Exploring duration and isochrony in nursery rhyme reciting for children with language impairments and typically developing children

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ABSTRACT

Previous research shows that children with language impairments (LI) are significantly less rhythmic during *motor* tasks than typically developing children who are chronologically and linguistically age- matched. This study aims to explore a *speech* rhythm task and to shed new light on the rhythmic abilities of children with LI. Specifically, the authors investigate whether children with LI are impaired during speech rhythm production in nursery rhyme reciting in a) an internally-generated rhythm task, b) a rhythmic copying task, c) a *paced* rhythmic entrainment task and d) an *unpaced* rhythmic entrainment task. Children with LI were found to be impaired in the internally-generated rhythm and copying tasks. However, they performed equally well as controls during nursery rhyme entrainment tasks (both paced and unpaced). Results are discussed as they relate to possible clinical implications for children with LI.

Keywords: language impairment, child speech, isochrony, duration, speech rhythm

1. INTRODUCTION

By definition, the main deficit for children with language impairments is in language. However, many researchers suggest that children with language difficulties also exhibit several non-linguistic deficits, including motor deficits. Motor deficits include problems with motor speed and motor sequencing during peg moving tasks [2, 4], motor imitation for finger, hand, and arm gestures [21] and rhythmic motor entrainment during finger and hand tapping tasks [5, 22]. Rhythmic motor entrainment abilities in children with language deficits were first explored by Corriveau & Goswami [5] after findings from a previous study [6] showed that children with language difficulties were significantly less sensitive than typically developing children to auditory cues related to rhythmic timing. Findings from the Corriveau & Goswami study [5] showed that children with language difficulties were significantly impaired when tapping in synchrony with a metronome beat compared to age-matched and language-matched typically developing (TD) children. Thus it was suggested that the co-morbidity between language and motor impairments seen in children with language deficits might result from a *rhythmic processing deficit* and that the motor skills of children with LI may not be globally impaired but specific to certain tasks. Additionally, it has been long proposed by Tallal and colleagues [1, 19] that *auditory processing* is a core deficit for children with language problems. More recently, Tierny & Krauss [20] suggested that auditory processing skills rely on processes that are shared with rhythmic and language processing.

Holliman, Wood, & Sheehy [11] suggest that rhythmic awareness and sensitivity may be prerequisite skills for speech segmentation and for establishing phonemic representations, and thus, poor rhythmic skills could hinder normal language development and could be an underlying factor in some language impairments. Language may be viewed as rhythmic as it follows a rhythmic-patterning of stressed and unstressed successive syllables, defined as an alternating pattern of *strong* and *weak* elements [14]. The repetition of strong-weak beat patterns generates an acoustic framework of metrical regularity [14]. This acoustic regularity in speech is important for humans from a very young age. It has been proposed that the rhythmic patterns of language allow infants to distinguish between languages that belong to different rhythmic classes [15, 16]. Some researchers also suggest that stress is a salient part of the speech signal and that stressed syllables help infants find words in multi-word utterances [8, 12, 13]. Cutler [7] proposed that children use the rhythm of their native language to identify lexically significant chunks, and that in English, a stress-timed language, children assume that strong syllables signal the beginning of a word. Children with better sensitivity to the rhythmic aspects of language have been found to have better rhyming skills and rhyming skills are, in turn, an effective predictor of language and reading success for young children [11].

This study aims to explore the *rhythmic processing deficit* hypothesis proposed by Corriveau & Goswami [5] and to shed new light on the rhythmic abilities of children with LI. An aspect of rhythm that has not yet been examined as it relates to children with LI is speech rhythm. Specifically, the authors investigate aspects of speech rhythm production in a nursery rhyme recitation task. This task requires children to produce a strong rhythmic beat as the nursery rhyme follows the acoustic framework of metrical regularity or simply the rhythmic patterning of stressed and unstressed syllables. It was expected that children with LI would show difficulties during nursery rhyme production tasks, while reciting the rhyme with and without an external auditory stimulus. This assumption is based on previous findings indicating that children with LI are impaired during expressive *motor* rhythmic entrainment tasks, which may extend to speech rhythm.

