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Speech and oro-motor function in children with Developmental Coordination Disorder: A pilot study

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Abstract

The protracted maturation and development of speech articulation underlies the complexity of the skill, and suggests it may be an area susceptible to a general deficit in motor control. Recent research suggests a high co-occurrence between Developmental Coordination Disorder (DCD) and disordered speech production. Despite this there has been no systematic investigation of speech motor control in children with DCD. We conducted a pilot study which looked at speech motor control in a group of children with DCD (N=5) and a group typically developing (TD) children (N=5). Movements of the upper and lower lip were recorded during: non-verbal movements; single words; syllable sequences; and sentence repetition. In the baseline conditions (normal talking speed or an isolated utterance) children with DCD demonstrated a typical pattern of movement, albeit a slower and shorter movement. In contrast, when task complexity was increased the children with DCD showed an atypical pattern of movement.It was concluded that children with DCD demonstrate inferior motor control for complex speech gestures, suggesting that the motor deficit in DCD may indeed be a more generalized phenomenon affecting the speech motor system.

Introduction

The articulation of speech is a mechanical act that is executed by the complex speech apparatus including infralaryngeal (e.g. lungs), laryngeal and supralaryngeal (e.g. tongue, lips) involvement as well as neural control mechanisms. In this way, speech articulation can be conceptualised as a complex skill of the oral motor system that requires careful and precise coordination (Keller, 1990). Studies of speech motor development have shown that children, and even adolescents, produce speech gestures that are similar to adults but do so more slowly and with greater temporal variability (Smith & Goffman, 1998; Walsh & Smith, 2002). A similar increase in variability is seen in adults with stutter (Bousten, Brutten, & Watts, 2000; Smith & Kleinow, 2000) and apraxia (Strand & McNeil, 1996)this has been attributed to underlying motor control mechanisms (Walsh & Smith, 2002). The protracted development of speech articulation throughout adolescence underlines the complexity of this skill and the underlying deficits in motor control mechanisms in disordered speech suggests that the development of speech articulation may be an area particularly susceptible to a general deficit in motor function.

Within the normal population a small proportion of children (~5%) present with Developmental Coordination Disorder (DCD) and exhibit difficulties in the coordination of eye and body movements which cannot be accounted for in terms of an intellectual impairment or identifiable physical disorder (American Psychiatric Association, 1994). Children with DCD have difficulties with fine motor tasks such as tracing, writing and fastening buttons, and/or in gross motor tasks such as jumping, hopping and catching a ball (Sugden & Wright, 1998). Children with DCD continue to exhibit problems throughout adolescence and do not simply grow out of their coordination problems (Losse et al., 1991). Research has demonstrated the increased variability of movement seen in these children (for example see (Visser, 2003; Wilmut & Wann, 2008)) and the high co-occurrence with other childhood disorders (for example see (Kaplan, Wilson, Dewey, & Crawford, 1998; Visser, 2003)). One such co-occurrence is seen between DCD and speech and language disorders (Gaines & Missiuna, 2006; Hill, Bishop, & Nimmo-Smith, 1998). A review of the literature concerning motor skill in specific language impairment (SLI) has highlighted that many studies have found significant movement difficulties in children (Hill, 2001). Moreover, the movement difficulties seen in children with SLI are very similar to those seen in children with DCD (Hill, 2001; Hill et al., 1998). To our knowledge, however, speech motor control has not yet been systematically investigated in children with DCD.

The current pilot study aimed to directly investigate lip movement in a group of children with DCD; the secondary acoustic aspects of the speech output produced lie beyond the scope of this initial study. Tasko & McClean (2004) have suggested that a description of speech production needs to include more than simple open-and-close movements which may not be representative of day-to-day communication (Tasko & McClean, 2004). Therefore, kinematics were measured under four types of utterance ranging from open-and-close movements to sentence production. In addition, different levels of complexity were introduced: firstly each utterance was performed at a baseline level (normal talking speed or repeated just once); then performed again at a level demanding a greater degree of motor control (fast talking speed or a continuous string of utterances). It was hypothesised that speech gestures that were more complex would specifically disadvantage children with DCD and the resulting pattern of temporal and spatial labial kinematic measures in the DCD group would be different compared to age-matched controls.

