, (2) using their non-dominant hand only, and (3) using both hands together. Although many studies have found that children with SLI take longer to complete this task than age-matched, normally-developing children (Bishop, 2002; Bishop and Edmundson, 1987; Owen and

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doi:10.1016/j.cortex.2007.09.008

McKinlay, 1997; Powell and Bishop, 1992; Preis et al., 1997), several others have failed to find a significant difference on this same measure (Archer and Witelson, 1988; Bradford and Dodd, 1996; see Hill, 2001 for a review). One explanation for this inconsistency may be poor matching of the children with SLI to the typically developing children who usually comprise the control group. Most of the research on motor impairments in SLI to date has failed to match groups for nonverbal IQ. Further, many studies have failed to include a younger, language age-matched control group to control for linguistic development (with the exception of Bishop and Edmundson, 1987; see Hill, 2001 for a review). Nevertheless, poor control group matching alone is not sufficient to explain the variability in the motor abilities of children with SLI that is observed across studies.

An alternative possibility is that the motor skills of children with SLI are not globally impaired. Rather, the motor difficulties observed may be specific to certain tasks. Although children diagnosed with speech and language difficulties usually exhibit no obvious neurological dysfunction, our interest here is whether there are subtle neural impairments that affect both language and motor development. One possible candidate is an impairment in the neural mechanisms for the perception and expression of rhythm and timing. For example, children with SLI do seem to have difficulties with auditory cues to the rhythmic timing of language. Corriveau et al. (2007) tested children with SLI along with language age (LA)-matched and chronological age (CA)-matched controls using non-speech auditory discrimination tasks that isolated two rhythmic cues important for speech segmentation: amplitude envelope rise time and duration. Corriveau et al. found that children with SLI were significantly impaired in their discrimination of these rhythmic cues, but were not impaired on two non-speech auditory tasks that were not tied to rhythm (intensity and temporal order judgements). Furthermore, performance on the auditory rhythmic processing measures accounted for a significant amount of unique variation in language and literacy ability after controlling for age, IQ and task demands. One possibility is that the rhythmic processing deficit observed by Corriveau et al. (2007) in the auditory realm extends across receptive and expressive modalities.

In this study, we explore possible links between motor and auditory rhythmic timing in children diagnosed with SLI. Our motor timing task was tapping a finger in synchrony with a metronome beat. This task has been widely used in explorations of adult human rhythmic and timekeeping behaviour. In a recent study with 88 children aged 4–12 years, McAuley et al. (2006) reported that the range of accessible tapping rates widened during childhood, with older children able to tap accurately to a wider range of rates. The preferred spontaneous tempo between ages 8–12 years was around 500 msec (2 Hz). Correlational analyses carried out by McAuley et al. (2006) showed that children with higher nonverbal IQ could synchronize their tapping accurately to a wider range of rates. This latter finding illustrates the importance of controlling for non-verbal IQ in developmental studies of motor abilities. Tapping to a beat combines auditory and motor rhythms, and hence was expected to be impaired in our sample of children with SLI. It is often noted that timing, duration perception and rhythm perception and production activate the same brain areas, notably premotor and supplementary motor areas, the cerebellum and the basal ganglia (see Grahn and Brett, 2007). Although many studies of children with SLI have used *repetitive* tapping measures (in which children are asked to tap as fast as they can; Archer and Witelson, 1988; Bishop, 2002; Dewey et al., 1988; Hughes and Sussman, 1983), to date rhythmic tapping tasks have not been administered to an SLI population.

Some of the motor tasks used in previous studies of children with SLI have required expressive rhythm abilities, but these requirements have been indirect. An example is Powell and Bishop's (1992) throw-clap-catch task, in which children threw a ball, clapped, and then caught the ball again. Wolff and colleagues (Waber et al., 2000; Wolff, 2002; Wolff et al., 1990) have examined rhythmic finger tapping in children with developmental dyslexia, and some of these children may have also had language impairments. Wolff and colleagues have found consistently that children with reading problems have trouble with rhythmic finger tapping, using both unimanual and bimanual tapping tasks. For example, using a task requiring children to tap to a cued beat, Wolff (2002) found that children with dyslexia tended to overanticipate the cued stimulus by as much as 100 msec, unlike their CA-matched peers. Wolff interpreted this overanticipation as indicative of a deficit in an internal timing mechanism in children with developmental dyslexia. Meanwhile, Goswami and colleagues have reported deficits in tasks measuring sensitivity to auditory cues to rhythmic timing in children with developmental dyslexia (Goswami et al., 2002; Muneaux et al., 2004; Richardson et al., 2004).

Additional studies of rhythmic finger tapping in both children with developmental dyslexia (Wolff et al., 1990) and learning impaired children (Waber et al., 2000) have reported that in each case the clinical population showed increased variability (a greater standard deviation) in the time interval between finger taps (inter-tap interval – ITI). Furthermore, Waber et al. (2000) found that the children who exhibited reading problems were also the children with the greatest variability in ITI, and that variability in ITI predicted achievement in reading, spelling, and maths for both learning impaired and control children, even when non-verbal IQ was controlled. However, this study measured tapping ability by summing across paced tapping (for 10 sec to a metronome beat) and unpaced tapping (continuing to tap to the beat for a further 20 sec when the metronome had stopped). Hence both entrainment and tapping to an internally-generated rhythm were conflated in the analyses relating tapping performance to academic performance.

Similar impairments in auditory and motor rhythm abilities were found in a recent study of adults with developmental dyslexia by Thomson et al. (2006). They examined auditory and motor rhythm abilities in college students with dyslexia and age- and IQ-matched controls. Participants were asked to tap to a metronome beat both in the presence and the absence of a cue; data from these two conditions were analyzed separately. The students with developmental dyslexia showed reliably greater ITI variability at rates of both 1.5 and 2 Hz when tapping to a metronome beat, and at the 2 Hz rate when tapping in the absence of a beat. Partial correlations