2. METHOD

2.1 Participants

Fifty one children aged 7;8 to 11;2 years participated. All children spoke English as their primary language and none of the children had a history of persistent hearing or vision problems or had a diagnosis of an additional learning difficulty (e.g., dyslexia, ADHD, autism spectrum disorder). Seventeen children (14 male, 3 female; mean age 8;9, SD, 12 months) had a statement of language impairment (LI group) from their local education authority, seventeen children (4 male, 13 female; mean age 8;8, SD, 11 months) were chronologically age-matched (TD-CM group) controls, and seventeen children (7 male, 10 female; mean age 6;5, SD 1;6) were linguistically age-matched (TD-LM group) controls. These children were matched to the LI children using raw scores from the core language subtests of the CELF-4^{UK} [18] (scores were matched to within 5 points). To assess nonverbal IQ, all children were tested on the Raven's Coloured Progressive Matrices (RCPM) [17]. Statistical testing confirmed that the LI group had significantly lower CELF-4^{UK} scores than the TD-CM group. No significant differences were found between the groups for the RCPM/nonverbal IQ task.

2.2 Speech Rhythm Tasks

2.2.1 Materials

Humpty Dumpty, a well-known, English nursery rhyme was selected for this task. Two sentences (8 syllables in length) were used in this rhythm production task. The two sentences ("Humpty Dumpty sat on a wall, Humpty Dumpty had a great fall") had an alternating binary rhythm of strong (s) and weak (w) syllables and a trochaic stress pattern (s-w-s-w-s-w-w-s). Participants recited these two sentences twice (32 syllables). Participants also watched video recordings of a female native British English speaker (the model) reciting the two sentences in time to a metronome beat. However, the metronome beat was not audible to the children as the model heard the beat through headphones.

2.2.2 Task description

This task was designed to assess speech rhythm production in an internally-generated rhythm condition (*self*), in a rhythm copying condition (*copy*), in a paced rhythmic entrainment condition (*paced*), and in an unpaced rhythmic entrainment condition (*unpaced*). During the *self* condition, the examiner instructed each child to recite the two lines of *Humpty Dumpty* at a comfortable speed. During the *copy* condition, the model recited the nursery rhyme at a rate of 2 Hz (500 msec between stressed vowels) and the child imitated the model's reciting after the model had finished reciting the rhyme. For the *paced* conditions, the child entrained his/her reciting with the model's speed, *simultaneously*. During the *unpaced* conditions, each child continued reciting *Humpty Dumpty* after the model had stopped. Both paced and unpaced entrainment conditions were performed at the rates of 1.5 Hz (666.66 msec), 2 Hz (500 msec), and 2.5 Hz (400 msec). Prior to each condition, all children completed a practice session lasting for approximately 10 seconds. Note however that children did not have a practice session for the *self* condition so as not to influence their internally-generated rhythm performance.

2.2.3 Analysis

It was expected that children would produce approximately 16 stressed syllables in total during the two sentences recited twice ("Hum" "Dum" "sat" "wall" "Hum" "Dum" "had" and "fall"). To avoid effects of familiarization, fatigue, or final lengthening, only the middle 6 stressed syllables (highlighted in bold) produced during each condition were used for analysis ("Humpty Dumpty **sat** on a **wall**, **Hum**pty **Dum**pty **had** a great **fall**. Humpty Dumpty sat on a wall, Humpty Dumpty had a great fall").

The approach used to measure speech rhythm relates to inter-stressed syllable durations. The middle of each stressed vowel was used as a marker of beat location for all the stressed syllables. The mid-point of the 6 stressed syllables of interest were identified using Praat [3]. Two measures were then obtained: 1) *average duration* between mid-vowels in milliseconds, as a measure of speed, with higher durations showing slower speech and 2) *durational isochrony* expressed as the standard deviation of the average duration, as a measure of rhythmicity. Here, lower standard deviations relate to higher rhythmicity.

