BRAIN RESEARCH 1156 (2007) 168–173

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Research Report

Modification of dichotic listening (DL) performance by musico-linguistic abilities and age

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ARTICLE INFO

Article history:
Accepted 18 April 2007
Available online 24 April 2007

Keywords:
Musical expertise
Linguistic skills
Maturation
Lateralization

ABSTRACT

To increase our understanding of the phonemic processing skills of musical and non-musical subjects, the Dichotic Listening task was performed in children and adults with varying degrees of musical aptitude. The roles of maturation and musical training were also investigated. The results showed superior left ear monitoring skills among the adults who practised music regularly. This may indicate altered hemispheric functioning. Other musically talented subjects did not have the ability to control left ear functioning in an equal manner, for instance, the performance of musical children and their non-musical controls in the forced–left / left ear condition did not differ. Thus, regular music practice may have a modulatory effect on the brain's linguistic organization and therefore, the beneficial effects of music on other cognitive skills should not be underestimated.

1. Introduction

Since the early findings of Broca, observations and theories on hemispheric specialization have been the focus of neuropsychological research. Clinical and experimental studies suggest that the left hemisphere of the brain is specialized for speech processing and the right hemisphere deals with different non-linguistic material, such as music (Peretz, 2002; Zatorre et al., 2002; Tervaniemi and Hugdahl, 2003).

However, it is possible that brain organization can be modulated by diligent practice; for example, musical expertise could have neurological concomitants also in terms of hemispheric lateralization (Bever and Chiarello, 1974). Additionally, previous studies suggest a connection between music and language aptitudes (Milovanov et al., 2004; Gilleece, 2006). We therefore hypothesized that musical expertise affects the laterality of the musical and linguistic processing in the human brain. The present study aims at defining whether hemispherical phonemic processing is different between non-musical and musical subjects as indexed by a dichotic listening task. Furthermore, to reveal the roles of maturation and musical training, we compared the dichotic listening performance of school age and adult subjects.

In the dichotic listening technique, two different auditory stimuli are presented at the same time, one in each ear (Kimura, 1967; see Hugdahl, 1999 for an overview). In the non-forced (NF)

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Abbreviations: CV, consonant–vowel; DL, dichotic listening; FL, forced-left condition; FR, forced-right condition; NF, non-forced condition; REA, right-ear advantage

0006-8993/$ – see front matter © 2007 Published by Elsevier B.V.
doi:10.1016/j.brainres.2007.04.048

condition, the subject is free to report the stimuli heard, which, with consonant–vowel (CV) syllables, the majority of cases report the sound presented to the right ear. This data pattern is taken as a behavioural measure of left temporal lobe processing superiority for phonological stimuli. This right-ear advantage (REA) is probably caused by the fact that although auditory input is transmitted to both auditory cortices in the temporal lobes, the contralateral projections are stronger and more preponderant, interfering with the ipsilateral projections. Thus, while reporting the stimuli, the subjects rely more on right-ear input, which predominantly and more directly entered the left auditory cortex (Hugdahl, 2000).

Since a stronger REA with linguistic material processing in the non-forced condition has been reported numerous times (see for a review Tervaniemi and Hugdahl, 2003), our attention was mainly focused on forced-right (FR) and forced-left (FL) conditions. Instructing the subject to focus attention on the right ear stimulus requires different cognitive processes than instructing the subject to focus attention on the left ear. It is suggested that in the FR condition, sensory based bottom–up (REA) and attention based top–down processes would act synergistically. However, with the FL condition, it is proposed that the bottom–up and top–down processes would be in conflict, with the bottom–up effect favouring the right ear stimulus and top–down processing favouring the left ear stimulus. Moreover, it has been shown that maturation (Hugdahl and Andersson, 1986; Hugdahl et al., 2001) and ageing (Thomsen et al., 2004) have a selective influence on top–down processing. In the present study, using the Finnish version of the original "DLCV-108" dichotic listening test by Hugdahl and Andersson (1986) to determine the laterality effects among children and adult groups, musical/non-musical and English philology students, special attention was therefore paid to FR and FL conditions to determine whether these two are differentially affected by musico-linguistic abilities and age.

