Beat sensitivity in musical context of Children between 8 and 10 years old: an auditory-tactile teaching intervention

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ABSTRACT

The central nervous system automatically tends to integrate various musical stimuli into one multimodal percept, organizing the inputs as being produced by a common extraneous source. Music making is considered to be a plurisensory experience where auditory, visual and tactile signals, as well as body movements, contribute to the perception of several musical attributes, such as beat, meter, rhythm, pitch and timbre. The proposed "in-classroom" study examined beat sensitivity on 29 third-grade and 31 fourth-grade greek students during the school year 2018-2019. In this paper is presented the initial part of an on-going project aiming at enhance beat perception of children between 8 and 10 years old with an audio-tactile teaching approach. As far as the transmission of audible sound and tactile feedback is concerned, an experimental system was built which consisted of twelve MDF plates shaping a music-vibrating floor. Children could listen to the musical sounds from two loudspeakers while "feeling" the sound waves coming from the floor. Main research goal was to investigate whether there is a greater improvement of beat perception for children who experienced the audio-tactile teaching approach. Here we present the results of the initial control tests examining possible amusia and beat sensitivity before the intervention. Further analysis will shed more light on our conclusions.

INTRODUCTION

One fundamental characteristic of humans, thought to be universal, is the ability to perceive an underlying pulse that represents isochronous time points in music, the *beat* ([3], [11]). The sense of beat requires not only sensitivity to rhythm and meter, but also the collaboration of auditory and somatosensory systems and the capability of evaluative judgement ([3], [12]). Beat perception develops early in age; even newborns are able to infer the underlying beat in a given rhythmic pattern. Rhythm is a fundamental music attribute, defined as the temporal organization of music, consisting of silences and tones that draw a surface-level patter; perceiving the underlying beat of a particular rhythmic pattern involves prediction and abstraction of the particular surface-level [11]. Beat is perceived while listening to non-isochronous temporal sequences which do not necessarily include prominent accents or when the on-beat points do not occur on sound onsets in the so-called *syncopated* patterns, suggesting that beat perception is generated by an internal inductive procedure [12]. Beat perception is strongly associated with cultural aspects: most western music is written usually in *simple* metric structures, where the emphasis is given either every second or every third beat, while music from other cultures, such as Arab countries or the Balkans contains *complex* metric structures, where the accented points are not equally distributed [1]; it is therefore assumed that different cultures develop different mental representations of beat in different musical context ([11], [12]). Recent research has proven that this culturally worldwide ability is improved when the convention of the surface music level is supported by low-frequency sounds, underlying a neurobiological mechanism by which the neural representation of rhythmic patterns is formed by lower frequencies that enhance beat extraction [13]. This finding supports our research objective, which examines beat sensitivity and synchronization capacity before and after an auditory-tactile music teaching intervention. This research paper constitutes a fundamental part of an on-going project aiming at investigating perceptual and sensorimotor timing skills of young children. Measuring musical abilities in childhood is challenging, considering the difficulties in separating the efficacy of musical training from developmental aspects in cognitive and kinaesthetic abilities [16]. This research was designed mainly based on results from studies on auditory-tactile interactions, auditory-motor interactions, beat perception, sensorimotor synchronization and embodied learning. Music learning is consciously or unconsciously strongly correlated with tactile perception and body movements. During music playing, singing, dancing, or even just listening, auditory and tactile inputs are integrated into a common multimodal percept ([5-7], [9], [13]). The full-length "in-classroom" study examined beat sensitivity on 65 greek elementary school students. Its goal was to obtain data for improving the practiced teaching perspectives, introducing a novel auditory-tactile music teaching approach. In this paper, we set out to test beat perception in a musical context and to examine the relationship between beat sensitivity and other musical abilities. We assume that the outcomes of the rhythm and beat sensitivity tests will be correlated, while other musical capacities such as recognition of scale, interval, contour and memory will be dissociated. Furthermore, we examine beat misalignments between simple and complex meter stimuli; our hypothesis is that greek children's sensitivity to simple metrical structures will not be significantly better than to complex structures. We also predict that performance in all tests will be independent of age and gender. These hypotheses were tested with the following two procedures: 1) a full version of the Montreal Battery for Evaluation of Musical Abilities in Childhood (MBEMA), introduced to explore musical disorders, and 2) a perceptual task of the complex Beat Alignment Task (cBAT), developed by Kate Einarson [14] which examines beat sensitivity in a musical context.

