Relationships Among Prosodic Sensitivity, Musical Processing, and Phonological Awareness in Pre-Readers

Gina C. Cardillo

Department of Speech & Hearing Sciences
Institute for Learning and Brain Sciences
University of Washington, Seattle
{ginacc}@u.washington.edu

Abstract

This study investigates how children's sensitivity to prosodic characteristics in speech is related to their processing of musical melody and rhythm, and how these are related to phonological awareness (PA), in a sample of 23 5-year-old pre-readers. Measures included non-word prosodic imitation, melody and rhythm discrimination, a battery of phonological awareness tasks, and general expressive and receptive vocabulary tests. Main findings were that 1) prosodic sensitivity predicted PA skills beyond what was predicted by general language ability alone, 2) musical processing also predicted PA skills after general language ability was accounted for, but was not as strong a predictor as prosodic sensitivity, and 3) pitch and rhythm sensitivity in music did not differentially predict PA, contrary to hypotheses postulated in recent literature. Findings support the notion that a child's sensitivity to suprasegmental characteristics of both speech and music may be a feasible way to predict their later PA skills, given the similar auditory processing mechanisms underlying their development.

1. Introduction

It has been debated whether generalized auditory processing mechanisms underlie early reading and pre-reading skills, versus whether the link is primarily linguistic (phonological) in nature (7). In support of the former notion, a growing body of recent research suggests that children's development of phonological awareness (PA) is related to sensitivity to pitch and rhythm patterns contained in both speech and non-speech (e.g., musical) contexts. Several lines of investigation exploring relationships between early reading, PA, and the processing of prosodic, pitch, and rhythm information have led to promising but somewhat inconsistent conclusions, though all agree that a more precise characterization of these relationships remains an important question (1, 6, 9).

The general assertion is that prosodic cues of rhythm, intonation and stress help segment the continuous speech stream into syllables, words, phrases, and even phonemes, contributing to underlying phonological representations that support phonemic awareness. The purpose of this study is to integrate several themes from this literature to investigate how awareness of suprasegmental rhythm and intonation are related to PA skills in pre-readers.

It is of interest to understand the predictors of PA because the process of learning to read is facilitated by strong PA skills. That is, children who are more advanced in the ability to discern and manipulate individual phonemes and syllables within words, shown in tasks such as rhyming, segmentation, and phoneme deletion, show advantages in learning to map written phonemes to their phonological counterparts during the early stages of reading (8).

1.1. The role of prosodic sensitivity in PA and reading

A recent special issue was published highlighting recent work in this area (9). For instance, in a study with typical children 5-7 years old, Wood (11) found that metrical stress sensitivity (measured by the detection of mispronounced words containing reversed stress patterns, e.g., /'tedi/ vs. /tedi'/) predicted unique variance in PA skills of rhyme detection and spelling, controlling for age and vocabulary. However, effects were relatively weaker for the youngest age group, as the authors speculate that the task format may have been too demanding. In the same study, 4- and 5-year olds were worse at detecting mispronounced words that contained reversed metrical stress patterns compared to other types of mispronunciations, suggesting that in some contexts, measures of prosodic processing may be less sensitive than others due to developmental level. Other studies have directly predicted reading from prosodic sensitivity, while controlling for PA skills, further emphasizing the important role of suprasegmental processing (10).

1.2. The roles of pitch and rhythm in music

A related line of research has investigated whether pitch and rhythm skills in musical contexts predict reading as well as traditional PA skills do. The aim is understand what processes may be unique to language and its underlying phonology, and which are accounted for by non-linguistic auditory processing. Previous reports found strong links between musical aptitude and PA (6), and more recent studies have attempted to tease apart pitch and rhythm within music. Some studies show pitch processing to be superior to rhythm processing in predicting PA, while others found the converse (see 1, 4) – a problem for model development.

1.3 The present study

The purpose of the present study was to investigate how children's sensitivity to prosodic information (as measured by their ability to imitate speech rhythm and intonation) is related to both pitch and rhythm perception in musical contexts and to a broad range of PA skills.

If the underlying perceptual mechanisms that contribute to PA are based on general auditory processing not restricted to the speech (or language) domain, a feasible prediction would be that children who are more sensitive to speech prosody would also have stronger PA, and would also be more sensitive to pitch and rhythm patterns music. It was also predicted that prosodic sensitivity will be more strongly related to PA than to musical sensitivity, because the former two constructs are measured in the linguistic (speech) domain. Given the conflicting evidence in the literature as to whether pitch (frequency) or rhythm (temporal) processing within music is more related to pre-reading skills, each of these may differentially predict PA.