Method

Participants

Children with DCD were recruited through the Dyspraxia Foundation, UK. Five families agreed to participate and the age range of this group was from 9 to 13 years. For each participant with DCD a typically developing (TD) participant was recruited and age matched to within 6 months. All children were assessed using the Movement Assessment Battery for Children (MABC Henderson, Rose, & Henderson, 1992). Children with DCD all fell below the 2nd percentile and TD children all fell above the 20th percentile. Participants were also assessed using the WISC-R and all fell within a normal range (an IQ score between 85 and 125). See table 1 for details of participant scores. From the pre-screening it was judged that the children with DCD met criteria A-D of the DSM IV, but also that their selection was in tune with the 2006 Leeds Consensus Statement (Sugden, 2006). None of the participants had a history of speech and language therapy referral or intervention and none reported difficulties with speech production.

INSERT TABLE 1 HERE

Apparatus

A Vicon motion capture system running at 120Hz was used to track the movement of four reflective markers (6.5mm in diameter). The markers were placed in the middle of the forehead, upper lip, lower lip and chin.

Procedure

The research underwent ethical review by the University of Reading ethics committee and was allowed to proceed. Children were asked to repeat or mimic the sounds of the experimenter. The study consisted of 4 main sections: non-verbal; single words; syllable sequence; and sentence repetition. For the *non-verbal section* children were asked to open and close their mouth at both a normal speed and a fast speed in a continuous fashion until asked to stop. The *single words*, consisted of the child repeating back 35 single syllable words at a normal talking speed (Kent, Weismer, Kent, & Rosenbek, 1989). For *syllable sequence* children uttered plosive consonant-vowel (CV) nonsense syllables i.e., ‘pa’, ‘ta’, ‘ka’, ‘ba’, ‘da’ and ‘ga’ in several ways. Initially these were uttered once in isolation (single sequence, mono-syllable type, e.g. ‘pa’), then each syllable was repeated continuously (repeated sequence, mono-syllable type, e.g. ‘papapa…’), this was done using a normal talking speed only. Following this, the CV syllables were combined and uttered once as a single nonsense word (single sequence, tri-syllable type, i.e. ‘pataka’, and ‘badaga’). These tri-syllabic nonsense words were also repeated continuously (repeated sequence, tri-syllable type, i.e. ‘patakapataka…’, and ‘badagabadaga…’). For repeated sequences, children were asked to repeat the sound continuously as many times as they could, without pausing or taking a breath. For the *sentence repetition* section, children were asked to repeat the sentence ‘Buy bobby a poppy’. This was done at a normal talking speed and then at a fast talking speed. For all sections: non-verbal, single words, syllable sequence and sentence repetition children completed two trials of each manipulation. If a trial was not completed correctly e.g. the child laughed or turned away, that trial was repeated. Tasks were completed in a set order and this was the same for all children.

Data analysis

Movements of the mouth were analysed using tailored MatLab routines which calculated two dependent variables: duration of lip movement (ms) and; movement extent between the lips (mm). Duration of lip movement was calculated as the difference between movement onset and movement offset, these time points were determined from velocity profiles, the time at which velocity departed from zero (>3% max vel) or returned to zero (<3% max vel) was identified by eye to avoid the localisation of spurios jitters. Changes in the position of the forehead marker were used to eliminate movements of the head. Data were averaged across the two trials. Effect size (partial-eta squared, η^2, equivalent to r^2) which quantifies the magnitude of the observed effect independently of sample size, is reported for all significant results. Cohen (1992) reported a small effect size is indicated by r=0.10 (r^2=0.01), a medium effect size by r=0.30 (r^2=0.09) and a large effect size by r=0.50 (r^2=0.25) (Cohen, 1992).

Results

Non-verbal movements and single words

Data for non-verbal movements and for single words can be found in Table 2. Open-close movements were compared using a two-way ANOVA (speed x group) which found a main effect of speed for both duration of movement [F(1,8)=38.18 p<.001 η^2=.83] and extent of movement between the lips [F(1,8)=13.06 p=.007 η^2=.62]. No significant effects or interactions of group were found [F<1]. These results show that both groups reduced duration of movement and extent of lip excursion to a similar extent in the fast condition relative to the normal speed condition. For the single words two independent samples t-tests (group, only a normal speed was used) found no significant effect of group for either duration of movement or extent of movement between the lips.

INSERT TABLE 2 HERE

<u>Syllable sequence</u>

The six sounds (pa, ta, ka, ba, da, ga) were collapsed across consonant types (labial vs. alveolar vs. velar), for the tri-syllable types this meant splitting one utterance into component parts. Duration of movement and extent of movement between the lips were then considered across syllable type (mono-syllable [‘pa’] vs. tri-syllable [pa from ‘pataka’]), consonant type (labial vs. alveolar vs. velar), sequence type (single [‘pa’] vs. repeated [each pa in ‘papapapa’]) and group (TD vs. DCD).