STYDY DESIGN AND METHODOLOGY

PARTICIPANTS

65 children were recruited from a public elementary school in Athens, Greece (29 F, 31 M, age range 8 to 10, mean age 8.5). The selection was based on research findings suggesting that children between 8-10 years old are considered equal for their musical abilities [16]. All participants attended either the 3rd or the 4th grade. They were randomly assigned to either one of two control groups or to one of two experimental groups. Due to several absences 5 children were excluded from the study, and their data were removed from any subsequent analysis.

EQUIPMENT

Both tests were conducted using a Macbook Pro 15.4' Laptop, running the open source software Reaper. Stimuli were played back to participants using a set of M-Audio BX5 D2 Studio monitors. Children arranged their desks in a semicircular configuration. Both speakers were placed in the centre in front of the children, and SPL was measured using the EoSUN EM-2242 SL-401 sound meter level. The final position of the monitors was selected such that SPL levels did not differ more than 0.1 dB along the perimeter of the semicircle, ranging between 70.00-70.1 dB SPL.

STIMULI

The experiment began with a **M**ontreal **B**attery of **E**valuation of **M**usical **A**bilities (MBEMA) in **C**hildhood task, in order to identify possible amusia cases. Individuals with amusia face difficulties in discriminating between musical tones and/or rhythmical patterns or in recognizing familiar compositions [14]. Amusia can be congenital or acquired later in life. MBEMA is one of the most efficient tools for assessing such a weakness or disorder. The children version was introduced in 2013 and contains five subtests: rhythm, contour, interval, scale, and memory. All subtests use the same 20 original melodies, in 10 different keys. All melodies (duration: M=3.5sec) are computer-generated, presented in different timbres or instruments.

The perceptual task, which followed, explored the participants' timing skills, helping us to examine auditory perception apart from sensorimotor skills. Perceptual timing was examined using the anisochrony detection task **cBAT** (**c**omplex **B**eat **A**lignment **T**est) developed by Kate Einarson [3], in which participants were asked to detect deviations from isochrony in 16 different musical excerpts. Each trial consisted of a musical excerpt and a superimposed woodblock sequence, either "on-" or "off-beat". In our study an audio-only presentation of the musical excerpts was chosen as more appropriate. Half of the excerpts had simple metric structures (4/4, 3/4)) and the remaining complex (7/4, 7/8, 5/8 and 5/4). Aiming to add the factor of familiarity in our study we created 4 more musical excerpts of greek music. All audio files were created by superimposing isochronous woodblock sounds that matched each excerpt's BPMs on commercial audio recordings of the selected melodies, and adjusting the isochronous sequences. Each musical excerpt (duration: M=17.8 sec, tempo range: 87 to 122 BPM) was presented three times: once in its original version accompanied by the woodblock isochronous sequence "on-beat", and twice with a misaligned "off-beat" accompaniment. To create misaligned tracks the isochronous woodblock sequences were phase-shifted backwards or forward 25% of each excerpt's average BPM (phase shift of ±25% Inter Beat Interval). All misaligned tracks maintained the correct inter-beat-interval. The magnitude of the misalignment between the musical excerpt and the isochronous sequence was held constant. The stimulus set for this study consisted of 54 audio files in total (2 standard practice trials, 4 phase shifted practice trials,16 standard test trials, 16 misaligned trials with a -25% phase shift, and 16 misaligned trials with a +25% phase shift).

