Neuroperception

Superior auditory spatial tuning in conductors

Conducting a large orchestra is an impressive feat that simultaneously requires the intake of the whole musical *gestalt* and the analytical decomposition of the orchestral sound into its components[1]. How, for example, does a conductor identify a specific musician within a multiplayer section? Here we provide evidence from brain-potential recordings that experienced professional conductors develop enhanced auditory localization mechanisms in peripheral space.

Seven classical-music conductors (mean age, 45 yr; mean conducting experience, 19 yr; minimum, 6 yr), seven pianists (mean age, 43 yr; mean professional playing experience, 16 yr; minimum, 7 yr) and seven non-musicians (mean age, 43 yr) were tested in a paradigm used originally to demonstrate superior sound localization in congenitally blind subjects[2] (Fig. 1a). Specifically, the subjects listened to brief pink-noise bursts delivered by central and peripheral arrays of three loudspeakers each (C1–3 and P1–3 in Fig. 1a); these speakers were arranged along a semicircle extending from the midline to 90 degrees right of centre.

While frequent stimuli (84%; frequency of 500–5,000 Hz, 75 decibels, and 80 ms duration) and infrequent 'deviant' stimuli of increased bandwidth (16%; 500–15,000 Hz) were delivered in random order from all speakers (interstimulus interval, 90–270 ms), the subject's task was selectively to attend — in different runs — to the centremost (C1) or rightmost speaker (P1) and to press a button to indicate the 'deviant' stimuli occurring at the designated location (called targets). We recorded multichannel event-related brain potentials (ERPs) using standard methodology[2] and these showed a typically enhanced negativity (termed 'Nd attention' effect) for the relevant speakers (Fig. 1a). In the conductors, ERPs invoked in response to stimuli from adjacent locations showed a similar attention effect of smaller amplitude, indicating that auditory spatial attention is distributed in a gradient fashion[3] for both central and peripheral auditory space.

Attentional effects are also revealed by computing the difference between ERPs to attended-direction and unattended-direction stimuli (Fig. 1b, c). Although a spatial gradient was evident in all three groups for central auditory space, only the conductors displayed a gradient for the periphery. This improved spatial tuning in conductors also has behavioural consequences, as attested by a significantly reduced false-alarm rate for adjacent locations (P2, P3) in the periphery.

The very similar scalp topography of the attention effect (Fig. 1d) for the different groups indicates that conductors probably do not engage different neural populations to perform the task. From magnetoencephalographic recordings[4], the attention effect is known to arise in the secondary auditory cortex, an area also implicated from functional imaging[5]. Improved learning-induced use of spectral cues generated by the head and outer ears, and analysed by the auditory cortex[6], might underlie the localization advantage experienced by conductors. Although conductors probably employ other mechanisms such as perceptual grouping[7,8] to identify single musicians, our findings provide another example of how extensive training can shape cognitive processes and their neural underpinnings.

