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Performance in a Pitch Memory Task by Visually Handicapped Children and Youths

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The present work discusses results concerning sound perception obtained in a pitch memorization experiment for blind and visually impaired subjects (children and teenagers). Listeners were divided into two age groups: 7–13 year olds and 14–18 year olds. The study tested 20 individuals (8 congenitally blind and 12 visually impaired) and 20 sighted persons comprising reference groups. The duration of the experiments was as short as possible due to the fact that our listeners were children. To date, no study has described results of such experiment for blind/visually handicapped children and teenagers. In the pitch memory experiment blind teenagers outperformed blind children and both age groups of visually impaired subjects in two out of three tested cases. These results may have implications for the development of auditory training in orientation and mobility of young visually handicapped people.

Keywords: pitch memory, blinds, visually impaired, children, teenagers.
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1. Introduction

There are a number of papers about pitch memory in adult musicians and non-musician with normal vision (Rakowski, Rogowski, 2007; 2010; Rakowski, 2009; Gaab *et al.*, 2003; Moore *et al.*, 2007). It was also shown that adult blind or visually handicapped people perform better than sighted individuals in tasks related to attention focusing (Gougoux *et al.*, 2004) and pitch discrimination (Gougoux *et al.*, 2004; Wan *et al.*, 2010), but not in the pitch memory task (Wan *et al.*, 2010). Some papers indicate that congenitally blind or early-blind adult individuals display superior performance compared to late-blind persons (Gougoux *et al.*, 2004; Wan *et al.*, 2010; Voss *et al.*, 2008). The possible reasons for such behavior of early and late blind persons are beyond the scope of this paper as they are of neuropsychological nature. In brief, it may be said that blind subjects (especially early blind) may be more susceptible to changes in the brain function induced by blindness (Wan *et al.*, 2010), e.g. for blind persons a larger tonotopic map in the auditory cortex was found compared to the sighted reference group (Elbert *et al.*, 2002).

The present work discusses results concerning pitch memorization in blind or visually handicapped children and teenagers. Children and teenagers (blind/visually handicapped and normal sighted reference persons) were divided into two age groups: 7–13 year olds (children) and 14–18 year olds (teenagers) Most of our subjects have been blind/visually handicapped since the first days of their life.

Our aim was to investigate pitch memory skills in blind and sighted children and teenagers, as no equivalent studies have been reported in literature yet. Additionally we wanted to compare our results to those obtained for blind adults (Gougoux *et al.*, 2004; Wan *et al.*, 2010) Thus, we wanted to check to what extent results recorded for younger and older visually handicapped groups would be similar to the performance of blind adults.

2. Subjects

The study was approved by the Bioethical Committee at the Poznań University of Medical Sciences. A total of 20 visually impaired persons and 20 sighted reference persons took part in the experiments. Table 1 lists demographic characteristics of the blind/visually handicapped subjects, information about their musical experience (“none” – no experience of music, “small” – singing or playing melodic instruments for three years

Table 1. Characteristics of the blind\visually handicapped group.

	Congenitally blind					Visually impaired					Early-onset				
	No.	Age [yrs]	Gender	Preferred hand	Musical experience	No.	Age [yrs]	Gender	Preferred hand	Musical experience	No.	Age [yrs]	Gender	Preferred hand	Musical experience
Age group 7–13	1	12	male	left	none	1	13	female	left	none					
	2	7	male	right	none	2	13	male	right	none					
	3	10	female	right	small	3	13	female	left	none					
	4	10	female	right	small	4	12	female	right	none					
						5	9	female	right	small					
						6	10	female	right	small					
						7	7	female	right	small					
Age group 14–18	1	15	female	left	large	1	15	male	right	small	1	16	male	right	small
	2	15	female	right	large	2	15	male	right	small					
	3	16	male	left	large	3	15	male	right	none					
						4	17	female	left	small					
						5	15	male	left	none					

or less, "large" – music school students and singing for no less than 4 years) and preferred hand (right-handed people prefer the right ear, left-hand people prefer the left ear) The tested subjects took part in our earlier experiments (Bogusz *et al.*, 2012)

For each blind participant a sighted control person was recruited that corresponded in terms of age, gender, musical experience, preferred hand. None of the subjects had absolute pitch. All our subjects have had problems with vision ever since birth or soon after it, i.e. they were congenitally or early blind individuals. The early blind group comprised those who became blind after birth and before the 13th year of age (Wan *et al.*, 2010; Bogusz *et al.*, 2012). Consequently, none of our subjects was a late blind person. There was only one early blind subject. He was treated as a congenitally blind individual. Similarly, the only visually handicapped subject having sight problems from the age of 4 was treated as visually impaired from birth.