Overall movement duration and number of syllables produced

Initially overall duration of each repeated syllable sequence and number of syllable produced was considered for each group. These data can be found in table 3. For the mono-syllable sequences duration and number of syllables was analysed using a two-way ANOVA (consonant type x group). A significant main effect of group was found for both duration [$F(1,8)=5.72$ $p=.044$ $\eta^2=.42$] and number of syllable produced [$F(1,8)=7.24$ $p=.028$ $\eta^2=.48$]. A significant main effect of consonant was also found or number of syllable [$F(2,16)=8.743$ $p=.003$ $\eta^2=.522$], post-hoc tests indicated that this was due to a higher number of syllables produced in the labial consonant type compared to the other consonant types. The tri-syllable sequences were analysed using a one-way ANOVA (group), again a significant main effect of group was found for both duration [F(1,8)=8.65 p=.019] and number of syllable produced [F(1,8)=6.87 p=.031]. These results of group indicate that typically developing children produced longer repeated syllable sequences (mono- and tri-) with a greater number of syllables per sequence.

INSERT TABLE 3 HERE

Duration of movement

A four-way ANOVA (syllable type x consonant type x sequence type x group) was used to consider the duration of movement. Results indicated that: duration was shorter for mono- vs. tri-syllable types (syllable type effect [F(1,8)=12.14 p=.008 η^2=.60]); movement extent between the lips was variable across consonant type (consonant type effect [F(2,16)=7.43 p=.005 η^2=.48]); and duration of movement was shorter for single vs. repeated sequence types (sequence type effect [F(1,8)=17.30 p=.003 η^2=.65]). An interaction between sequence type x consonant type x group was also seen [F(2,16)=7.09 p=.006 η^2=.47]. To further consider this three-way interaction; sequence type was considered separately across consonant type, syllable type and group using a three-way ANOVA. For the single sequence type: duration was shorter for mono- vs. tri-syllable types (syllable type effect [F(1,8)=15.99 p=.004 η^2=.67]); duration was different across consonant types (consonant type effect [F(2,16)=8.09 p=.004 η^2=.50]); and the difference in duration across consonant types was different across groups (consonant type x group interaction [F(2,16)=4.02 p=.038 η^2=.33]). For the repeated sequence type movement duration differed across the three consonant types (consonant type effect F(2,16)=3.89 p=.042 η^2=.33]). Together these results indicate no overall difference between groups in terms of duration;

however, there are some differences across groups in the single sequence type in terms of how duration of movement changes across consonant type.

Movement extent between lips

Movement extent between the lips across the four variables is illustrated in Figure 1. A four-way ANOVA (syllable type x consonant type x sequence type x group) considered movement extent between lips and found: movement extent was less for mono- vs. tri-syllable types (syllable type effect [F(1,8)=7.21 p=.028 η^2=.47]); extent between the lips was variable across consonant types (consonant type effect [F(2,16)=16.34 p<.001 η^2=.67]); and extent between the lips was less for single vs. repeated sequence types (sequence type effect [F(1,8)=42.61 p<.001 η^2=.84]). A sequence type x group interaction was also seen [F(1,8)=48.46 p<.001 η^2=.86]. To further consider this two-way interaction single and repeated utterances were considered separately using a three-way ANOVA (consonant type x syllable type x group). For the single sequence type: extent between the lips was less for the children with DCD vs. TD children (group effect [F(1,8)=16.44 p=.004 η^2=.67]); extent was greater for mono- vs. tri-syllable types (syllable type effect [F(1,8)=11.25 p=.001 η^2=.85]); and there was a variable pattern of movement across consonant type (consonant type effect [F(2,16)=3.43 p=.057 η^2=.30]). For the repeated condition: extent between the lips was lower for mono- vs. tri-syllable types (syllable type effect [F(1,8)=5.69 p=.004 η^2=.42]) and; there was a variable pattern of movement across consonant types (consonant type effect [F(2,16)=31.89 p<.001 η^2=.79]). An interaction between consonant type and group [F(2,16)=6.29 p=.01 η^2=.44] was also found, suggesting the change in extent across syllable type (mono to tri) and the change in extent across consonant type (pa/ba, ta/da, ka/ga) are not the same for the two groups, due to children with DCD showing larger movement extent for bilabial consonants. Overall these results indicate that although the children with DCD move their lips less in single sequence types they show a pattern of movement across consonant and syllable types similar to that seen in the controls. In contrast, for the repeated sequence type there is no overall movement extent difference.

