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Note

Music training and mental imagery ability

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Abstract

Neuroimaging studies have suggested that the auditory cortex is involved in music processing as well as in auditory imagery. We hypothesized that music training may be associated with improved auditory imagery ability. In this study, performance of musically trained and musically naive subjects was compared on: (1) a musical mental imagery task (in which subjects had to mentally compare pitches of notes corresponding to lyrics taken from familiar songs); (2) a non-musical auditory imagery task (in which subjects had to mentally compare the acoustic characteristics of everyday sounds); and (3) a comparable measure of visual imagery (in which subjects had to mentally compare visual forms of objects). The musically trained group did not only perform better on the musical imagery task, but also outperformed musically naive subjects on the non-musical auditory imagery task. In contrast, the two groups did not differ on the visual imagery task. This finding is discussed in relation to theoretical proposals about music processing and brain activity.

Keywords: Music; Imagery; Temporal lobes

1. Introduction

Musical mental imagery, or the ability to 'hear' melodic sound-sequences with the 'mind's ear' in the absence of external stimulation, plays an important role in musical performance [2]. Musicians often rely on musical imagery to guide their performance and to memorize or compose new music. Moreover, the ability to read written music silently is an acquired skill that often involves mental imagery. Halpern [4] devised a task aimed at measuring mental scanning in auditory imagery for songs, modeled on the visual scanning study by Kosslyn et al. [6]. Subjects were asked to mentally compare pitches of notes corresponding to lyrics taken from familiar songs (e.g. 'The Star Spangled Banner'). Results showed that reaction times increased as a function of the distance between two beats and as a function of the starting point of the earlier lyric [4], and thus provided evidence that auditory imagery is not only a strong subjective experience, but, analogous to visual imagery, can be quantified to a certain extent.

It has been suggested that music training and listening to music may have beneficial effects on other cognitive processes. For example, Rauscher et al. [12] reported that college students who listened to the first 10 min of Mozart's Sonata for Two Piano's in D Major (K.448) subsequently scored significantly higher on a spatial–temporal task than after listening to 10 min of progressive relaxation instructions or after 10 min of silence (although this effect has not always been replicated for other cognitive tasks, [15]). Indeed, evidence has also been provided that music training may improve pre-school children's spatial–temporal reasoning [14].

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The putative effects of music training on cognitive performance may not be limited to spatial–temporal tasks, however. Chan et al. [1] recently reported higher verbal but not visual memory performance in subjects with at least 6 years of music training before the age of 12 compared to a control group without music training. These authors argued that the improved verbal memory in musically trained subjects may be due to a larger planum temporale in the left hemisphere relative to the right hemisphere in musicians, as has been shown in previous MRI-studies [17]. However, there is no evidence of involvement of the planum temporale in memory processing [18] and in a recent review on structure and function of the planum temporale [18] it is concluded that 'the functional significance of asymmetrical planum temporale remains obscure' (p. 41).

A more straightforward approach would be to predict which cognitive processes may be enhanced in musically trained individuals compared to non-trained individuals by taking into account the neural structures activated in music processing. Two studies using positron emission tomography (PET) have been reported [5,20], in which basically the same auditory cortical areas (in the temporal lobes, bilateral) were activated during musical imagery and musical perception, and it has been proposed that these areas are involved in auditory imagery in general [20]. A related finding was recently reported in an fMRI-study of vivid auditory imagery associated with auditory hallucinations in patients with schizophrenia, which activated sensory auditory cortex [3]. In the present study we compared performance of subjects with and without music training on tasks of musical auditory imagery, non-musical auditory imagery and visual imagery. If music training leads to more proficient processing of mental images in auditory cortical areas, better performance of musically trained subjects on musical imagery may well extend to non-musical auditory imagery. This is not a trivial prediction, as there is evidence that music (the domain in which the training occurs) concerns a very specific type of auditory information processing and representation, that may dissociate with other types of auditory information [11]. According to our hypothesis, musically trained subjects will not perform better on a visual object imagery task compared to subjects without musical training, as visual imagery activates different cortical areas [7].

2. Method

2.1. Subjects

A total of 35 college students from Utrecht University participated in the study. Subjects were assigned to either a 'musically-trained' group (15 subjects) or a 'non-trained' group (20 subjects). Subjects in the musical group had to: (1) actively play a musical instrument at the moment of testing; and (2) have received at least 2 years of formal music training. The two groups differed significantly ($P < 0.01$) in number of years of music training (musicians 5.4; non-musicians 1.5). The two groups did not differ in terms of age (musicians 22.5 years; non-musicians group 21.1 years; $t = 1.25$) or number of years of education (musicians 16.3; non-musicians 16.0; $t = 0.49$). The male/female ratio was 6/9 in the trained group and 5/15 in the non-trained group.

2.2. Measures

2.2.1. Musical auditory imagery task

Musical imagery was assessed with a pitch comparison task (based on the task described by Halpern [4]) that consisted of a perception and an imagery condition and required subjects to compare the pitches of notes corresponding to song lyrics.