EXPERIMENTAL PROCEDURE

To control for possible outliers, MBEMA data were collected at the beginning of the study. In rhythm, contour, interval, and scale tasks 20 short test trials were presented which consisted of a target melody and a comparison one, separated by a 1.5 sec pause. Each trial was presented after a warning tone, followed by 500 ms of silence. Trials were separated by a 4 sec pause. Children listened to each trial once and assessed whether the target and the comparison melodies were identical or different (forced-choice method SAME/DIFFERENT). The memory task was presented last. It examined incidental memory and consisted of 10 melodies from the prior trials and 10 new. Children were asked to respond with a YES if they had heard each melody before, or a NO if they had not. The total duration of the MBEMA test was approximately 40 minutes. Each group completed the test in one teaching hour.

The cBAT task was also completed during one teaching hour, following the MBEMA. For this part of the experiment participants had to respond with YES/NO to the question: "You are listening to a short melody accompanied by a woodblock sequence. Do you believe that the sequence follows exactly the beat of the music?". The task started with a familiarization phase, where children repeatedly listened to two practice trials, one with simple and another with a complex metrical structure, until they understood their task. Feedback was provided during this phase. The main experiment began once participants indicated that they had fully understood the experiment task. The total duration of cBAT was up to 38 minutes.

RESULTS

MBEMA

The reliability analysis of MBEMA gave a Cronbach's $\alpha = .87$, indicating a high internal consistency of the scale. There was a great difference in the mean scores between the two grades (Mc = 75.4% correct; Md = 85.0% correct). In order to determine if the means of the two sets of data differed significantly, t-tests were conducted with *grade* as a grouping variable. Due to unequal variances, both Student's and Welch's test were conducted. Results of the independent t-tests indicated that there were significant differences in mean scores between the two grades in all subtests except for *Rhythm*. Children in the 4th grade scored significantly higher than those in the 3rd.

Independent Samples T-Test grouping Variable *GRADE*					
	Test	Statistic	df	p	Cohen's d
RHYTHM	Student	-.950	58.000	.346	-.245
	Welch	-.945	55.377	.349	-.245
SCALE	Student	-3.631	58.000	< .001	-.938
	Welch	-3.613	55.335	< .001	-.936
CONTOUR	Student	-3.916	58.000	< .001	-1.012
	Welch	-3.908	57.030	< .001	-1.011
INTERVAL	Student	-3.068	58.000	.003	-.792
	Welch	-3.065	57.500	.003	-.792
MEMORY	Student	-3.339	58.000	.001	-.863
	Welch	-3.294	47.811	.002	-.857
MBEMA	Student	-4.182	58.000	< .001	-1.080
	Welch	-4.174	57.135	< .001	-1.079

Table 1: t-statistics MBEMA subtests and total Battery

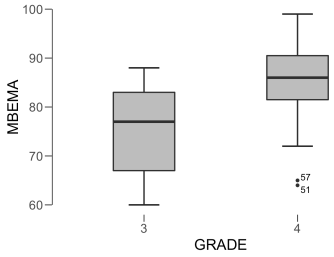

Fig2:MBEMA mean scores (%) for C=3 and D=4 grades.

cBAT

First, we assessed the reliability of the cBAT test for greek students. Cronbach's α was calculated at .67, indicating a high reliability of the scale. To directly compare the mean performance of 3rd and 4th grade, independent sample t-tests were conducted. Besides the overall performance, we examined the mean scores of complex and simple metrical structures, separately (simple metre: Mc=55.6%; Md=60.3%; complex:Mc=54.9%; Md=56.05%). Results indicated that there were no significant differences in mean performances between the two grades (Mc=55.25%; Md=58.2%). In addition, independent sample t-tests were conducted taking *gender* as a grouping variable. Results indicated that there were significant differences in mean performances between male and female participants; boys performed significantly lower than girls. Mean performances are visualised in figure 3. Students of the 3rd grade had better scores in complex meter music, while in simple meter they scores just above chance levels. Girls performed in both categories of metrical structures significantly better than boys (cBAT: Mb=53.4%; Mg=60.4%; simple: Mb=52.3%; Mg=58.9%; complex: Mb=54.4%; Mg=61.9%)

Independent Samples T-Test grouping variable *GENDER*					
	Test	Statistic	df	p	Cohen's d
cBAT	Student	2.462	58.000	.017	636
	Welch	2.450	55.559	.017	634