INSERT FIGURE 1 HERE

Sentence repetition

Overall utterance duration

In order to determine whether utterance duration of ‘Buy Bobby a Poppy’ changed from the normal to the fast speed condition a paired-samples t-test (speed) was carried out for both groups. A significant effect of speed was seen for the TD children [t(4)=3.51 p=.025] but not the children with DCD [p=.266]. These results indicate children with DCD did not speed up in the fast condition relative to their normal speed, while TD children did.

Duration of component syllables

The sentence was split down into component syllables: ‘buy’, ‘bob’, ‘bya’, ‘pop’, ‘py’, syllable was then treated as an independent variable with five levels, this data is illustrated in Figure 2. For duration of movement a three-way ANOVA (speed x syllable x group) found a syllable x group interaction [F(4,32)=2.53 p=.006 η^2=.24] suggesting that the change in pattern across syllables was different for the two groups. To investigate this interaction, speed and syllable were considered separately for each group. The TD children showed a shorter duration of movement in the fast vs. the normal speed condition (speed effect [F(1,4)=11.13 p=.029 η^2=.73]) and; a variable pattern of duration across syllables (syllable effect [$F(4,16)=3.35$ $p=.036$ $\eta^2=.46$]). No speed x syllable interaction was found, indicating that although the TD children shorten duration of movement from the normal to fast speed they maintained a similar pattern of duration across syllables for both speed conditions. For the children with DCD an effect of syllable [$F(4,16)=10.06$ $p<.001$ $\eta^2=.37$] but not speed was found, more interestingly a marginal interaction of speed x syllable was found [$F(4,16)=2.38$ $p=.094$ $\eta^2=.37$]. This marginal interaction needs to be treated with some caution given the small sample size. However, this would seem to indicate that the children with DCD do not shorten duration of movement across speed conditions, but they tended towards changing the pattern of duration across syllables from the normal to fast condition. Specifically, the DCD group slowed towards the end of the sequence in the latter condition.

Movement extent between the lips for component syllables

A similar three-way ANOVA (speed x syllable x group) was carried out for movement extent between the lips. Extent between the lips was smaller for the fast vs. normal speed (speed effect [$F(1,8)=16.90$ $p=.003$ $\eta^2=.68$]); extent between the lips was variable across syllable (syllable effect [$F(4,32)=44.14$ $p<.001$ $\eta^2=.85$]) and; extent was smaller in children with DCD compared to the TD children (group effect [$F(1,8)=9.02$ $p=.017$ $\eta^2=.53$]). An interaction between group and syllable [$F(4,32)=3.71$ $p=.014$ $\eta^2=.32$] and group and speed [$F(1,8)=9.43$ $p=.015$ $\eta^2=.85$] was also found. To further consider these interactions syllable and speed were considered for each group separately using a two-way ANOVA (speed x syllable). The TD children showed an effect of speed [$F(1,4)=40.37$ $p=.003$ $\eta^2=.91$] and syllable [$F(4,16)=48.42$ $p<.001$ $\eta^2=.92$]. No speed x syllable interaction was found, indicating that the shortening of movement extent is proportional across all syllables. In contrast, the children with DCD show an effect of syllable [$F(4,16)=9.14$ $p<.001$ $\eta^2=.97$] and a marginal syllable x speed interaction [$F(4,16)=2.81$ $p=.061$ $\eta^2=.41$]. These results indicate that the children with DCD do not shorten extent across conditions, but they do tend towards altering the pattern of movement from the normal to the fast speed condition. In the DCD group, movement extent for the initial syllable is compromised in the fast condition, but speed (as reported in the previous section) was similar to the TD group. Again interpretations from marginal effects need to be treated with caution.