All the subjects were volunteers; they were not paid for their cooperation. The visually impaired subjects were recruited from the Special Training and Education Centre for Blind Children in Owińska, Poland. None of the subjects had any significant hearing loss (as assessed by a tonal audiogram), and they were all free of neurological effects. They could stop tests at any time if they felt tired or uncomfortable.

3. Experiment

Sounds were prepared before the experiment in the Matlab environment. The experimental method of constant stimuli was used. The sounds were presented in a random sequence via headphones to the preferred listener's ear chosen in relation to the preferred hand. The duration of the experiment was as short as possible due to the fact that some of our subjects were children below ten years of age. The subjects were given a practice session prior to testing. In the practice session the same sounds were used which were used in the proper experiment. The length of the practice session was adjusted to the age, concentration, intellectual development and individual needs of the subjects and took ca. 5 minutes. Subjects answered to the experimental tasks verbally and the experimenter copied their answers.

The pitch memory experiment was adopted from the experiments of Wan *et al.* (2010), Gaab *et al.* (2003) and Moore *et al.* (2007). Sequences of tones having different number of components (4, 6 or 9) were presented. The sequence comprised the first (target) tone, the last (probe) tone and distracting tones not belonging to the musical pitch scale. Each trial contained 300 ms tones with the attack and decay rate of 20 ms, the time interval between successive tones in a pair being 300 ms The duration of 300 ms is long enough to evoke pitch sensation (Ozimek, 2002).

The attack and decay rates were much longer than the time constants of auditory filters, which may play a role in the discrimination task (Moore, 1999). The time interval between tones was long enough to avoid both backward and forward masking (Moore, 1999). After each presentation there were 4 seconds for answering. The first tone in a sequence was 330, 349, 370, 392, 415, 440, 466, 494, 523, 554, 587 or 622 Hz (pitch of the first tones differed from 100 cents (semitone) to 1100 cents (11 semitones). The final tone in the sequence had exactly the same pitch as the first tone or, in other cases, it diverged within the range of ±41–55 Hz. The largest intervals between the first tone and the final one in the sequences are also given in cents in Table 2. The differences between the first tone and the final one ranged from 147 cents (slightly more than one semitone) to 316 cents (more than three semitones i.e. minor third).

Table 2. The largest intervals in cents between the first tone and the final one in the sequences.

Frequency of the first tone (f_1) [Hz]	Interval between the first and the final tone (cent)	
	when f_1 was −55 Hz	when f_1 was +55 Hz
330	316	267
349	297	253
370	279	240
392	262	227
415	246	215
440	231	204
466	217	193
494	204	183
523	192	173
554	181	164
587	170	155
622	160	147

The frequencies of distracting tones (distractors) contained between the first and the last tone diverged randomly within the range of ±55 Hz. The maximum difference between the pitch levels in a sequence was 110 Hz. Each sequence was presented twice to each subject. The subjects were asked to determine whether the last and first tones had the same pitch.

The experiment was conducted in three stages at different times. Examples of frequency compositions of the tone sequences are listed in Table 3. The tone sequences were presented in a random sequence in three groups equivalent in terms of duration of the sequence. The first part of the experiment (sequences of 4 tones) took ca. 14 minutes with breaks included. The second stage (sequences of 6 tones) lasted 17 minutes, while the third stage (9 tones) – up to 20 minutes because it required more frequent interruptions. For the younger group of subjects, sequences containing 4 or 6 tones were presented. For the older group, sequences having 4, 6 or 9 components were played.

Table 3. Examples of frequencies used in the tone sequences in the pitch memorization experiment.

	Frequency [Hz]								
	f1	f2	f3	f4	f5	f6	f7	f8	f9
4-tone sequence	330	341	329	330					
	330	374	298	376					
6-tone sequence	330	370	314	319	312	330			
	330	346	298	375	317	380			
9-tone sequence	330	328	378	362	363	363	369	358	330
	330	334	281	319	297	317	312	379	284

4. Results

Similarly to Wan *et al.* (2010) proportion correct was a primary dependent variable for all the experiments. For the pitch memory task a question similar to that of Wan *et al.* (2010) and Moore *et al.* (2007) was asked: is there any advantage of the blind\visually handicapped over sighted subjects and if so, does it vary for the two age groups and for the difficulty level?

To evaluate the differences in means between any two groups, the *t*-test for independent variables was used. The equality of the variances assumption was verified with the Levene's and Brown-Forsythe's test. There were no statistically significant differences in variances in any of the compared pair of groups.