2. Results

2.1. *Musical aptitude test*

Fig. 1 illustrates the combined score obtained by four subtests (pitch discrimination, duration, timbre, and tonal memory accuracy) of the Seashore musical aptitude test. The choir members and musically non-talented subjects clearly differed from each other in terms of the musical aptitude scores. English philology students performed rather well in the musical aptitude test even if only two subjects practiced music actively and regularly either by singing or playing an instrument. Five English philology students reported never having shown an interest in practising music in any form at all, and six subjects had played an instrument for a couple of years in their early teenage years but ceased playing it due to a lack of interest or skill. Neither of the child test groups practised music on a regular basis. The non-musical adults had never shown any interest in practising music in any form.

The group differences in the Seashore musical aptitude test were confirmed in ANOVA which indicated a group main effect [$F(4,64)=37.9$, $p<0.001$]. Post-hoc comparisons showed no significant group difference between the test performances of the choir members and English philology students ($p>0.05$), the English philology students and musically advanced children ($p>0.05$), and the choir members and musically advanced children ($p>0.05$). However, the group differences between any other groups were significant ($p<0.001$).

2.2. *Dichotic listening test*

While excluding the musical aptitude factor and taking only the age factor (all the children vs. all the adults) into account, the interaction Ear × Age × Condition [$F(2,134)=8.08$, $p<0.01$]

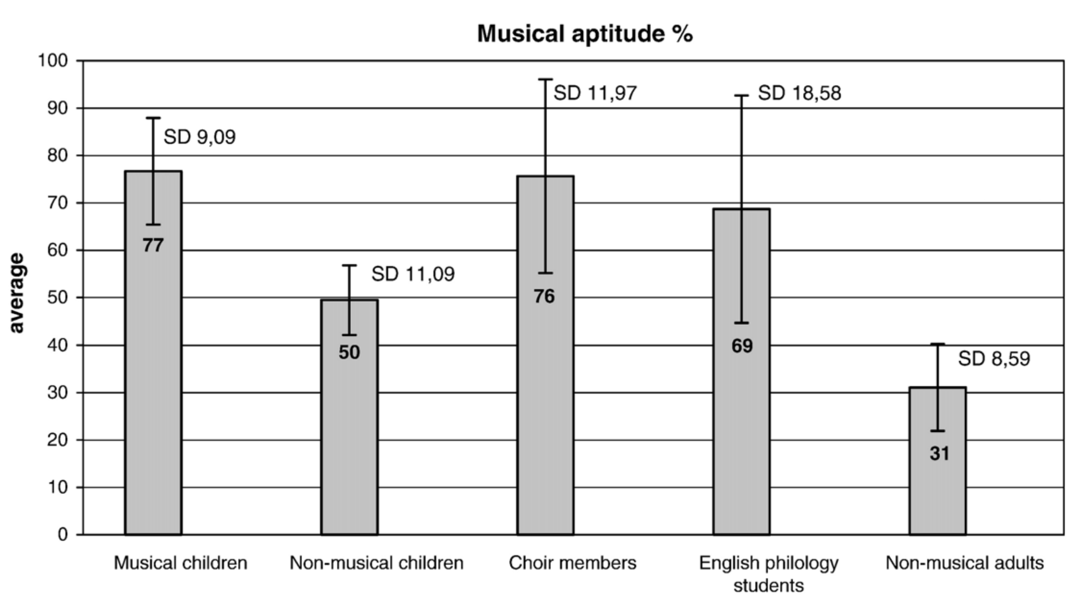

Fig. 1 – Percent correct reports from the Seashore musical aptitude four subtests: pitch discrimination, duration, timbre and tonal memory accuracy.

