Rhythmic Perception, Music and Language: A New Theoretical Framework for Understanding and Remediating Specific Language Impairment

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Background to the Project

In this project funded by the Nuffield Foundation, we were interested to see whether a difficulty with rhythm perception was associated with the speech and language difficulties experienced by children with oral speech and language impairments (SLIs). In particular, we were interested in whether sensory difficulties with auditory cues to rhythm might be causally related to spoken language difficulties in SLI, and accordingly whether musical interventions might be of benefit to such children. Our reasoning was that rhythm is much more overt in music than in language. Therefore, by matching the prosodic phrasing in language with musical melodies, it might be possible to ameliorate acoustic rhythmic impairments and improve the processing of the language system in affected children.

Accordingly, we devised a series of experiments to test a novel theoretical framework, shown schematically overpage. This framework was originally developed to explain auditory processing difficulties in children with developmental dyslexia. Children with developmental dyslexia have difficulty in discriminating the rates of change of intensity in sounds – the "rise times" of sound loudness changes. These difficulties with rise time are related to their phonological difficulties. By analogy to music, a sound with a rapid "rise time" reaches peak loudness very abruptly, like a note on a trumpet. A sound with a more extended "rise time" reaches its peak more slowly, like a note on a violin. Musically, to play a trumpet in time with a violin, peak intensity must be reached at the same moment by both the violin and the trumpet player – rhythmic alignment. As speech contains many simultaneous variations in intensity (energy) that each have their own rise times, a brain that has difficulty in discriminating these rise times will have difficulties in language processing. Speech rhythm is perceived on the basis of the alignment over time of slower energy changes in speech at two rates, around 2 Hz and 5 Hz (two sound peaks per second and 5 sound peaks per second). Essentially, if a difficulty with acoustic rhythm were to be established in children with SLIs, then musical experiences may help to improve their language development.

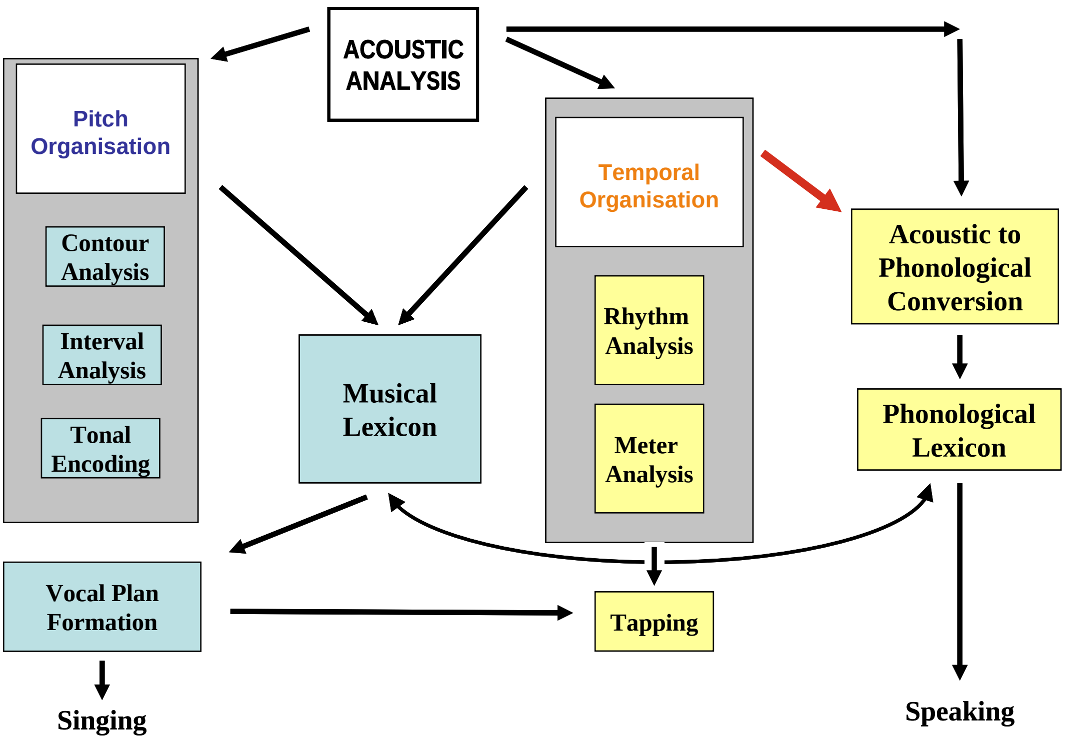


Figure 1. *Theoretical Framework underpinning the Project, adapted from a Model of Amusia proposed by Peretz and Coltheart, 2003. See ''Language, Music and Children's Brains: A Rhythmic Timing Perspective on Language and Music as Cognitive Systems', Goswami, U. 2012, In P. Rebuschat, M. Rohmeier, J. Hawkins & I. Cross (Eds), Language and Music as Cognitive Systems, 2012, Oxford University Press.*