Independent Samples T-Test grouping variable *GRADE*					
	Test	Statistic	df	p	Cohen's d
cBAT	Student	-.989	58.000	.327	-.255
	Welch	-.988	57.377	.327	-.255

Table 2: t-statistics cBAT

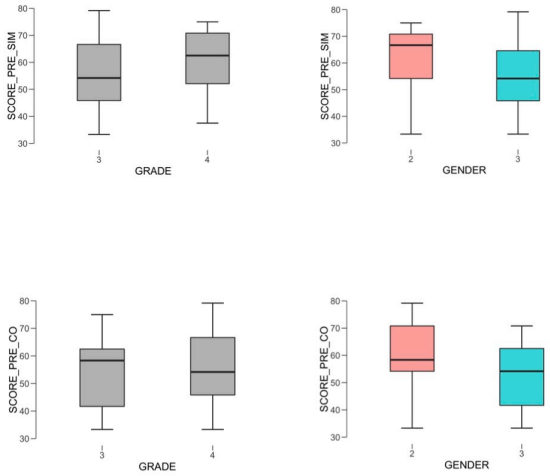

Fig 3: cBAT mean scores (%) for simple and complex metrical structures depicting grade (C=3 and D=4) and gender (girls =2 and 3= boys)

CORRELATIONS

Correlational analyses were used to examine the relationship between grade, gender, and students' performances in both tests. Pearson's and Spearman's coefficients were calculated. Results indicated a non-significant correlation between MBEMA and cBAT scores, showing that performances in both tests are hardly related. Participant gender and cBAT scores had an inverse relationship, with girls performing better than boys. Results indicated that there was a positive

Correlation Table					
		cBAT	MBEMA	GRADE	GENDER
cBAT	Pearson's r	—			
	p-value	—			
	Spearman's rho	—			
	p-value	—			
MBEMA	Pearson's r	.145	—		
	p-value	.268	—		
	Spearman's rho	.137	—		
	p-value	.296	—		
GRADE	Pearson's r	.129	.481	—	
	p-value	.327	< .001	—	
	Spearman's rho	.120	.492	—	
	p-value	.363	< .001	—	
GENDER	Pearson's r	-.308	.097	-.001	—
	p-value	.017	.460	.993	—
	Spearman's rho	-.316	.091	-.001	—
	p-value	.014	.491	.993	—

Table 3: Correlation Matrix

association between performance and grade in MBEMA subtests.

DISCUSSION

In this study we examined beat sensitivity in musical context for 60 children between 8 and 10 years of age. To eliminate participants with possible amusia, all children completed the Montreal Battery for the Evaluation of Musical Abilities in Childhood, at the beginning of the study. No child was defined with possible difficulty in music perception. We assumed that scores in the cBAT and the *Rhythm* subtest would be associated. However, results indicated that MBEMA and cBAT are not correlated. This finding is consistent with research results suggesting that beat sensitivity is a unique attribute that should be investigated separately, and is commonly associated with learning disabilities or language impairment, rather than with difficulties in music perception ([4], [8], [10], [15]). Moreover, though MBEMA mean performance was highly above chance levels, most children scored just above chance levels in cBAT. Therefore, conducting the MBEMA may be helpful for exploring the particular musical attributes that are under investigation, providing no evidence for further musical abilities. Surprisingly, age was correlated with the MBEMA performance in all tasks except for *Rhythm*, despite the fact that children of the 3rd and 4th grades are considered equal in their musical aptitude. Greek students are exposed to complex metres from early childhood singing several children's songs or dancing traditional dances; this fact led as to hypothesise that there would be no significant differences in the perception of simple and complex metrical structures[2]. Indeed, total scores of complex and simple grouping variables did not significantly differ between grades. However, results showed significant differences between gender; girls performed significantly better than boys. We observed this phenomenon of gender differentiation in beat sensitivity with great interest, without drawing final conclusions, since we are expecting that the future analysis of the further research results will shed more light on all findings.

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