The effect of musical expertise on the representation of space

Silvia Cucchi [*,•], Carlotta Lega [*,#,1], Zaira Cattaneo [#,••], Tomaso Vecchi [*,••,2]

** Cognition Psychology Neuroscience Lab, University of Pavia, Italy*

#Department of Psychology, University of Milano-Bicocca, Italy

•Il Musicatorio, Torino, Italy

•• Brain Connectivity Center, IRCCS Mondino, Pavia, Italy

[1]carlotta.l88@hotmail.it, [2]vecchi@unipv.it

ABSTRACT

Background

Individuals typically show a leftward bias – known as pseudoneglect – in bisecting physical lines possibly reflecting a right hemisphere dominance in spatial representation. Previous studies demonstrated that musicians, in visually based tasks, have a more accurate performance in bisection tasks, and even show a rightward bias (Patston et al., 2006), thus suggesting that musical experience may influence the representation of peripersonal space. The pitch of isolated tones is mentally represented along spatial axes (SMARC effect) (Lidji et al., 2007). Pitches appear to be mapped onto a mental spatial representation in a way that affects motor performance (Rusconi et al., 2006). A series of RT experiments explored response device orientation (horizontal vs. vertical) task and musical expertise: the pitch of isolated tones triggered the automatic activation of a vertical axis independently of musical expertise; in contrast automatic association with the horizontal axis seemed linked to music training for pitch (Lidji et al., 2007). Previous studies have demonstrated that different spatial representations may interact with each other when activated simultaneously: for instance, the presentation of numbers of different magnitude affects performance in line bisection, due to numbers activating a spatial mental representation (mental number line) that modulates allocation of attention to the physical line (Cattaneo et al., 2009;2010; Fisher, 2001; Lacey et al., 2009; Laeng et al., 1996). Up to now, the possible effect of pitch height on perception of the external space has not been investigated. Moreover, spatial biases using a line bisection paradigm in musicians have so far been studied exclusively in the visual modality (Patston et al., 2006).

Aims

This study aims to clarify the effects of music on the representation of external space in musicians and non. musicians by using a crossmodal paradigm. By using an haptic rod-bisection task, we first verify whether musicians show a different directional bisection bias compared to non musicians in horizontal and radial bisection. Then, we evaluate the possible crossmodal influence of different auditorily presented pitches on haptic spatial judgments in musically trained and untrained participants.

Method

Participants

Participants were 10 skilled piano players (3 males, mean age=24.4 years, SD=4.6, range 20-36; years of piano 15.2, SD= 2.7, range 11-20) and 10 non musicians (3 males, mean age=23.2 years, SD=1.6, range 21-26), all right-handed as assessed with the Edinburgh handedness questionnaire.

Material and procedure

Blindfolded participants had to bisect a series of wooden rods of different lengths (30, 35, 40, 45,50 cm). The rods were positioned horizontally or radially in front of the subject. Six seconds were given for each rod's exploration. The participants were instructed to explore the length of the rod in their preferred direction, using the right index finger only. At the beginning of each trial, the experimenter placed the palm of the participant's right hand on the rod, so that it covered the midpoint of the rod, but the middle of the palm could be either slightly to the left or right of the rod's midpoint. This starting point for haptic exploration was used in order to avoid systematic biases in scanning direction, which are induced when exploration begins at either end of the rod. These systematic biases have been shown to influence bisection performance (cf. Baek et al., 2002). This palm-based starting position could not be used as an accurate estimate of the rod's midpoint, due to its approximate nature and because, at the start of each trial, the participants were asked to lift the palm off the rod and to begin to explore it with the right index finger.

During the haptic exploration, participants were simultaneously presented with an auditory stimulus lasting 6 sec, that started with the beginning of the exploration. Following the bisection, in the "height judgment task" participants had to indicate whether the auditory stimulus was a low tone (DO- C3 131Hz and SOL – G3 196Hz), a high tone (MI- E5 659 Hz and SI – B5 988 Hz) or consisted of white noise; in the "timbre judgment task" participants had to indicate whether the auditory stimulus was a normal tone (DO and SI), a distorted tone (DO and SI distorted) or consisted of white noise. The tones used were piano notes; they were created using the software Sibelius and reproduced with Quick Time Player using a MacBook. The white noise and the distorted notes used in the timbre task were obtained using the software Audacity. Each task consisted of 25 trials (5 trials for each rod's length, one for each auditory condition) preceded by a few practice trials. Hence, each participants performed 50 trials in the horizontal and 50 trials in the radial plane.