Subjects viewed the lyrics from the first phrase of a familiar Dutch song on a screen and were asked to decide whether, of two highlighted lyrics which appeared in uppercase letters, the pitch of the second lyric was higher or lower than that of the first lyric. An English-language example of a song-line would be 'OH say can you SEE', taken from the American national anthem. Lyric refers here to a monosyllabic word, or one syllable of a two-syllabic word. Subjects responded by means of a key-press and were asked to respond as fast as possible. In the perceptual condition, subjects were actually presented with the song, which was played on a tape-recorder, and thus viewed the lyrics and heard the song at the same time. The imagery condition was identical, with the exception that the song was not presented, and subjects had to rely on their musical imagery in order to be able to perform the task correctly. The task consisted of 31 trials, divided over five well-known Dutch songs. Number of correct responses and reaction times were recorded.

2.2.2. Non-musical auditory imagery task

This task was modeled on the visual imagery object comparison task developed by Mehta et al. [9], described below. The task concerned a quantitative comparison between imagery and perception of acoustic characteristics of common sounds. A triad of common sounds was presented, and subjects had to indicate the most deviant item in terms of acoustic characteristics. In the perceptual condition, the sounds were actually presented (with use of a personal computer), whereas in the imagery condition the names of the sounds were read from cards, which required subjects to form mental images in order to be able to make a correct judgement. An example of a sound triad that was presented is 'crying baby', 'laughing baby' and 'meow-

Table 1
Means (and SDs) of subjects in the musically trained group and in the non-trained group on measures of auditory and visual imagery and perception

Task	Condition	Trained group ($n = 15$)	Non-trained group ($n = 20$)
Musical pitch comparison	Perception	29.0 (1.7)	27.8 (2.9)
	Imagery	28.1 (3.4)	24.3 (4.0)
Everyday-sound comparison	Perception	20.6 (1.3)	19.8 (1.9)
	Imagery	17.6 (1.6)	15.8 (2.8)
Visual form comparison	Perception	21.2 (1.3)	20.7 (1.8)
	Imagery	19.5 (2.0)	19.1 (2.4)

ing cat', where 'laughing baby' was regarded the deviant item. The task consisted of 23 triads.

2.2.3. Visual imagery task

This task was adapted from Mehta et al. [9] Subjects had to indicate the odd-one-out in terms of visual form characteristics of a triad of common objects. The task consisted of 24 object names printed on cards and 24 triads of line drawings of common objects [19]. From the triads of line drawings, the item that was most deviant in terms of visual form characteristics had to be indicated. In the perceptual condition the line drawings were actually presented, whereas in the imagery condition the object names were read from cards. For example, in the perceptual condition pictures of a 'pumpkin', 'lettuce' and 'tomato' were presented, whereas in the imagery condition only the names of these three objects were presented to the subject. Thus, the imagery condition requires the subjects to form mental images in order to be able to make a correct judgement of the odd-one-out (in the example given, 'lettuce').

3. Results

We conducted a 2 (Group: musicians, non-musicians) × 2 (Condition: perceptual, imagery) × 3 (Measure: musical, non-musical, visual) multivariate analysis of variance (MANOVA). Number of correct responses was the dependent variable included in the analysis for the three imagery measures. A z-transformation was applied to the scores before analysis, as the scales of the different measures are not comparable. Only the between-subjects factor Group was significant, $F(1, 33) = 6.6$, $P < 0.02$. Table 1 shows the means and SDs of both groups on the different measures.

In a subsequent MANOVA on only the imagery measures, again only a significant effect of Group was obtained, $F(3, 31) = 3.6$, $P < 0.03$. Follow-up univariate analyses of variance (ANOVA) revealed a significant difference between the musically trained and the non-trained group on the musical imagery task, $F(1, 33) = 8.6$, $P < 0.01$. Musically trained subjects had more correct responses for this task. The groups did not differ in reaction time, $F(1, 33) = 0.04$, $P > 0.10$. The difference between both groups was also significant for the non-musical auditory imagery task, $F(1, 33) = 4.9$, $P < 0.05$. Again, musically trained subjects performed better. There was no difference between the groups for performance on the visual imagery task, $F(1, 33) = 0.3$, $P > 0.10$. In Fig. 1, mean percentage correct responses of both groups are presented graphically for the three imagery tasks.

The MANOVA with perceptual conditions of the three tasks as dependent variables did not reveal significant differences between the musically trained and the non-trained group, although a trend seemed to emerge, $F(3, 31) = 3.6$, $P < 0.07$. Follow-up ANOVA's, in order to examine the direction of this trend, failed to reach significance ($P > 0.10$). We also performed within-group analyses to examine whether subjects within a group differed on the three tasks. No significant differences were found ($P > 0.20$), indicating that the three measures did not differ importantly in difficulty level.