INSERT FIGURE 2 HERE

Discussion

This study considered the motor control of speech in a group of children with DCD and a group of TD children. Results have shown no differences in terms of duration or extent of movement between these groups for non-verbal movements or for single syllable words. There was a small group difference in the syllable sequence task, where the DCD group was primarily slowed on single syllable sequences. For the more complex sentence repetition task, under normal self-selected talking speed, children with DCD simply showed shortened movements in terms of extent and duration. At this level, the children with DCD showed a similar pattern of movement across the syllables compared to the TD children. However, when task demands increased and children had to speak faster, a different pattern emerged. TD children shortened movement extent and duration of movement but they maintained the same pattern of lip movement across syllables. That is to say, the proportion of time and distance allocated to each syllable was unchanged. In contrast, for the fast condition, children with DCD did not shorten lip movement in terms of time or distance, however, they did tend towards changing the pattern of movement across the syllables, such that it started to deviate from what was seen in the baseline condition and what was seen in the TD controls. Children with DCD showed a reduction in lip movement extent at the start of the sequence and an increase in movement time at the end of the sequence, suggesting a trade-off between these two parameters in response to the increased task demands in terms of speed. In sum, these results suggest that with low task demands (open-close movements, single syllable words, self-paced speech) the children with DCD, at best show a pattern of performance indistinguishable from the controls and at worse show slightly spatially and temporally shortened movements. With a more complex sentence repetition task and higher task demands (faster production) the children with DCD show patterns of motor control which are markedly different from TD children.

The children with DCD who took part in this study showed no overt speech and language problems but they did display some difficulties with oro-motor control. As the control group of healthy age-matched children were typical in that they had no reported or observed speech or cognitive concerns, we have no reason to believe that the typical children would be anything but typical in the types of tasks used in the study and comparable with other children, although it should be noted that comparison between studies is not straightforward due to differences in the age of children, exact stimuli, instructions and scoring parameters (Williams & Stackhouse, 2000). While the results of this novel pilot study, therefore, provide preliminary evidence that an underlying movement coordination disorder can disrupt typical oro-motor functioning upon kinematic examination even though this may not be evident from casual observation. Previous studies have indicated that children with SLI and with Developmental Verbal Dyspraxia both show overt motor difficulties on fine motor reach-and-grasp type tasks (for a review see (Hill, 2001)). Given than DVD is characterised by a difficulty in programming movement (Parisse & Maillart, 2009) we would expect to see similar disordered oro-motor functioning in children with DVD as has been seen in the current study. Further investigation, including a thorough investigation into children with DCD both with and without speech and language problems is needed to unpick these findings. It has been suggested that children with DCD recruited from community settings show a lesser degree of difficulties compared to those recruited through clinical settings (Wilmut, 2010). Given this, it is possible that a group from a clinical setting may show a greater deviance from a typical population in this task than is seen here; this could plausibly coincide with a higher rate of speech and language comorbidities in such a sample.

In conclusion, children with DCD who do not display overt speech and language problems, tend towards an atypical pattern of lip movement during complex speech tasks. This small scale pilot study suggests that oro-motor control in children with DCD is an area worthy of examination in understanding the full motor phenotype of DCD. These early results show that the motor deficit in DCD is not confined to the limb control and may indeed be a more generalized phenomenon affecting the speech motor system as well.

References

American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: APA.

Bousten, F. R., Brutten, G. J., & Watts, C. R. (2000). Timing and intensity variability in the metronomic speech of stuttering and nonstuttering speakers. *Journal of Speech, Language and Hearing Disorders, 43*, 513-520.

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*(1), 155-159.

Gaines, R., & Missiuna, C. (2006). Early identification: are speech/language-impaired toddlers at increased risk for Developmental coordination disorder. *Child: Care, Health and Development, 33*(3), 325-332.

Henderson, L., Rose, P., & Henderson, S. (1992). Reaction-time and movement time in children with a developmental coordination disorder. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 33*(5), 895-905.

Hill, E. L. (2001). Non-specific nature of specific language impairment: a review of the literature with regard to concomitant motor impairments. *International Journal of Language and Communication Disorders, 36*(2), 149-171.

Hill, E. L., Bishop, D. V. M., & Nimmo-Smith, I. (1998). Representational gestures in Developmental Coordination Disorder and specific language impairment: Error-types and the reliability of ratings. *Human Movement Science, 17*(4-5), 655-678.

Kaplan, B. J., Wilson, B. N., Dewey, D., & Crawford, S. G. (1998). DCD may not be a discrete disorder. *Human Movement Science, 17*(4-5), 471-490.

Keller, E. (1990). Speech motor timing. In W. J. Hardcastle & A. Marchal (Eds.), *Speech Production and Speech Modelling*. Boston: Kluwer Academic Publications.