Results

Deviations from the veridical center were converted to signed percentage scores by subtracting the true half-length of the rod from the measured distance of each setting from the left extremity of the rod, and then dividing this value by the true

half-length and multiplying the quotient by 100. Percentage signed deviations for the three different lengths were collapsed together. Signed percentage deviations for the five different lengths were collapsed together in the following analyses.

Horizontal plane

We used t-tests to compare averaged bias scores in the control (white noise) conditions of each task (height and timbre judgment). Overall, musicians showed a tendency to bisect to the right ("minineglect") of the veridical midpoint, but this deviation was not significant, t(9)= 1.06, p=.32 in the height judgment task (mean rightward deviation = 1.44%) and t(9)=.21, p=.84 in the timbre judgment task (mean rightward deviation = 0.56%).

Non musicians showed a tendency to bisect to the left ("pseudoneglect") of the veridical midpoint but this tendency failed to reach significance in both tasks, t(9)= 1.89, p=.09 in the height judgment task (mean leftward deviation = -6.4%), and t(9)=.1.17, p=.27 in the timbre judgment task (mean leftward deviation = -3.3%).

A mixed repeated measures ANOVA, with condition (low tone, high tone, white noise) as within-subjects variables and group (musicians vs. non musicians) as a between-subjects variable was performed on the signed percentage scores reported in the height judgment task. The analysis revealed a significant main effect of condition, F(2,36)=6.39, p=.004, and a significant interaction condition by group, F(2,36)= 8.09, p=.001. The main effect of group was not significant, F(1,18)=2.66, p=.12. The main effect of condition was further analysed in light of the significant interaction condition by group. An analysis of the simple effect of condition within each group showed that condition was not significant for non musicians, F(2,18)=.85, p=.44, whereas it was significant in the musician group, F(2,18)=10.23, p=.001. Pairwise comparisons (Bonferroni correction applied) revealed that in musicians the low tones shifted the perceived midline significantly to the left compared to the white noise condition and to the high tones condition, t(9)= 5.84, p=.001 and t(9)= 3.10, p=.038, respectively. Conversely, the bisection bias shown in the high tone condition was not significantly different form that shown in the white noise condition (p=.99).

A similar ANOVA was performed for the timbre judgment task, with condition (low tone, high tone, white noise) as within-subjects variables and group (musicians vs. non musicians) as a between-subjects variable. The main effect of condition was not significant, F(2,36)= .14, p=.87; however, the interaction condition by group reached significance, F(2,36)= 3.98, p=.027. The main effect of group was not significant (p=.94). An analysis of the simple effect of condition within each group showed that condition was not significant for non musicians, F(2,18)=1.14, p=.34, whereas it was significant in the musician group, F(2,18)=3.55, p=.05. Pairwise comparisons (Bonferroni correction applied) revealed that in musicians the low tones shifted the perceived midline significantly to the left compared to the high tones condition, t(9)=3.06, p=.041, whereas no differences in the bisection bias were reported between the white noise condition and either the low tone, t(9)= 1.76, p=.33, or the high tone condition, t(9)=.70, p=.99.

Radial plane

T-tests were used to compare averaged bias scores in the control (white noise) conditions of each task (height and timbre judgment). Overall, musicians showed a tendency to err in the direction away from the body, but this tendency did not reach significance in either the height judgment task (mean "away from the body" deviation = 2.38%), t(9)=.85, p=.42, or in the timbre judgment task (mean "away from the body" deviation = 2.03%), t(9)=1.02, p=.34.

Non musicians showed a tendency to bisect toward their body compared to the veridical midpoint but this tendency failed to reach significance in both tasks, t(9)= .58, p=.56, in the height judgment task (mean "toward the body" deviation = -2.30%), and t(9)=.65, p=.53, in the timbre judgment task (mean "toward the body" deviation = -2.17%).

A mixed repeated measures ANOVA, with condition (low tone, high tone, white noise) as within-subjects variables and group (musicians vs. non musicians) as a between-subjects variable was performed on the signed percentage scores reported in the height judgment task. The analysis revealed a significant main effect of condition, F(2,36)=5.35, p=.009, whereas the interaction condition by group failed to reach significance, F(2,36)= 1.82, p=.18. The main effect of group was not significant, F(1,18)=.78, p=.39. The main effect of condition was further analysed by means of pairwise comparisons (Bonferroni correction applied). T-tests showed that low tones shifted the perceived midline significantly toward the body compared to both the white noise condition, t(19)=2.85, p=.026 and the high tones condition, t(19)=2.72, p=.030, whereas the bisection bias was comparable in the high tone condition and in the white noise condition (p=.87).