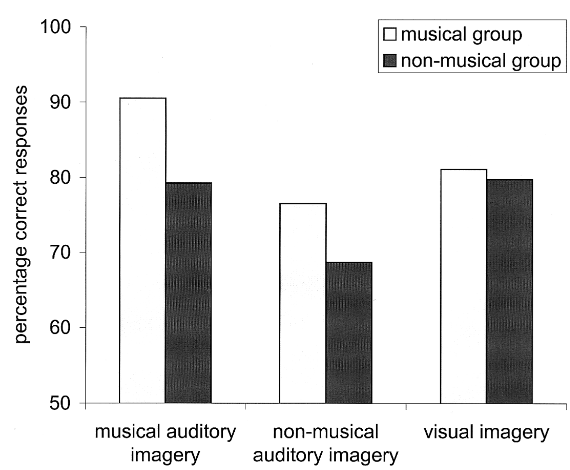

Fig. 1. Mean percentage correct responses given by subjects with and without music training on the musical auditory imagery task, the non-musical auditory imagery task and the visual imagery task.

4. Discussion

In this study, the hypothesis was tested whether musically trained subjects would perform better than non-trained subjects on a musical imagery task and whether this better performance would extend to a non-musical auditory imagery task. The results suggest that music training may improve both musical and non-musical auditory imagery but not visual imagery, consistent with the evidence of temporal association cortical involvement in auditory imagery [20].

The musically trained group did not differ from the non-trained group on the perceptual condition of the musical imagery task. The fact that people with little musical training performed as well as trained subjects on this task may be due to the use of relatively easy stimuli: familiar songs with well-known melodies. This could likewise explain why the non-trained group also performed fairly well on the imagery task. Indeed, as most of us will confirm from personal experience, the experience of having 'tunes running through ones head' is not confined to musicians only. Notwithstanding, the musically trained group performed significantly better than the non-trained group on the imagery condition of the musical imagery task, suggesting more efficient processing of musical image representations in people with musical training.

Alternatively, one could argue that this is not a result of better processing of auditory image representations, but rather of an enhanced ability to organize and manipulate musical information in working memory. For example, analogous to expertise in chess, extensive music training may lead to the use of effective strategies involving abstract schemata, in this case regarding pitch relationships within melodic sound-sequences. However, the fact that trained subjects did not perform better than the non-trained subjects on the perception condition of the musical task is at odds with this possibility. More importantly, such an explanation would not predict better performance of musical trained subjects on non-musical auditory imagery tasks with everyday sounds (e.g. 'a train passing') as stimuli. However, this was exactly what we found in the present study: musically trained subjects also performed better on a non-musical auditory imagery task than non-trained subjects.

An alternative explanation for the observed relation between music training and auditory imagery ability could be that it may be due to other variables, such as attention and memory, on which the two groups may differ and that may influence imagery performance. However, the subjects were drawn from a group (college students of identical age) that is relatively homogeneous in terms of cognitive abilities. In addition, the fact that the two groups did not perform differently on the visual imagery task, which has similar cognitive processing demands as the auditory tasks, suggests that the groups did not differ importantly on such variables. Another possibility would be that the musically trained subjects might be more interested in auditory tasks, thus causing more attention to this condition. However, if musicians are more interested in auditory tasks than in visual tasks, one would expect higher performance on the auditory tasks than on the visual tasks, which was not the case.

The possibility could also be considered that music training leads to a general improvement of imagery ability, regardless of the modality involved. Contrary to this hypothesis, the musically trained group did not perform better on a visual imagery task that was comparable to the non-musical auditory imagery task in terms of task-related characteristics. This finding is consistent with theoretical proposals regarding the neural basis of auditory imagery as involving auditory cortical areas in the temporal lobe [20] and visual imagery as involving occipital cortical areas [7]. Music training, which involves musical mental imagery, may thus lead to more proficient processing of imagery representations in auditory cortical areas, which may eventually result in a general enhancement of auditory imagery ability. It is important to note that the lack of a difference between musicians and non-musicians on the visual imagery task is not in contradiction with the findings by Rauscher et al. [12]. As Rauscher and Shaw [15] have explicitly pointed out, the Mozart effect is only observed on tasks which strongly require spatial–temporal processing (e.g. paperfolding tasks). Thus, measures that mainly require visual object recognition or imagery (i.e. without the temporal component of image transformation) may not show improvement after listening to music.

Rauscher et al. [13] proposed a neurophysiological basis for the enhancement of spatial–temporal task performance after listening to a Mozart piano sonata. Their model is based on Mountcastle's [10] organizational principle in which the cortical column is the basic neural network of the cortex. These networks have a large repertoire of inherent, periodic spatial–temporal firing patterns which can be excited in specific symmetries. The computation by symmetry operations among the inherent brain patterns is considered a key property of higher brain function and, more specifically, of spatial–temporal tasks, and may be enhanced and facilitated by music. To complement this account, we suggest that this effect may be especially pronounced in localized networks, which may explain why non-musical auditory imagery is enhanced in musically trained subjects. This is consistent with the study by Samthein et al. [16] who observed enhanced synchrony between the neural activity in right frontal and left temporo-parietal cortical areas in an EEG coherence study of the Mozart effect. Indeed, recent studies have shown that training in a specific domain alters structure and function of localized brain areas [8]. Without doubt, more research is needed on the relation between music training and mental imagery and the neural correlates involved before strong conclusions can be reached. For example, it would be interesting to compare musicians and non-musicians in a functional magnetic resonance imaging (fMRI) design on patterns of brain activation during various imagery tasks.

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