Kent, R. D., Weismer, G., Kent, J. F., & Rosenbek, J. C. (1989). Toward phonetic intelligibility testing in Dysarthia. *American Speech-Language-Hearing Association, 45*, 483-499.

Losse, A., Henderson, S., Elliman, D., Hall, D., Knight, E., & Jongmans, M. (1991). Clumsiness in children - do they grow out of it? A 10 year follow up study. *Developmental Medicine and Child Neurology, 33*, 55-68.

Parisse, C., & Maillart, C. (2009). Specific language impairment as systemic developmental disorders. *Journal of Neurolinguistics, 22*, 109-122.

Smith, A., & Goffman, L. (1998). Stability and patterning of speech movement sequences in children and adults. *Journal of Speech, Language and Hearing Research, 41*(1), 18-30.

Smith, A., & Kleinow, J. (2000). Kinematic correlates of speaking rate changes in stuttering and normally fluent adults. *Journal of Speech, Language and Hearing Research, 43*, 521-536.

Strand, E. A., & McNeil, M. R. (1996). Effects of length and linguistic complexity on temporal acoustic measures in apraxia of speech. *Journal of Speech, Language and Hearing Research, 39*(1018-1033).

Sugden, D. (Ed.). (2006). *Leeds Consensus statement. Developmental Coordination Disorder as a specific learning difficulty*. Leeds.

Sugden, D., & Wright, H. C. (1998). *Motor coordination disorders in children* (Vol. 39). London: SAGE publications.

Tasko, S. M., & McClean, M. D. (2004). Variations in articulatory movement with changes in speech task. *Journal of Speech, Language and Hearing Research, 47*, 85-100.

Visser, J. (2003). Developmental coordination disorder: a review of research on subtypes and comorbidities. *Human Movement Science, 22*, 479-493.

Walsh, B., & Smith, A. (2002). Articulatory movements in adolescents: Evidence for protracted development of speech motor control processes. *Journal of Speech, Language and Hearing Research, 45*, 1119-1133.

Williams, P., & Stackhouse, J. (2000). Rate, accuracy and consistency: Diadochokinetic performance of young, normally developing children. *Clinical Linguistics and Phonetics 14*, 267-293.

Wilmut, K. (2010). Selection and assessment of children with Developmental Coordination Disorder. *Developmental Medicine and Child Neurology, 52*(3), 229.

Wilmut, K., & Wann, J. P. (2008). The use of predictive information in goal directed action in children with Developmental Coordination Disorder. *Experimental Brain Research, 191*(4), 403-418.

Table 1. Details of age, MABC percentile score and WAIS score for each individual participant. Matches between DCD and TD participants are indicated by rows.

Participants with DCD				Typically developing participants			
Number	Age	MABC percentile	WAIS score	Number	Age	MABC percentile	WAIS score
1 DCD	9yrs 9mo	1	96	1 TD	9yrs 3mo	32	124
2 DCD	9yrs 11mo	1	122	2 TD	9yrs 6mo	70	92
3 DCD	12yrs 2mo	2	85	3 TD	11yrs 9mo	20	100
4 DCD	12 yrs 6mo	1	106	4 TD	12yrs 4mo	26	104
5 DCD	13 yrs 6mo	1	89	5 TD	13yrs 2mo	29	100

Table 2: Mean duration of movement and mean extent of the lips for open-close movements and for single words. Data is given for both typically developing (TD) children and children with DCD (DCD). Standard deviation is given in parenthesis.

		Mean duration of movement (ms)		Mean extent of movement between the lips (mm)	
		TD	DCD	TD	DCD
Non-verbal: Open-Close	Normal speed	853 (107)	829 (359)	33.4 (4.4)	29.0 (4.1)
	Fast speed	413 (127)	506 (304)	24.5 (2.6)	23.6 (6.3)
Single words (normal speed only)		616 (116)	581 (52)	7.8 (1.9)	6.7 (2.6)

Table 3. Mean overall utterance duration and mean number of syllables produced in the syllable sequence task. Given for each consonant type and for mono- and tri-syllables. Standard deviation is given in parenthesis.