In examining these inter-relationships, it is important to take general expressive and receptive language skills into account, since children who exhibit more advanced language, especially vocabulary, also tend to perform better in PA tasks.

2. Methods

Data analyzed in this study are from a subset of a larger longitudinal project examining language development from age 7 months through 5 years.

2.1 Participants

Data were collected from 23 typically developing children (14 boys) who were within 1 month of their 5th birthday, originally recruited at age 7 months from the University of Washington Communication Studies Participant Pool. All were from monolingual English homes, without reported speech, language, or hearing concerns. Data were excluded from one additional child who failed to successfully complete the practice trials in the music tasks, and from another due to failure of recording equipment.

2.2 Materials and Procedure

The children were individually given several standardized tests over two sessions, each lasting approximately 90 minutes. Appropriate breaks were given to ensure optimal performance, Tests were administered according to their standardized protocols, given in random order, except the Melody Discrimination task always preceded the Rhythm task. Practice items were given to ensure task comprehension.

- **Speech Prosody.** The rhythm subtest from the *Tennessee Test of Rhythm and Intonation Patterns* (T-TRIP) was used as a measure of sensitivity to speech prosody. Stimuli, presented via an audio CD, consist of 12 reiterative sequences of the syllable /ma/, with varying stress patterns from 2-6 syllables, for example 'ma-MA' or 'MA-ma-ma-MA-ma' where capitals are stressed. Each item was presented twice; the child verbally repeated each instance into a microphone. An item was scored correctly if a child produced all syllables with the correct stress pattern in at least one of the opportunities. The total possible score was 12. Because 3 of the children completed less than all 12 items due to fatigue, a percentage score was used for all children.
- **Music Perception.** *The Primary Measures of Music* Audiation (PMMA) assesses discrimination for short tonal and rhythmic patterns. The first 15 items of each subtest were administered. In each item, a pair of melodic or rhythmic patterns plays via an audio CD, and children indicate whether the items of the pair are the 'same' or 'different' by circling a happy or sad face on a sheet. Percentage scores for both Tone and Rhythm were used because 2 children did not complete all items.
- **Phonological Awareness.** Three subtests of the Comprehensive Test of Phonological Processing (C-TOPP) were measured: Elision, Blending Words, and Sound Matching. Four subtests of the Phonological Awareness Test (PAT) were given: Rhyming Discrimination, Rhyming Production, Sentence Segmentation, and Syllable Segmentation. Sample items are given in Table 1. Each correct response received 1 point; the final PA score was the total number of points.
- **General Language**. To obtain a general measure of language ability we averaged the standard scores taken from the Peabody Picture Vocabulary Test -3 (PPVT-3) and the Expressive Vocabulary Test (EVT), which both used the same normative sample. A mean from both tests was used to obtain a more accurate estimate of the child's receptive and expressive language across tasks.

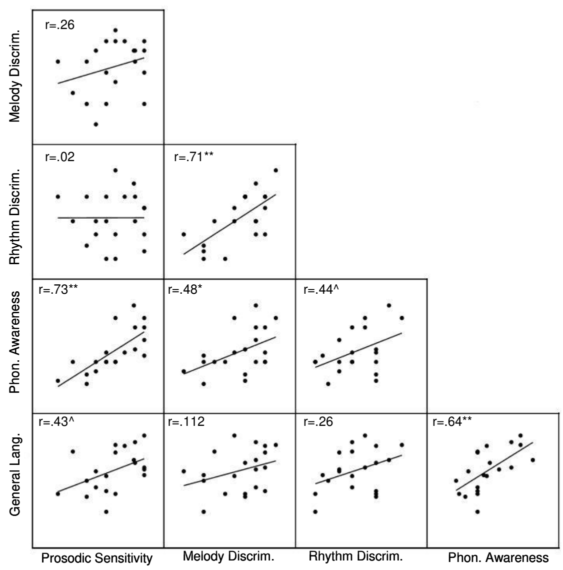
3. Results

First, data from 2 boys were removed from the dataset due to being outliers on (>2 SDs away from the mean on the language test and the rhythm discrimination, respectively), leaving N=21. Correlational and hierarchical regression analyses tested the extent to which pitch, rhythm and prosodic sensitivity each explain variance in PA skill, and whether these predictions hold while controlling for general language skills.