A similar ANOVA was performed for the timbre judgment task, with condition (low tone, high tone, white noise) as within-subjects variables and group (musicians vs. non musicians) as a between-subjects variable. Neither the main effect of condition, F(2,36)= .38, p=.68, nor the main effect of group, F(1,18)=1.14, p=.30, nor the interaction condition by group, F(2,36)= .026, p=.97, reached significance..

Conclusions

Bisection biases in musicians

Recently, a rightward bias in a visual line bisection task has been reported in musicians. The present data suggest that, in musicians, rightward biases are present also in the haptic modality, suggesting that the rightward bias is supramodal (as it is the case of the tendency to bisect to the left of the veridical midpoint in non musicians). Our findings also show that in the radial plane, musicians tend to err in the opposite direction compared to control participants, i.e., in the direction away from the body.

Pitch presentation can influence spatial judgments in a crossmodal auditory-to-haptic paradigm.

Horizontal bisection

In musicians, listening to low tones while haptically exploring a horizontal rod shifted its perceived midline significantly toward the left, as compared to listening to high tones or to white noise (control condition). This effect was more evident when participants had to judge the tone height compared to when they had to focus on a different aspect of the tones (timbre). Overall, our findings indicate that tones are likely to automatically activate a "music spatial line", left to right oriented (at least in piano players). The effect of this representation on spatial perception is larger when attention is specifically devoted to the "spatial" aspect of the musical tones (representation of the height of the tones). Listening to high tones did not affect bisection bias in musicians to a significant extent. This result is in line with previous evidence indicating that biasing in the direction of the pre-existing bias (rightward in case of musicians) may be more difficult than biasing against the pre-existing bias (Cattaneo et al, 2012).

Non musicians did not show an effect of tones listening on their bisection performance. This finding is in line with previous evidence indicating that association of musical tones with the horizontal axis is likely linked to music training for pitch (Lidji et al., 2007).

Radial bisection

In both musicians and non musicians, listening to low tones in the height judgment task shifted the perceived midline significantly to the body direction compared to both the white noise condition and the high tone condition. Overall, these findings are in line with previous evidence indicating that both musically trained and untrained participants were faster in responding to low tones pressing a lower button (with low and high buttons aligned along the radial axis, see Rusconi et al., 2006). However, in our case listening to a high tone did not modulate the bias shown in the control (noise) condition. As in the case of the horizontal bisection, the low tones seem to be more salient than the high tones in affecting modulation of attention.

When the tone height was irrelevant to the task (i.e., in the timbre task) no modulation of the height of the tones on the bisection bias was reported in either musicians or non musicians. This suggests that modulation of the bisection bias in the radial plane occurs only when participants pay attention to the height of the tones, that is, to that feature of sounds that is spatially represented.

Keywords

Spatial biases, pseudoneglect, crossmodal effects, musical expertise, pitch, SMARC

REFERENCES

Baek MJ, Lee BH, Kwon JC, Park JM, Kang SJ, Chin J, Heilman KM, Na DL. (2002).Influence of final search direction on tactie line bisection in normal subjects. Neurology, ;58, 1833-1838.

Cattaneo Z.,Fantino M., Tinti C., Silvanto J.,Vecchi T.(2010), Attention, Perception,& Psychophysics, vol.72(4): pp. 885-890.

Cattaneo Z., Silvanto J., Pascual-Leone A., Battelli L. (2009). Cognitive Neuropsychology, vol.14: pp.1-12.

Cattaneo, Z., Fantino, M, Mancini, F., Mattioli, F., Vallar, G. (2012). Listening to numbers affects visual and haptic bisection in healthy individuals and neglect patients. Neuropsychologia, vol. 50: pp. 913-925.

Fischer M.H. (2001), Neurology, vol.57(5): pp. 822-826.

Lidji P., Kolinsky R., Lochy A., Morais J. (2007), Journal of Experimental Psychology: Human Perception and Performance, vol.33(5): pp. 1189-1207.

Lacey S., Tal N., Amedi A., Sathian K. (2009), Brain Topography, 21, 269-274.

Laeng B., Butter C.M., & Buchtel H.A. (1996), Neuropsychologia, vol.34: pp. 1115-1121.

Patston L., Corballis M., Hogg S., Tippett L. (2006), Psychological Science, vol.17 (12): pp. 1029-1031.

Rusconi E., Kwan B., Giordano B., Umiltà C., Butterworth B. (2006), Cognition Vol 99(2): pp. 113-129

Rusconi E., Kwan B., Giordano B., Umiltà C., Butterworth B. (2006), Ann N Y Acad Sci Vol. 1060: pp. 195-197.