Younger groups of subjects (children) were tested using sequences consisting of 4 and 6 tones. Older groups (teenagers) listened to sequences consisting of 4, 6 and 9 tones. Results of the pitch working mem-

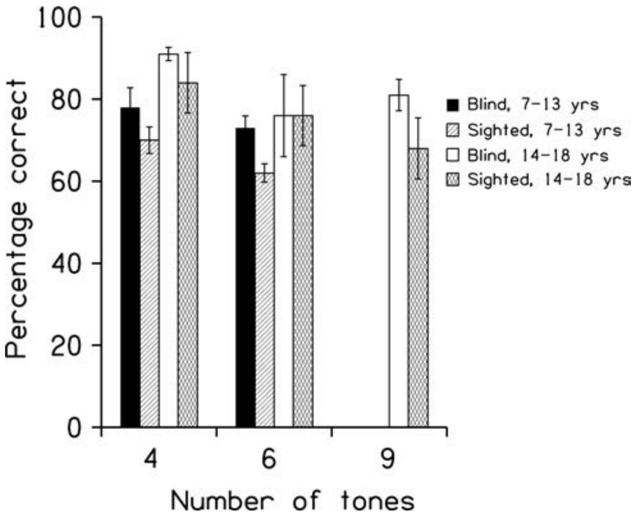

Fig. 1. Mean and standard in percentage of correct values in the pitch memory task for both age groups of blind subjects and corresponding reference groups.

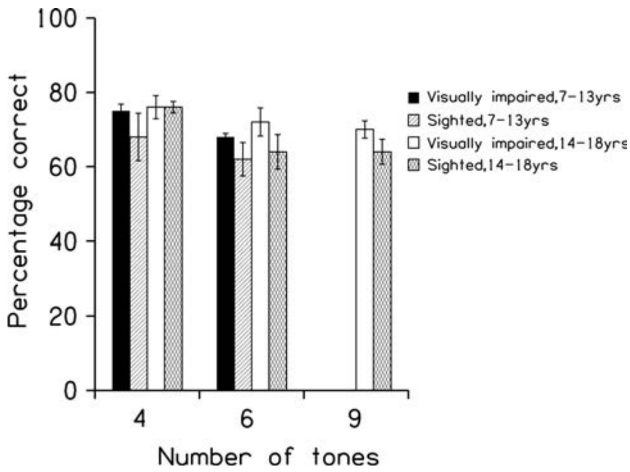

Fig. 2. Mean and standard errors in percentage of correct values in the pitch memory task for both age groups of visually impaired subjects and corresponding reference groups.

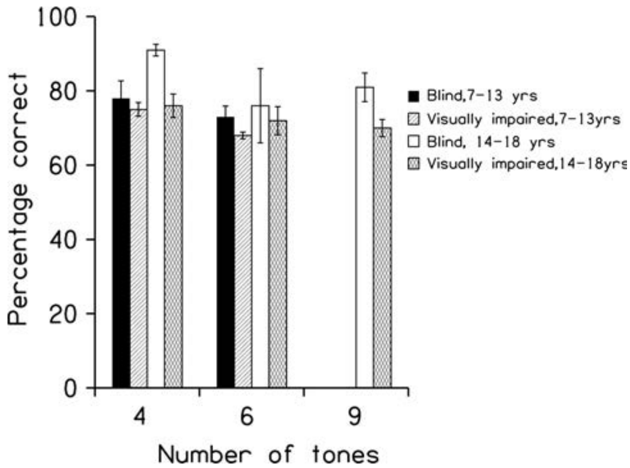

Fig. 3. Mean and standard errors in percentage of correct values in the pitch memory task for both age groups of blind subjects and both age groups of visually impaired subjects.

ory experiment are shown in Figs. 1–3. A statistically significant difference in means was found between the younger group of blind subjects and the reference group for the sequences consisting of 6 tones – the blind group performed much better than the reference group ($t_{(6,\ 0.033104)} = 2.754268$). A statistically significant difference was also found between the older group of blind and the older group of visually impaired individuals for sequences consisting of 4 and 9 tones ($t_{(7,\ 0.008046)} = 3.662298$ and $t_{(7,\ 0.042340)} = 2.477896$, respectively). The results of sighted reference groups were similar to those of Gaab *et al.* (2003).

5. Discussion

The pitch memory experiment was related to a higher-level process, i.e. to working memory, while the pitch discrimination and pitchtimbre categorization tasks, described in earlier works (Wan *et al.*, 2010; Bogusz *et al.*, 2012) relied on basic perceptual skills. We found that both the age groups of visually impaired subjects performed similarly to their reference sighted groups. This observation is consistent with the result obtained for blind adults (Wan *et al.*, 2010). The younger group of blind individuals, however, obtained a better score than its reference group for the 6-tone sequence. Blind teenagers performed better than their visually impaired counterparts for the 4- and 9-tone sequences This observation is consistent with the result of Wan *et al.* (2010) that congenitally blind adults outperformed those in the early-onset group.