3.1 Prosodic sensitivity, general language, and PA

Mean performance and standard errors for all tasks are shown in Table 1. In accordance with other reports, children in this sample performed quite well on both of the rhyming tasks, as the distributions were skewed toward high scores. Therefore, rhyming was excluded from further analyses. It may be that rhyming, especially in this format, is a highly familiar task in children this age, and is not representative of their underlying PA. Simple correlations and scatterplots among the remaining items are shown in Figure 1.

Figure 1. Scatterplots and correlations among variables



$^*p<.05$; $^{**}p<.01$; ^p=.05

As expected, prosodic sensitivity, as measured by the 'ma-MA' non-word imitation task, was significantly correlated with phonological awareness, and with general language to a lesser extent, though the latter approached significance. This is not surprising given the documented relationships between metrical sensitivity and reading skill, and between PA skills and reading (3). Interestingly, there were no strong relationships between prosodic sensitivity and either of the musical tasks.

Table 1. Tasks, Mean and SD of all measures

Sample Item	Measure	Mean[a]	SD
Repeat 'maMAma'	1. Prosodic Imitation	.73	.22
Same/Different 2-5 notes/melody	2. Melody Discrim.	.74	.21
Same/Different Temporal pattern	3. Rhythm Discrim.	.61	.14
Say 'spider' without 'der.'	4. Elision	3.57	2.87
'ham-er' makes?	5. Blending	3.81	3.59
Which one starts/ends with the same sound as 'pan?'	6. Matching	5.95	4.81
Pudding-Table Mop-Hop	7. Rhyme Discrim.	8.71	2.10
What rhymes with 'can?'	8. Rhyme Prod.	6.43	3.84
Clap once for each word	9. Sentence Seg.	2.70	2.72
Clap once for each syllable	10. Syll. Seg.	3.90	3.60
-Point to picture-PPVT -Name synonym of picture-EVT	11. Gen. Language	111.02	11.29

[a]Items 1-3 are the proportion of correct responses; 4-10 are raw number of correct items; 11 has a normed mean of 100, SD 15.

Given the strength of association between prosodic sensitivity and PA, a hierarchical regression analysis was conducted in which general language skill was entered as the first step, to see whether prosodic sensitivity could account for variance in PA independent of general language. This was found to be the case, as shown in Table 2.

Similarly, when general language was entered as the predictor variable after metrical stress sensitivity was controlled, it too was able to account for independent variance in PA, R^2 *change* = .11, *F change* = 5.5, *p*=.03. Data from these two analyses suggest that both prosodic sensitivity and general language skill are reliable predictors of PA, the former accounts for an additional 25% of the variance in PA, beyond what general language predicts (about 37%).

Table 2. Hierarchical regression predicting PA scores

	AdjR^2	β	ΔR^2	*F*	*p*
Step 1: -General Language	.37	.64	.40	12.19	.003
Step 2: -Gen. Lang. -Prosodic Sensitivity	.61	.38 .56	.25	11.91	.003

3.2 Rhythm and pitch: Differential prediction of PA?

The next set of analyses incorporates the music variables. Previous reports have found evidence, via factor analysis, that pitch and rhythm are processed separately by children at this age (1). Because the present study only had one observed measure for each of melody and rhythm, a confirmatory factor analysis to test whether these two indicators loads onto the same latent factor was not possible. However, the strong correlation between the two variables suggests that there may be a common underlying processing mechanism that links the two. This result is consistent with Anvari et al.'s data from 4-year-olds, in which the measures for both melody and rhythm loaded onto a single factor (1).

To investigate these disparate findings, analyses were conducted in two ways: 1) assuming the postulation that pitch and rhythm processing are separate abilities, and 2) combining the two into a single 'music' score by calculating their mean.

In the first approach, a hierarchical regression applied prosodic sensitivity as the first step, pitch as the second, and rhythm last, based not only on Anvari et al's findings, but also because the strength of the correlations were in that order.

As shown in Table 3, though rhythm discrimination accounted for significant variance in PA after prosodic sensitivity was taken into account, the addition of melody discrimination was unable to account for further variance.

Table 3. Hierarchical regression predicting PA scores

	AdjR^2	β	ΔR^2	*F*	*P*
Step 1: -Prosodic Sensitivity	.51	.73	.54	20.74	<.001
Step 2: -Prosodic Sensitivity -Rhythm Discrim.	.61	.73 .44	.19	22.94	<.001

In the next approach, a single 'music' score consisting of the mean of the melody and rhythm subtests was able to account for an additional 14% of the variance in PA, after prosodic sensitivity was taken into account, Adj. R^2 = .64, β = .38, ΔR^2 = .14, *F* = 17.83, *p* <.001. This result is inconsistent with studies finding either rhythm (1) or pitch (2) to predict PA.