Participants

We recruited 45 children with SLIs and 50 age-matched typically-developing (TD) control children from local schools and language support units. The children were aged on average 9 years. The children with SLIs were identified on the basis of a standardised test of language (the Clinical Evaluation of Language Fundamentals [CELF]). As a group, the children with SLIs scored over 2 SD below the test mean of 10 (SD = 1.5) for both Expressive Language measures (Formulating Sentences, 4.4, and Sentence Assembly, 4.1, respectively) and Receptive Language measures (Concepts and Directions, 5.4, and Semantic Relations, 5.8).

All children (SLI and control) were also given standardised tests for

- non-verbal IQ using the WISC III and the Ravens
- receptive vocabulary using the British Picture Vocabulary Scales
- reading development using the British Ability Scales

- spelling development using the British Ability Scales

Task Overview

A range of experimental tasks developed previously by Goswami and colleagues to measure children's sensitivity to rhythm and pitch contour in language and music were administered to all participants. The tasks measured sensitivity to syllable stress and to prosodic patterning (syllable stress misperception task, DeeDee task), sensitivity to musical rhythm (beat perception task, tapping to music task), and phonological development (rhyme awareness, phonological short-term memory, rapid automatized naming). A music-speech task specially-developed for the current project was also administered. The task compared sensitivity to pitch contour versus rhythm in a matched set of tasks using filtered speech or filtered tunes (6 tasks). Finally, a series of basic auditory processing tasks (testing auditory sensitivity to rise time, rising f0 and duration, in both tones and speech stimuli) and a set of filtered speech tasks was also administered, with the aim of identifying more precisely the nature of the expected auditory deficits.

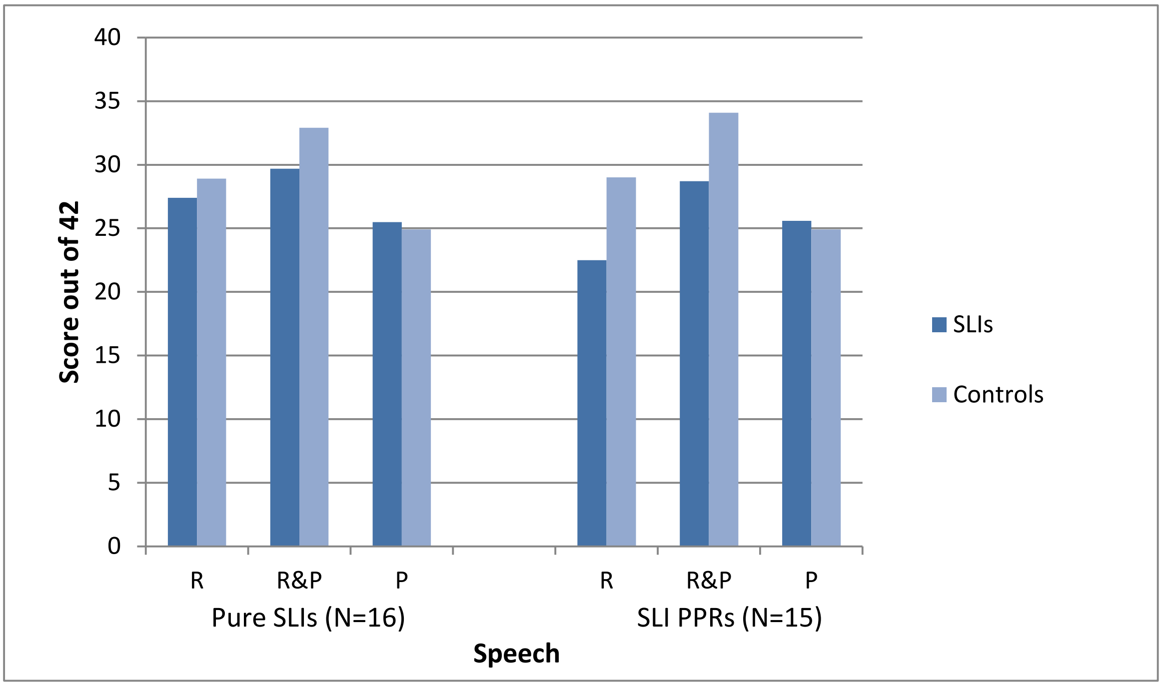
Findings

Overall, we found substantial difficulties for the children with SLIs in judging rhythm in both the speech and the music tasks. Sensitivity to pitch contours in both speech and music appeared relatively preserved. For example, the children with SLI:

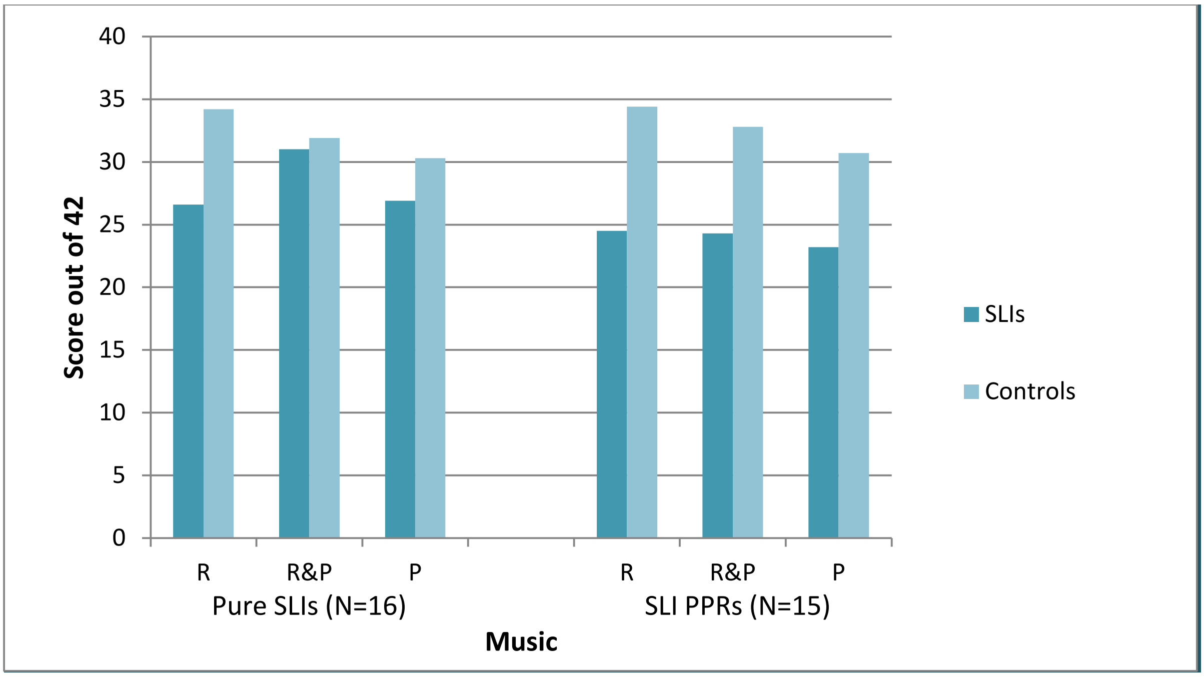
- found it difficult to judge when words like DIFFICULTY were mis-stressed
- found it difficult to match a pattern of stressed ("DEE") and unstressed ("dee") syllables to a familiar picture (e.g., Harry Potter = DEEdee DEEdee)
- found it difficult to decide whether two tunes were the same or different when rhythm was disrupted
- were less accurate at tapping in time with music in both 3/4 time and 4/4 time
- showed auditory processing deficits for rise time and duration
- were less accurate at matching filtered speech to clear speech when rhythm was disrupted
- were less accurate at matching a filtered tune to a clear tune when rhythm was disrupted

Performance in the novel music/speech AXB tasks is shown below. The graphs compare performance for two groups of children with SLIs and normal non-verbal IQ scores, "Pure SLI", children with language impairments but not phonological and reading impairments, and "SLI PPR", children with language, phonology and reading impairments.

Speech AXB Tasks (R = Rhythm; R&P = Rhythm + Pitch; P = Pitch)



Music AXB Tasks (R = Rhythm; R&P = Rhythm + Pitch; P = Pitch)



The children with SLIs were as good as unimpaired TD children in:

- matching filtered speech to clear speech when pitch contour was disrupted
- matching musical tunes with similar patterns of beats

Contrary to expectation, the children with SLIs found it as difficult to hear rhythm patterns in music as rhythm patterns in speech. Multiple regression analyses identified two consistent predictors of individual differences in language outcomes. These were musical beat perception and the perception of rhythm in speech. Detailed task performance is described in the published papers (Cumming et al., 2015a, b).