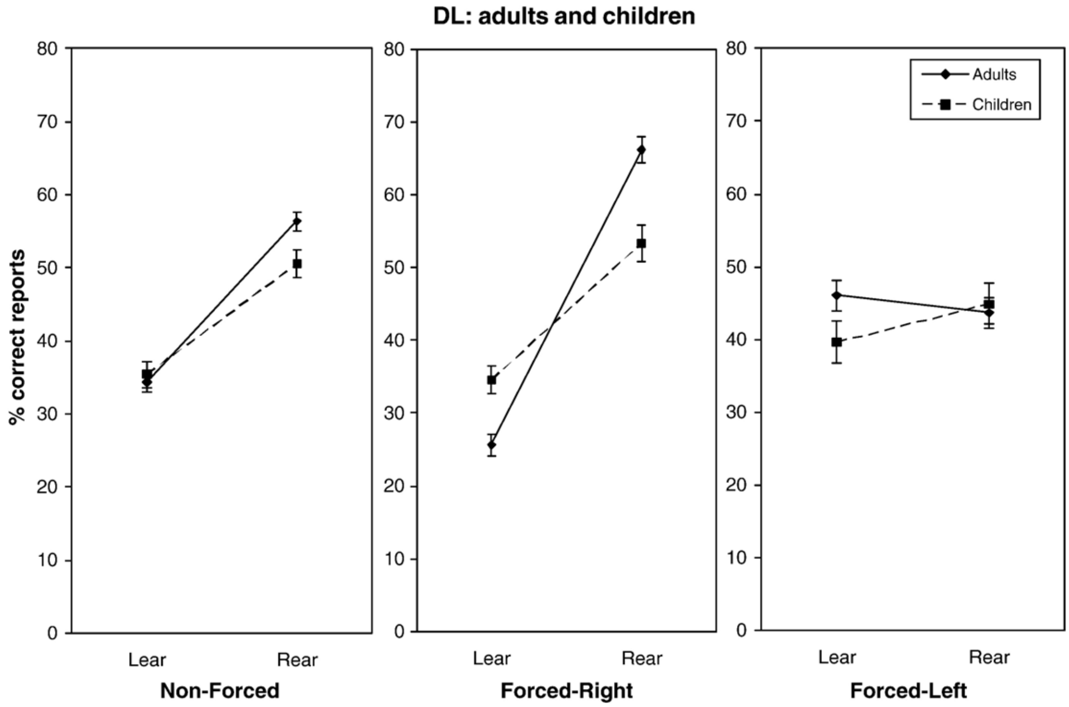

Fig. 2 – Percent correct reports (mean and SEM) for the left (Lear) and right (Rear) ear stimulus during all three conditions (Non-Forced, Forced-Right, Forced-Left) for the adults and children.

was confirmed (see Fig. 2). In the non-forced condition, all the subjects had a strong REA [$F(1,67)=2.60$, $p>0.05$]. On the other hand, the REA became stronger with adults in the forced-right condition [$F(1,67)=17.09$, $p<0.001$] when comparing them with children. There were no significant differences between the two age groups in the forced-left condition [$F(1,67)=1.33$, $p>0.05$].

When dividing the subjects into subgroups (see Participants), the greatest difference between the subject groups' DL performance was observed between the adult subject groups (choir members, English philology students, and non-musical subjects), particularly in the FL/left ear condition (Fig. 3). This was confirmed by a group main effect in the left ear performance [$F(4,64)=4.5$, $p<0.01$]. The effect was caused by choir members having a stronger left ear advantage than non-musical and English philology students ($p<0.01$).

When comparing the musical and non-musical children's performance (Fig. 3), no such difference was found between any of the conditions as was found among the adult subjects; for instance, no statistically significant group difference was found in the FL left ear condition [$F(1,22)=1.5$, $p>0.05$].