3. RESULTS

3.1 Speech rhythm

Mean scores for average duration and durational isochrony are displayed in Table 1.

Table 1: Means for duration (and isochrony) in each task by group (in milliseconds)

Group	**TD-LM**	**TD-CM**	**LI**
Self duration (isochrony)	640 (0.1)	521.76 (0.07)	752.94 (0.28)
Copy duration (isochrony)	564.7 (0.1)	487.6 (0.07)	564.7 (0.15)
Paced 1.5 Hz duration (isochrony)	671.18 (0.08)	670 (0.06)	667.65 (0.1)
Unpaced 1.5 Hz duration (isochrony)	645.88 (0.14)	599.41 (0.05)	648.23 (0.1)
Paced 2 Hz duration (isochrony)	525.29 (0.12)	515.29 (0.07)	521.18 (0.09)
Unpaced 2 Hz duration (isochrony)	538.82 (0.09)	501.18 (0.06)	544.12 (0.1)
Paced 2.5 Hz duration (isochrony)	421.87 (0.09)	398.23 (0.07)	430.59 (0.1)
Unpaced 2.5 Hz duration (isochrony)	490.62 (0.09)	422.94 (0.1)	497.06 (0.17)

One-way ANOVAs by group (TD-LM, TD-CM, LI) were conducted to determine group differences in average duration and durational isochrony. In the event of significant differences being found, these were followed with Bonferroni post-hoc analyses.

3.1.1 *Self* condition

Average duration between stressed vowels was significantly different between the three groups [$F(2, 23.23)=12.52$, $p<.05$]. Bonferroni post-hoc analysis revealed that the LI group was significantly slower than the two other groups. No other group differences were statistically significant. Durational isochrony (as determined by SD) was significantly different between the three groups [$F(2, 23.49)=10.44$, $p<.05$]. Post-hoc analysis revealed that the LI group was significantly less isochronous than the TD-CM or the TD-LM groups. No other group differences were significant.

3.1.2 *Copy* condition

Average duration was significantly different between the three groups [$F(2, 23.75)=5.63$, $p<.05$]. Post-hoc Bonferroni analysis revealed that no group differences were significant. However, mean average duration scores for the LI and the TD-LM groups were the same (see Table 1) and mean average scores for the TD-CM group differed and thus, a t-test was used to determine possible differences between the LI and the TD-CM as well as with the TD-CM and TD-LM groups. A significant difference was found between the LI and chronologically matched controls [$t(32)=-2.53$, $p=<.05$] and between the TD-LM and the TD-CM groups [$t(32)=2.42$, $p=<.05$]. No other group differences were statistically significant. This indicates that the LI and TD-LM groups copied at significantly slower rates than the TD-CM group. Durational isochrony was not significantly different between groups [$F(2, 48)=2.24$, $p>.05$].

3.1.3 *Paced* condition

Average duration was not significantly different between the three groups for any of the three rates. A significant group difference was found for durational isochrony at paced 1.5 Hz condition only [$F(2,28.52)=4.501$, $p<.05$]. Post hoc Bonferroni analysis revealed that the LI group was significantly less isochronous as compared to the TD-CM group. No other significant differences were found.

3.1.4 *Unpaced* condition

No significant group differences were found for average duration. Durational isochrony was significantly different only at the rate of 1.5 Hz [$F(2, 24.42)=7.09$, $p<.05$] but not at rates of 2 Hz or 2.5 Hz. Post hoc Bonferroni analysis revealed that the younger linguistically matched controls (TD-LM) were significantly less isochronous than the older chronologically matched controls (TD-CM).