		Overall duration (s)		Number of syllables produced	
		TD	DCD	TD	DCD
Mono-syllable	papapa…/bababa…	12.52 (2.24)	8.69 (1.39)	48.0 (9.6)	34.9 (10.5)
	tatata…/dadada…	11.42 (2.61)	8.73 (2.03)	37.0 (10.3)	23.9 (5.2)
	kakaka…/gagaga…	11.57 (1.87)	8.07 (2.35)	38.9 (11.9)	26.4 (11.0)
Tri-syllable	pataka…/badaga…	13.59 (1.20)	10.49 (2.40)	36.5 (4.4)	27.9 (4.8)

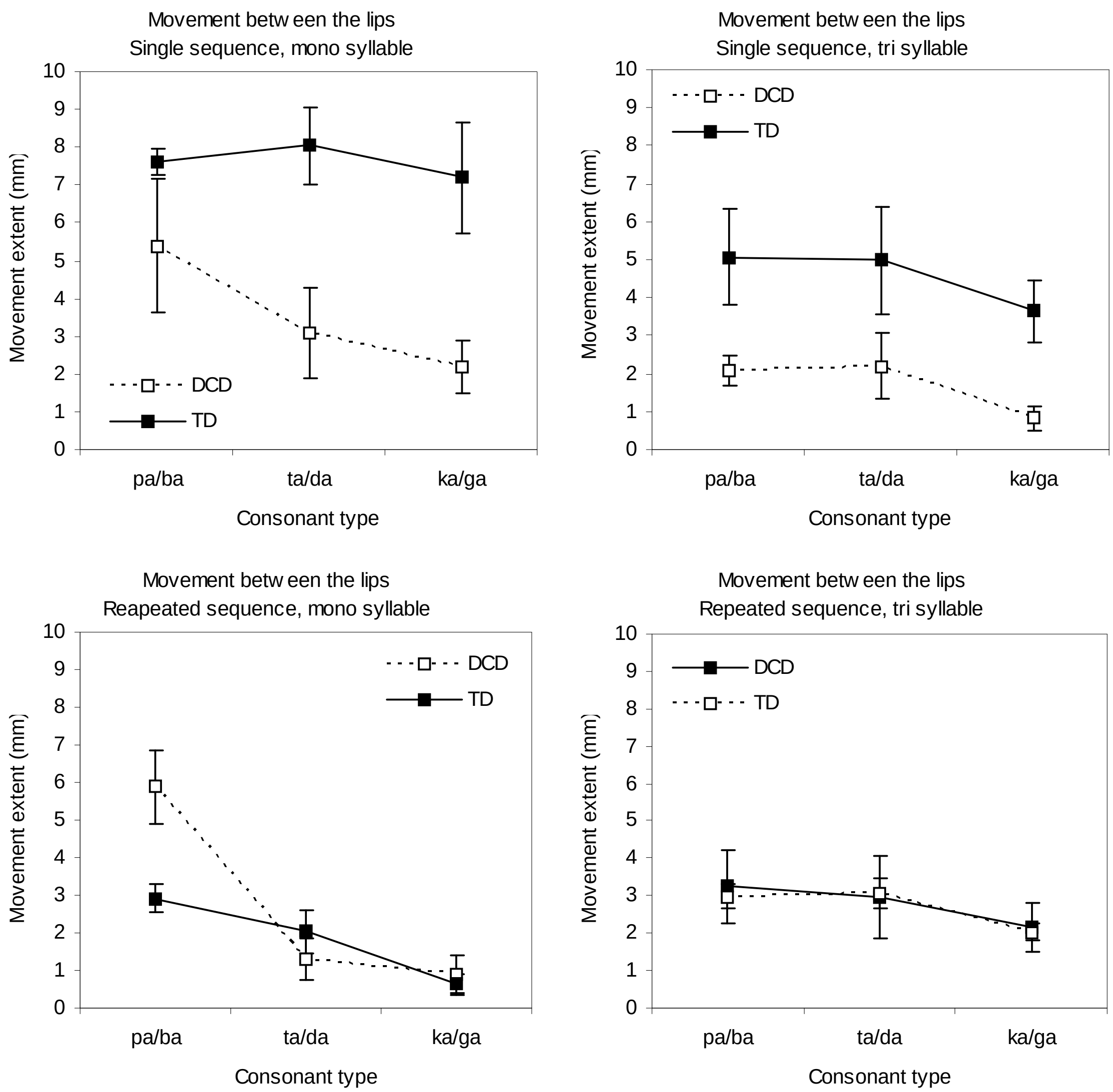

Figure 1. Movement extent between the lips for the novel sounds task. A. Syllable sequence type, mono-syllable type, e.g. ‘pa’. B. Repeated sequence type, mono-syllable type, e.g. ‘papapa….’. C. Single sequence type, tri-syllable type, e.g. ‘pataka’. D. Repeated sequence type, tri-syllable type, e,g, ‘patakapataka….’. Filled squares represent TD children and hollow squares represent children with DCD. Error bars represent standard error.