In addition, the laterality index score (see Data analysis) was calculated to further investigate whether DL performance and general musical aptitude interact. First, a group main effect was found in the laterality index score in the forced-left condition with the adult subjects [$F(2,42)=1.2$, $p<0.01$]. The post-hoc test revealed a significant group difference between choir members and non-musical university students ($p<0.01$). Second, a correlation was found between general musical aptitude and the laterality index score in the forced-left condition in adult subjects ($r=-0.300$, $p<0.05$). In other words, the more general musical aptitude the subject had, the stronger was the reliance on the left ear input in the forced-left condition. With children, no correlations between the laterality index score and general musical aptitude were found.

3. Discussion

The present study was conducted to compare the linguistic DL performance in children and adults with varying degrees of musical aptitude. In addition, the roles of maturation and musical training were investigated. The results showed superior left ear monitoring skills among the adult musical choir members. However, English philology students with comparable musicality test scores did not have the ability to control left ear functioning in an equal manner when CV pairs were presented to both ears with an instruction to focus on the left-ear input. No effect of musical aptitude on DL performance was obtained in children. Moreover, it was shown that the musical aptitude score correlated positively with the laterality index score, i.e., with the performance in the FL condition. The greater the general musical aptitude score was, the more correct left ear responses were obtained in the FL condition.

The data thus suggest that both maturation and musical aptitude modulate our cognitive abilities; the right ear advantage in the non-forced condition seems to become stronger and more preponderant with age. Moreover, personal choices we make, for instance, the amount of music one practises, can modify our brain functioning. Participants with good scores in a musicality test are not able to show good left ear monitoring skills in childhood, but those adults with good musicality test score who also practise music actively had better developed listening skills even in