Conclusions

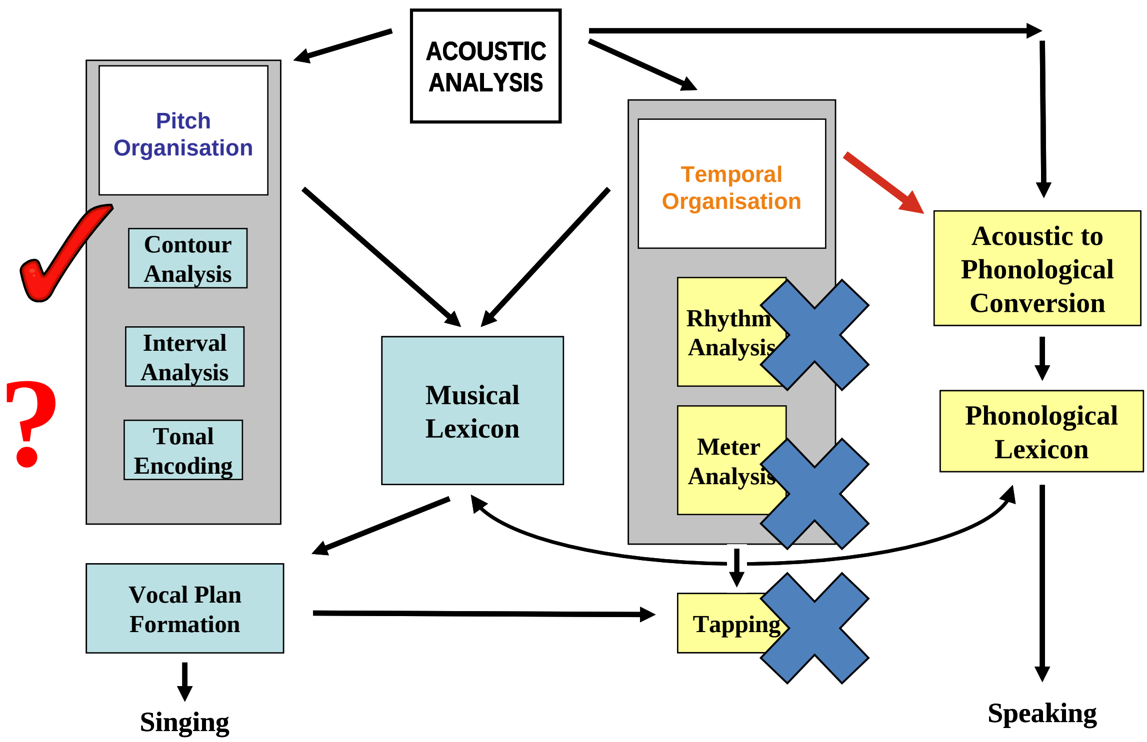
Overall, we conclude that children with SLIs are impaired in processing rhythm in both speech and music. Their difficulties appear primarily related to the basic auditory perception of rise time and duration, which are important for rhythmic processing. Our rhythm-based model was supported by our analyses of individual differences. For example, 68% of the variance in children's Receptive Language scores could be predicted on the basis of non-verbal IQ and the children's musical beat perception accuracy. Similarly, 67% of the variance in children's Receptive Language scores could be predicted on the basis of sensitivity to rhythm patterns in speech and non-verbal IQ. Almost identical outcomes were found for Expressive Language scores. Children with higher non-verbal IQ and better rhythm perception (for speech or music) had better language scores.

Implications for Supporting Learning

On the basis of these data, a *prosodic phrasing* hypothesis was proposed (Cumming et al., 2015a, b). The prosodic phrasing hypothesis suggested that auditory difficulties in the accurate processing of rise time and sound duration cause impairments in detecting the prosodic or rhythmic phrasing of utterances. This impaired perception of prosodic phrasing leads to language learning difficulties that manifest primarily as problems in processing morpho-syntax, but can also lead to associated difficulties with phonological awareness.

Accordingly, musical interventions may be of value for children with SLIs *when the musical phrasing supports the prosodic phrasing.* In other words, processing the prosodic patterns in language may be facilitated for children with SLIs if musical rhythms model the language rhythms that the children have difficulty in hearing. On this view, music therapies would be useful only if they were specific to the rhythm patterns of the particular utterances and grammatical constructions that a child was having difficulty with. For example, a child who has trouble repeating sentences accurately may benefit from having the specific rhythmic phrasing of each sentence played on a chime bar.

In summary, the data collected for this project are suggestive of the following strengths and weaknesses in the acoustic processing of language and music by children with SLIs:



For a fuller report of these data, please see:

Cumming, R., Wilson, A. & Goswami, U. (2015). Basic auditory processing and sensitivity to prosodic structure in children with SLIs: A new look at a perceptual hypothesis. *Frontiers in Psychology, 6*, 972.

Cumming, R., Wilson, A., Leong, V.,Colling, L.J. & Goswami, U. (2015). Awareness of rhythm patterns in speech and music in children with SLIs. *Frontiers in Human Neuroscience, 9*, 672.

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