AUDITORY MIDLINE AND SPATIAL DISCRIMINATION IN PATIENTS WITH UNILATERAL NEGLECT

Rhodri Cusack[1], **Robert P Carlyon**[1] **and Ian H Robertson**[1,2]

([1]MRC Cognition and Brain Sciences Unit,15 Chaucer Road, Cambridge, CB2 2EF, UK;
[2]Current address: Department of Psychology, Áras an Phiarsaigh, University of Dublin, Trinity College, Dublin 2, Ireland)

Introduction

Patients with unilateral neglect frequently show a bias in their subjective midline, as measured by pointing, or by a purely perceptual visual task (Ferber and Karnath, 1999). The subjective straight ahead has also been measured in audition. Vallar et al. (1995), Kerkhoff et al. (1999) and Tanaka et al. (1999) have all described a shift of the auditory midline to the right. We consider several causes for a shift in the auditory midline:

(a) Hypokinesia in pointing tasks
(b) Supra-modal distortion of space: neglect may be associated with a shift in the subjective midline that affects all modalities.
(c) Hearing loss
(d) Asymmetric performance
Performance on the task may vary as a function of side of space. For example, if performance is worse on the left, measurements of midline will be artefactually biased towards this side.

Where a shift in midline was found, we measured the hearing threshold of each ear independently to rule out low-level perceptual effects. We also calculated a measure of spatial discrimination performance overall and on each side, to rule out an effect of asymmetric performance. We presented sounds using headphones to allow tight control of the stimuli and to discourage use of an external visual reference. We always presented the sound at the same level to both ears, to avoid an interaction of any possible hearing loss with the level of the sounds in each ear, and to prevent the use of monaural cues in the three-interval task. We then altered the perceived location of sounds by adding a very small lag to the sound in one ear (an interaural time delay, ITD).

Conversely, the absence of a consistent shift in auditory midline (e.g., Sterzi et al., 1996) is also open to different interpretations. For example, it could be due to the patients tested having a purely visual deficit, or to neglect encompassing the auditory modality but without affecting the perceived midline. In the current study we included patients who have been shown to exhibit a non-lateralised auditory deficit in a previous study (Cusack et al., 2000).

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METHOD

Participants

Ten right-brain damaged patients exhibiting neglect were screened using the line bisection and star cancellation components of the behavioural inattention test (Wilson et al., 1987; mean age 66, s.d. 12 years; average time post-onset 2.0 years). All performed below cutoff on both of these two tests. The lesion locations were determined from CT scans and included patients showing only frontal damage (HR), and also mixtures of parietal, frontal and subcortical damage. We also tested seven healthy age-matched controls (mean age 67, s.d. 3 years).

Auditory midline measurement

On each trial, a single narrowband noise (570-630 Hz, 60 dB SPL) with an interaural time delay was presented. The listener was asked whether the sound was on the left or right. Two one-up one-down adaptive procedures that were randomly interleaved on a trial by trial basis were used to converge upon the midline. One started on the left and the other started on the right (initial ITD +/- 220 microseconds, step 40 microseconds). The adaptive staircases terminated when either 12 turning points (points where the patient changes their response from left to right or vice-versa) had been measured in both staircases, or after 100 trials, whichever was the lowest. The midline was estimated from the average of all of the turning points after the sixth in each staircase.

Hearing thresholds

Thresholds were measured using a two-interval task with a QUEST adaptive tracking procedure (Watson and Pelli, 1983). In a single practice block sounds were presented in both ears. Two test blocks in each ear were then presented in an ABBA design. Thresholds were re-measured for subject DDN using a one-interval constant stimulus procedure as he was found to find two-interval tasks difficult.

Non-lateralised auditory deficits

A subset of four of the neglect patients (SKZ, FBR, RTT & CGQ) performed a three-interval forced choice auditory spatial discrimination (ITD) task, which used similar sounds to those in the current study. It is described in detail by Cusack et al. (2000).

RESULTS

Auditory midline

The results of the auditory midline tracking task are shown in Figure 1. The patient data can be split into two groups. Five of the ten patients showed midlines within the normal range. Of the remaining five, two had symmetric hearing (DDN and KD), and two (KNC and NFX) had substantial asymmetric hearing loss. Unfortunately, further testing to obtain thresholds was not possible on subject FBQ.