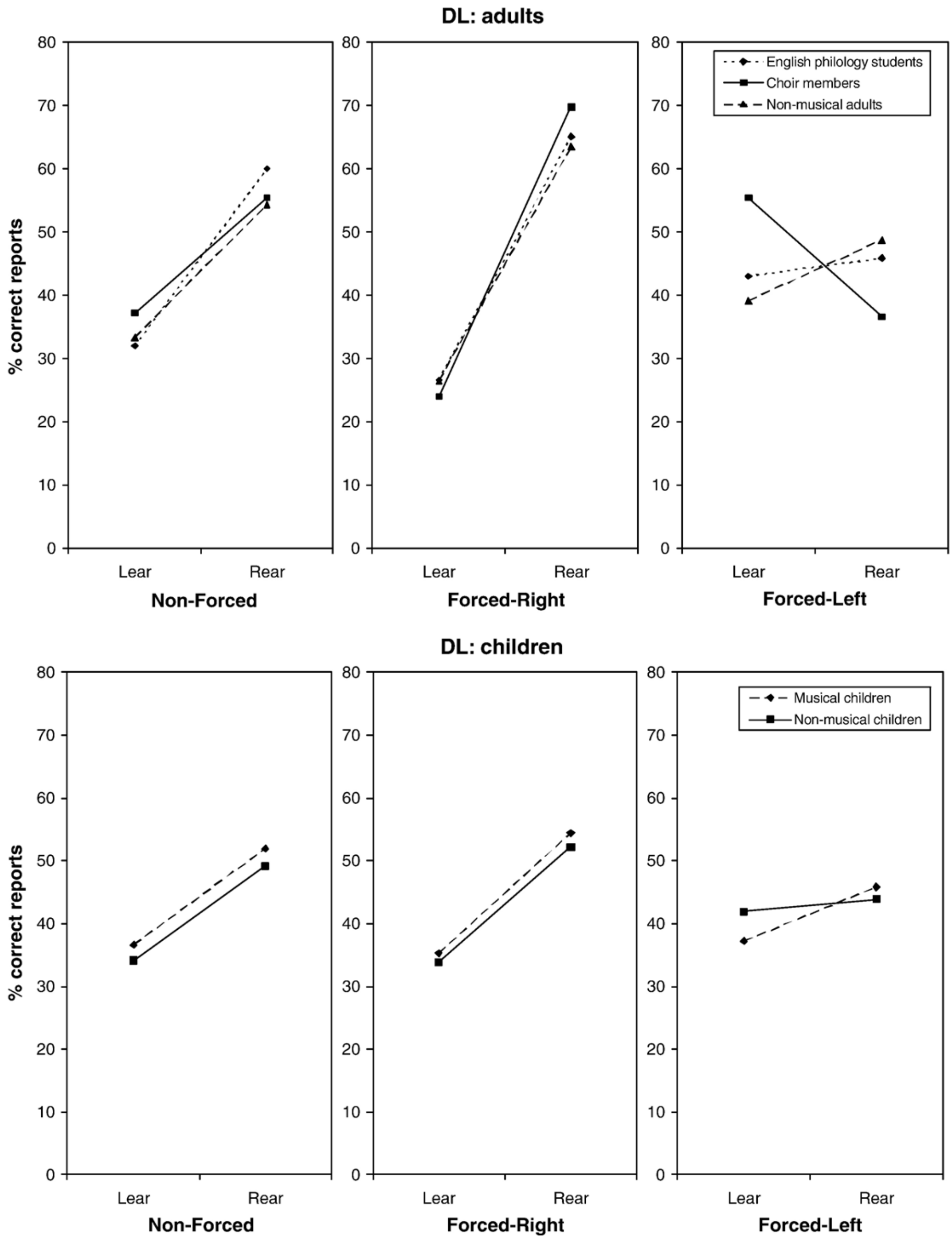

Fig. 3 – Percent correct reports for the left (Lear) and right (Rear) ear stimulus during all three conditions (Non-Forced, Forced-Right, Forced-Left) split for the results obtained from the adult subgroups (upper row) and children subgroups (lower row).

linguistic tasks. Yet, since the present study is based on a cross-sectional design, one has to take into account the possible existence of innate group differences in the attentional abilities of the adult groups. This explanation is unlikely, however, since the members of the other adult subject group, consisting of students specializing in language learning and thus with a high level of expertise in auditory monitoring and production comparable to choir members, were not able to alter their hemispheric functioning according to DL test instruction. Thus, we are persuaded to attribute the present finding specifically to musical training and regular practice.

The FL condition can be considered to be the most attention-engaging task in which the subjects have to override stimulus-driven and built-in REA. Therefore, the FL condition is a sensitive measure of top–down executive control and diverging attentional processes may even cause structural changes in left middle frontal gyrus as a function of age

(Thomsen et al., 2004). Our FL result suggests that musical adults may activate their right hemisphere more during language processing. This might result from their ability to subconsciously track the musical components of speech or, alternatively, to possibly activate more effectively some latent linguistic areas as yet unknown.

In addition to the enjoyment music provides to our everyday life, it may have the capacity to facilitate the learning of certain basic skills, such as linguistic orientation. Music and language have a set of common rules, for example, as music, language has a rhythm. When we talk, our speech is cultivated by a tempo and a beat. By using alternation in pitch, the syllables produced may receive a different meaning. This is ordinarily used with tonal languages. As Patel (2003) puts it, music, like language, is a human universal involving discrete elements organized into hierarchically structured sequences and the two phenomena may therefore serve as foils for each other in the study of brain mechanisms underlying complex sound processing.

Taken together, the beneficial effects of music on other cognitive skills should not be underestimated. The position of music education, especially, which is currently rather undervalued at most elementary and high schools, should therefore become a permanent and regular part of the curriculum. At least the importance of sung material in (foreign) language education should be further examined.

4. Experimental procedures

4.1. *Methods*

We used the Finnish version of the dichotic listening test (Hugdahl et al., 2004) which consists of phonetically meaningful but semantically irrelevant CV pairs /ba/, /da/, /ga/, /pa/, /ta/, /ka/. The CV pairs were presented to both ears, always two different pairs at a time. The presentation of the CV stimuli was randomized in order to balance the possible biasing effects of pairing voiced /voiceless CV pairs (Rimol et al., 2006).