4. Discussion

This study examined the relationships among prosodic sensitivity during a non-word repetition task, a variety of phonological awareness skills, rhythm perception, melody perception, and general expressive and receptive language skills in sample of typically developing 5-year-olds. Of initial value is that the overall estimated parameter values in this study are comparable in magnitude to those of other related studies with larger samples (typically at least 50). Thus, the relatively small sample size used here appears representative of the population. Taken together, results from a series of correlation and regression analyses suggest three encouraging findings.

4.1 Prosodic sensitivity predicted PA, beyond general language skills

This study found that children's sensitivity to suprasegmental rhythm and intonation patterns in speech was a strong predictor of phonological awareness, which is itself a nearly undisputed predictor of reading. This prediction remained significant even when overall language ability, also related to PA, was taken into account. This finding fits will with recent literature emphasizing the role of metrical stress sensitivity in real words, in relation to PA, reading and spelling (11). Wood asserts that because prosody is a part of the phonological system, a stronger ability to process it will facilitate decoding and lexical retrieval. Though segmental accounts of pre-reading skills can contribute to theory, the additional unexplained variance may be best predicted by models that incorporate suprasegmental processing.

This finding highlights the important role of prosodic sensitivity in speech in two ways:

1) The prosodic sensitivity task used here is production, as opposed to the more typically assessed perception. This is significant because the findings are consistent across perception and production modalities, despite the arguably more complex motoric demands in productive tasks.

2) The task used pseudo-words, (e.g., 'ma-MA-ma') which is in the speech domain, but without calling on particular lexical representations. Interestingly, some children in this study tended to interpret the syllables as 'mom' and would repeat it as such, whereas others tended to treat the task as a non-word sequence (8 of the 22 showed this pattern, though these 8 did not perform differently than the others in any other way that was measured here). How accurately children perceive and pronounce non-words is a display of how their phonological representations and working memory are organized, and facility with non-word repetition tasks are an important predictor of both language and reading success.

4.2 Pitch and rhythm did not differentially predict PA

When rhythm and pitch discrimination scores were analyzed separately, regression analyses showed that rhythm, but not pitch, was able to predict variance in PA above what was predicted by prosodic sensitivity. However, the two musical measures were highly correlated with each other. Thus, though other studies have provided evidence that pitch processing is more predictive of reading than rhythm, and still others have argued for the converse, current results not strongly support either of these arguments, but rather that musical pitch and rhythm are nearly equally predictive of PA, with a slight advantage for rhythm. However, this study only used one perceptual task each for rhythm and pitch, as opposed to a sampling the behavior in multiple contexts.

4.3 Other considerations and future directions

It is important to note that some measures of PA may be better predicted than others, based on their required level of representation (e.g., syllable vs. phoneme). In this study, a composite PA measure was based on performance across several tasks, to increase ecological validity. Though not reported in detail here, the speech prosody measure most strongly predicted the syllable and sentence segmentation subtests; the weakest predictions were for both rhyming tasks, which was not surprising, given the rhyming measures' non-normal distributions and ceiling effects.

Similarly, the measure of prosodic sensitivity did not take types of errors into account, but rather used a holistic scoring rubric (proportion of sequences that were produced correctly). More complex analyses that include the placement (e.g., omission, insertion or metathesis) of stress may be more sensitive to differences across children. However, a simple dichotomous measure such as the one used here has appeal for potential clinical application and theoretical parsimony.

Lastly, there was no evidence that either pitch or rhythm discrimination was related to performance on the prosodic imitation task. This may be due to the difference in tasks (i.e., production vs. discrimination), or due to different underlying processing mechanisms (i.e., speech vs. non-speech).

5. Conclusion

The data presented here support the notion that suprasegmental awareness of speech, measured through non-word prosodic imitation (the 'ma-MA-ma' task), is a reliable predictor of overall PA skills in 5-year-olds, above and beyond what is accounted for by general language skills. Further, sensitivity to pitch and rhythm in musical contexts also predicts PA, but to a lesser extent than sensitivity within speech contexts. Last, this data set lends credence to the notion that suprasegmental awareness skills contribute to PA, or that both may be driven by similar underlying mechanisms. Further work needs to be done to investigate what aspects within prosodic sensitivity contribute most to PA and other pre-reading skills, and to what extent prosodic sensitivity in younger children and infants can predict later language development, especially for those at risk for impaired learning (5).

6. References

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