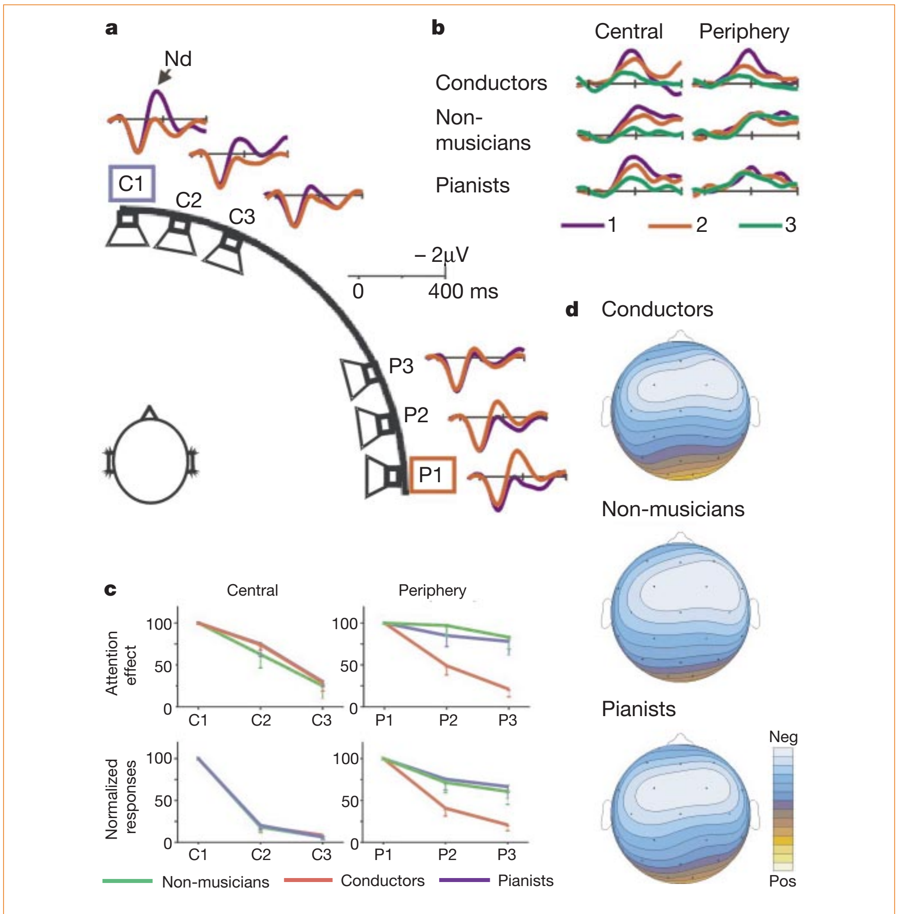

Figure 1 Effects of auditory attention in conductors, pianists and controls. **a,** Experimental set-up; speakers are spaced 6 degrees apart. Group-average event-related potentials (ERPs; frontal midline site) recorded from the conductors and invoked by frequent standard stimuli are represented by blue lines that indicate responses to stimuli from a particular speaker when attending to loudspeaker C1; red lines represent ERPs in response to the same stimuli when attending to speaker P1. Attended stimuli give rise to an enhanced negativity starting at 60 ms (Nd). ERPs associated with adjacent speakers show a similar declining gradient. **b,** Difference waves obtained by subtracting unattended-direction from attended-direction responses. All subject groups show a gradient ERP for central locations; for peripheral sounds, a gradient is evident only for the conductors. **c,** Top row, electrophysiological attention effect (frontal midline electrode; mean amplitude, 180–220 ms; C1/P1 set to 100%). No differences between groups were found for central locations. Conductors showed a steeper gradient in the periphery (groups by location interaction: conductors versus non-musicians, $P=0.015$; conductors versus pianists, $P=0.044$). Bottom row, button presses in response to infrequent stimuli (C1/P1 set to 100%). For peripheral sounds, only conductors show a decreased false-alarm rate for adjacent locations (group by location interaction: conductors versus non-musicians, $P<0.01$; conductors versus pianists, $P<0.01$). **d,** Spline-interpolated scalp maps of the attention effect for the centremost speaker (time window, 180–220 ms) show a similar topography across groups.

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1. Schuller, G. *The Compleat Conductor* (Oxford Univ. Press, Oxford, 1997).
2. Röder, B. *et al. Nature* **400,** 162–166 (1999).
3. Mondor, T. A. & Zatorre, R. J. *J. Exp. Psychol. Hum. Percept. Perform.* **21,** 387–409 (1995).
4. Woldorff, M. G. *et al. Proc. Natl Acad. Sci. USA* **90,** 8722–8726 (1993).
5. Grady, C. L. *et al. NeuroReport* **28,** 2511–2516 (1997).
6. Rauschecker, J. P. *Trends Neurosci.* **22,** 74–80 (1999).
7. Bregman, A. S. *Auditory Scene Analysis: The Perceptual Organization of Sounds* (MIT Press, Cambridge, MA, 1990).
8. Feng, A. S. & Ratnam, R. *Annu. Rev. Psychol.* **51,** 699–725 (2000).