The musical experience of our subjects and pitch naming ability were not taken into account in the analysis of results since recently it was shown that superior auditory abilities in congenital and early-blind subjects were not explained by musical experience only but rather by the vision loss (Wan *et al.*, 2010). However, it is worth noting that in the group of blind teenagers three of the four subjects had a large music experience, while in the other three groups, a part of the subjects had no or only a small musical experience. As Deutsch (1978) showed, moderately left-handed subjects were superior in a pitch memory tasks. The handedness of subjects has not been analyzed because only a small number of not-right-handed subjects was tested; in all groups was a similar number of right-handed and left-handed people, but there were no ambidextrous people. Finally, it must be pointed out that while the congenitally blind groups of participants were homogenous groups, the groups of visually impaired subjects were non-homogenous, because they consisted of persons having various degrees of vision loss and residual light perception

This is the first study to evaluate the performance in the pitch memory task of blind and visually impaired children and teenagers as separate groups Our results show that blindness or visual impairment does not necessarily lead to a superior performance in the pitch memory task. A proper and correct distinction of differences in frequency is extremely important for safe and independent orientation and mobility of visually handicapped people in an urban environment. Gaab *et al.* (2006) suggested that auditory training might improve the performance in a pitch memory task in young sighted adults. Performance in auditory tasks after any kind of auditory training of blind and visually impaired children and youths has not been investigated yet.

6. Conclusions

We conclude that in the pitch memory task:

- Some differences and similarities were found in performance between our subjects themselves (blind and visually impaired children and teenagers) as well as between our subjects and congenitally blind adults;

- Both the age groups of visually impaired subjects performed similarly to the reference sighted groups;
- Blind teenagers outperformed the remaining groups of our subjects in trials comprising 4- and 9-tone sequences what may be connected with larger musical experiences.

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References

1. Bogusz E., Koprowska H., Skrodzka E. (2012), *Investigation of performance in selected auditory tasks by blind and visually impaired teenagers*, Acta Physica Polonica A, **121**, 1-A, 13–18.
2. Deutsch D. (1978), *Pitch Memory: An Advantage for the Left-handed*, Science, **199**, 559–560.
3. Elbert T., Sterr A., Rockstroh B., Pantev C., Muller M.M., Taub E. (2002), *Expansion of the tonotopic area in the auditory cortex of the blind*, Journal of Neuroscience, **22**, 9941–9944.
4. Gaab N., Gasler C., Schlaug G. (2006), *Improvement-related functional plasticity following pitch memory training*, Neuroimage, **31**, 255–263.
5. Gaab N., Gaser C., Zaehle T., Jancke L., Schlaug G. (2003), *Functional anatomy of pitch memory – an fMRI study with sparse temporal sampling*, Neuroimage, **19**, 1417–1426.
6. Gougoux F., Lepore F., Lassonde M., Voss P., Zatorre R.J., Belin P. (2004), *Pitch discrimination in the early blind*, Nature, **430**, 309–1309.
7. Moore B.C.J. (1999), *An introduction to the psychology of hearing* [in Polish: *Wprowadzenie do psychologii słyszenia*], PWN, Poznań.
8. Moore R.E., Keaton K., Watts C. (2007), *The role of pitch memory in pitch discrimination and pitch matching*, Journal of Voice, **21**, 5, 560–567.
9. Ozimek E. (2002), *Sound and perception* [in Polish: *Dźwięk i jego percepcja*], PWN, Warszawa-Poznań.
10. Rakowski A. (2009), *The domain of pitch in music*, Archives of Acoustics, **34**, 4, 429–443.
11. Rakowski A., Rogowski P. (2007), *Experiments on long-term and short-term memory for pitch in musicians*, Archives of Acoustics, **32**, 4, 815–826.
12. Rogowski P., Rakowski A. (2010), *Pitch Strength of Residual Sounds Estimated Through Chroma Recognition by Absolute-Pitch Possessors*, Archives of Acoustics, **35**, 3, 331–347.
13. Voss P., Gougoux F., Zatorre R., Lassonde M., Lepore F. (2008), *Differential occipital responses in early – and late-blind individuals during a sound-source discrimination tasks*, Neuroimage, **40**, 746–758.
14. Wan C.Y., Wood A.G., Reutens D.C., Wilson S.J. (2010), *Early but not late-blindness leads to enhanced auditory perception*, Neuropsychologia, **48**, 344–348.