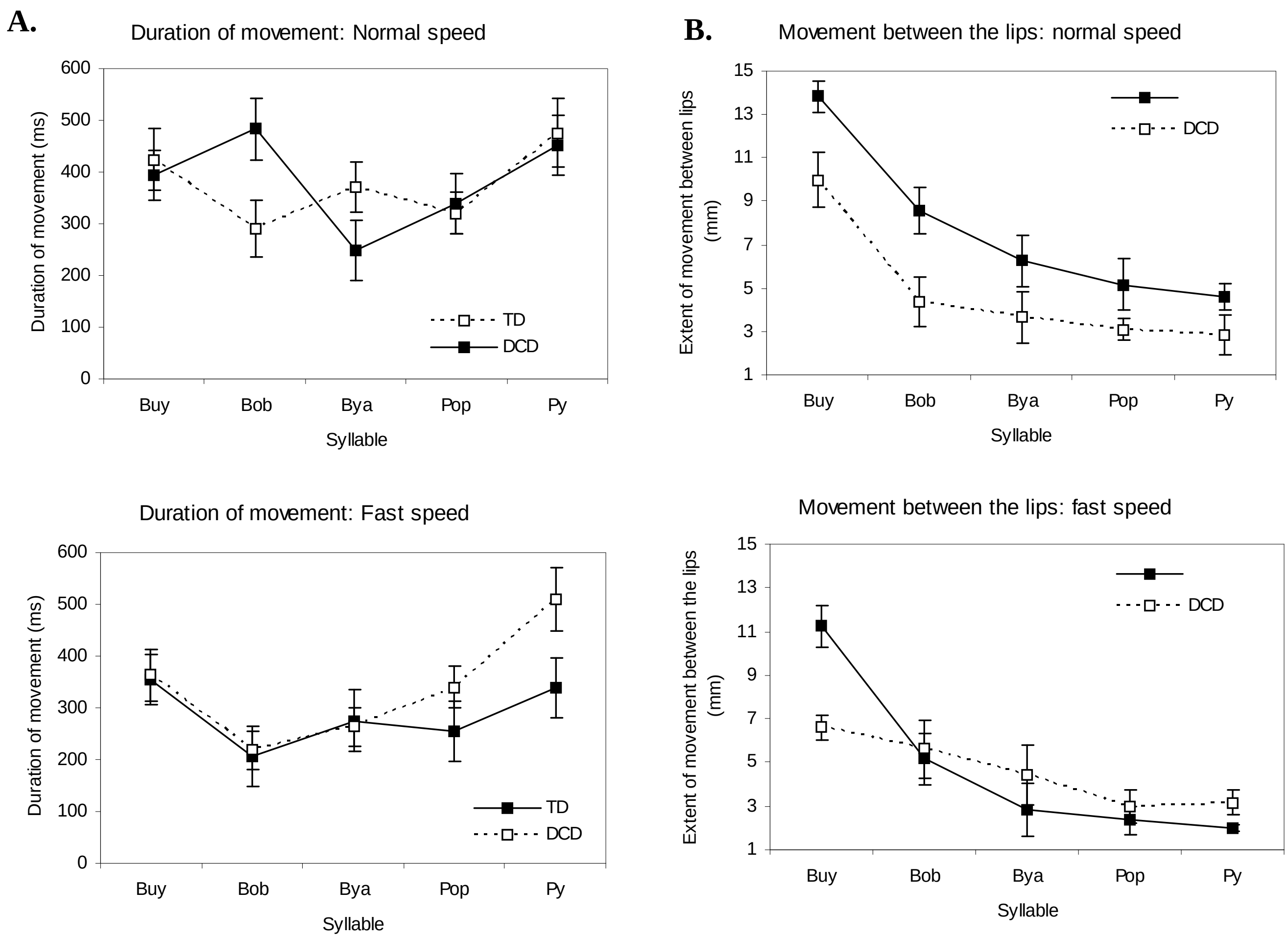

Figure 2. Data from sentence repetition task 'Buy Bobby a poppy'. A. movement duration for each syllable at a normal speed (upper graph) and a fast speed (lower graph). B. movement extent between the lips for each syllable, at a normal speed (upper graph) and a fast speed (lower graph). Filled squares represent TD children and hollow squares represent children with DCD. Error bars represent standard error.