4. DISCUSSION

The aim of this study was to explore whether children with LI show rhythmic difficulties during nursery rhyme reciting as compared to typically developing controls. We explore an aspect of rhythm that has not been examined previously for this population. Our findings reveal systematic trends with isochrony and duration/motor speed in responding to tasks with and without an external auditory and visual stimulus. Although our findings are important towards a further understanding of language impairment, they should be interpreted with caution as they represent only a few of the multitude of complex processes that are required during a linguistic-rhythmic task.

Findings relating to *average duration* show that children with LI performed significantly slower than the two control groups during the *self* condition and that they performed slower than TD-CM controls but similarly to younger controls during the copy condition. However, they performed similar to the other two groups (TD-CM and TD-LM) during all three rates (1.5 Hz, 2 Hz, and 2.5 Hz) for both the *paced* and *unpaced* conditions. In terms of the *self* condition, our findings concur with previous research [2] showing that children with LI performed slower than controls during self thumb-tapping tasks. In addition, Hill [10] proposed that the slow motor performance observed in some children with LI is related to a general slowing of cognitive processing and Bishop [2] further suggested that slow performance for LI children could be a marker of neurodevelopmental immaturity. However, these results contradict a recent study [4] showing that children with LI were as fast as typically developing children on a speeded fingertip tapping task. Further research that focuses on durational characteristics during both motor and speech tasks might shed light on this discrepancy.

In the *copy* condition, LI children were also found to perform at slower rates than chronologically matched peers and they performed at similar rates to younger controls. Previous research on motor imitation tasks is in agreement with the current study. Children with LI were found to imitate fewer movements [21] and fewer hand positions [4] than chronologically matched peers. Brookman et al. [4] propose that difficulties with imitation tasks may underlie slow learning in some children with LI.

Surprisingly, however, children with LI performed similarly to controls in terms of duration during entrainment tasks (both paced and unpaced). These results may indicate that certain external stimuli assist children with LI in rhythmic tasks. So far, most studies examining entrainment abilities including those that have found deficits for children with LI have used a metronome beat as the external auditory stimulus. This study used a visual/auditory external stimulus (the model) during all entrainment tasks and this may have had a positive effect for LI children. Further research into these different modalities (auditory/visual and model vs. metronome beat) may shed new light for the entrainment abilities of LI children.

Findings relating to *isochrony* show that children with LI were significantly less isochronous in the *self* condition as well as during the *paced* condition at the slower rate of 1.5 Hz. There were no significant differences in isochrony during the *copy*, the *paced* (during the faster rates of 2 Hz and 2.5 Hz) or the *unpaced* conditions. From our findings it is clear that children with LI are able to achieve isochrony during copying and entrainment tasks, which could perhaps indicate that an external stimulus helps with isochrony. Nevertheless, results showing that LI children have more difficulties with isochrony during the slow rate of 1.5 Hz are similar to findings from Corriveau & Goswami [5] study where the language impaired group showed increased rhythmic variability (a greater standard deviation) than controls during paced entrainment motor tapping tasks at the slowest rate of 1.5 Hz.

Considering previous findings on the similarities of the domains of speech and music and the commonalities between language and music processing, a plausible approach for future research might be to additionally examine the musical rhythm abilities of children with LI. This would provide opportunities to further explore clinical intervention for children with language problems and it could potentially create a more holistic approach in our understanding of the rhythmic skills of children with LI. An integrated approach for a comprehensive analysis of rhythm for children with language deficits might be to create a rhthose that have found deficits for children with ythmic model that combines information on several aspects of rhythm, namely speech, motor, and music. This model could potentially form the basis for a diagnostic as well as a treatment tool for children with language deficits. First steps towards this new rhythmic framework [9] combine elements from language and music processing models. This framework would perhaps allow researchers and clinicians to account for children’s difficulties with either metrical, linguistic, or motor structures and to utilize this information to further guide their research or their clinical practice.

Finally, when considering clinical implications for children with language difficulties it might be beneficial to include clinical interventions that focus on rhyme reciting and other rhythmic language games that incorporate entrainment opportunities.

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