The musicality of the subjects was tested by using the Seashore Musical aptitude test (Seashore et al., 1960a,b), which considers musicality as an entity emerging from relatively independent subskills organized along the different sound parameters and cognitive demands (e.g., pitch discrimination accuracy/durational accuracy, vs. memory for pitch/duration). The subjects were asked to complete the following subtests of Seashore: pitch discrimination, duration, timbre, tonal memory accuracy, rhythm, and loudness. Since only the melodic elements of language and music were compared, the results of the Seashore subtests rhythm and loudness were not analyzed in the present context.

4.2. *Participants*

The adult subjects consisted of three subgroups: relatively musical English philology students ($N=13$, 10 females, mean age 24, musical aptitude score=69%, 13 right-handed), musically talented choir members ($N=16$, 16 females, mean age 27, musical aptitude score=76%, 16 right-handed) and non-musical university students ($N=16$, 14 females, mean age 25, musical aptitude score=31%, 16 right-handed). These subjects were recruited by displaying advertisements on notice boards around the campus of the University of Turku or sending e-mails via the university's mailing lists.

The musical children ($N=12$, 6 females, mean age 10.6, musical aptitude score=77%, 12 right-handed) and non-musical children ($N=12$, 7 females, mean age 10.5, musical aptitude score=50%, 12 right-handed) were recruited in elementary schools in the Turku district in the south-western part Finland.

All the subjects were right-handed as determined by a modified version of the Edinburgh Handedness Inventory questionnaire (Oldfield, 1971). All the subjects had intact hearing as evidenced by clinical audiometer (Inter acoustics model, AC4 serial 0204, Denmark) test results. Moreover, there were no significant differences between the levels of sounds heard with the two ears, the 500 to 5000 Hz range was used when defining the hearing thresholds due to most of the spectral energy in the CV syllables takes place in this range (Hugdahl et al., 2004).

To rule out the possibility that the differences in test results among different groups might result from differences in the cognitive capacity of the subjects, the subjects were tested by WISC-III (children) and WAIS-R (adults). The analysis of variance (ANOVA) confirmed that there were no significant group effects between any of the test groups ($p>0.05$ for both adults and children).

4.3. *Procedure*

The experiments with children were conducted during the school day in a quiet test room. The adult subjects were tested in equal conditions in the Centre for Cognitive Neuroscience laboratories. The NF condition was always presented first. The presentation order of the FR and FL conditions was counterbalanced across subjects. Each participant gave informed consent; with children, the parent's signature was an absolute prerequisite for participation. The experiments were in accordance with the Helsinki declaration.

4.4. *Data analysis*

The effects of age on lateralization in both age groups were studied with a repeated measures ANOVA [Age (adult, child)×Ear (left, right)×Condition (NF, FR, FL)]. The statistical significances of the group differences in DL performance were determined by analysis of variance (ANOVA) for the NF, FR, and FL conditions. In order to test the presence of significant ear advantages separately in different age groups, Age (adult, child) and Ear (left, right) were used as factors.

The effects of musical aptitude on ear advantages in all the subgroups were tested with one-way ANOVA. Significant effects were further analyzed with Tukey's HSD post-hoc tests for selected contrasts. Analysis of variance was also used in order to determine the group differences in musical aptitude skills. Moreover, a laterality index score $[(RE-LE)/(RE+LE)\times 100]$ was calculated, and the statistical significances of the group differences were investigated with ANOVA. If a group main effect was found, the laterality index score was correlated with the musical aptitude score.

Acknowledgments

The present research was financially supported by Pythagoras Graduate School (Ministry of Education, Helsinki, Finland). Thanks to Mr. H. Railo and Dr. M. Koivisto for their contributions to the data analysis and Ms. M. Köynnös, Ms. P. Savolainen and Ms. R. Tammisto for their assistance in the data collection. Special thanks to Dr. H. B. Jacobster for providing us the original Seashore musical aptitude test in a CD format and Ms. P. Hirkman for editing the illustrations.

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