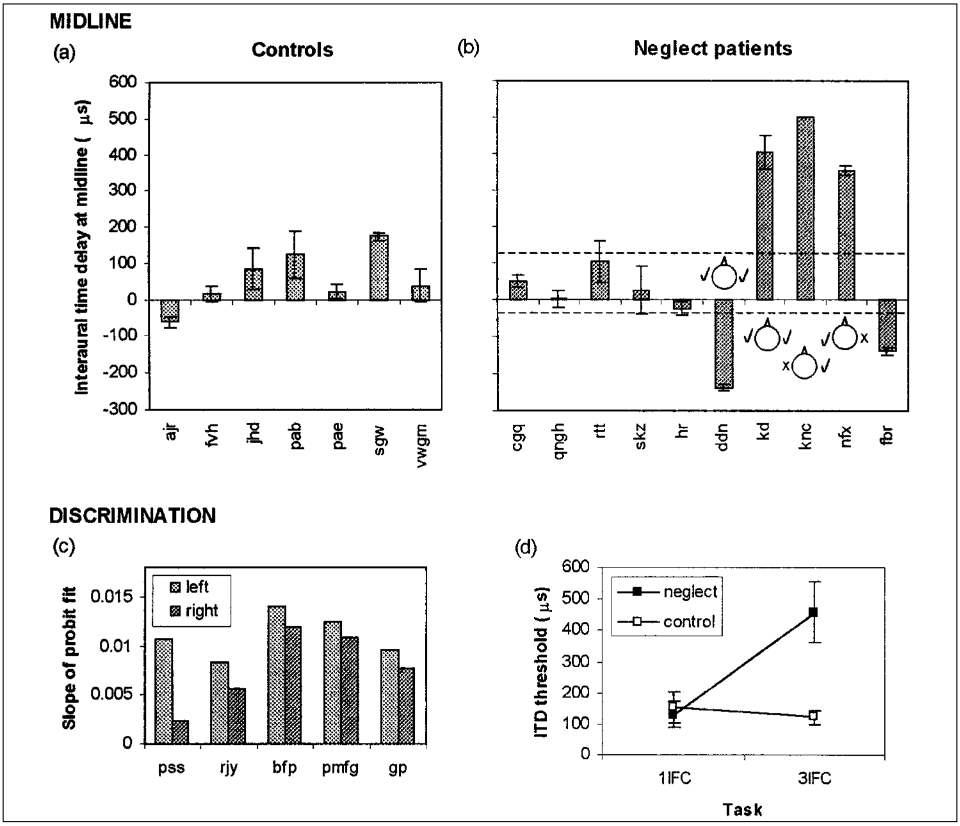

Figure 1 – *Panels (a) and (b) show the mean interaural time delay of the midline. The error bars denote standard errors over the four runs for that listener. The dotted lines in (b) denote the Bonferroni corrected 95% confidence limits for the control data. The head schematic four of the patients with abnormal midlines denotes their hearing deficits (X=more than 10dB impairment). (c) shows a measure of the discrimination ability (the slope of the probit fit function) for sounds on the left and the right. (d) compares the discrimination performance of normals and controls in the current study with that obtained in a three-interval ITD discrimination task (see Cusack et al., 2000).*

Spatial discrimination

To assess the spatial discrimination performance on each side, the responses were first binned as a function of ITD. A probit fit was then applied to the left and right halves of these psychometric functions. The slope of this curve gives an estimate of discrimination performance: a better observer will show a sharper change from left to right responses as they cross the midline. In the five patients with midlines in the normal range, performance was not worse in the left: in fact, discrimination performance showed a near-significant trend towards being better in the left than in the right ($F(1,4)=7.05$; $p=0.057$).

Non-lateralised auditory deficits

The bottom right panel of Figure 1 compares the ITD discrimination thresholds as derived using a probit fit on the current data, and the thresholds obtained from the 3IFC, for the neglect and control group. All the neglect patients performed worse than any of the controls on the 3IFC task, leading to a significant group by task interaction ($F(1,9)=7.58$, $p<0.025$). A further four of the neglect patients were impaired on a non-spatial auditory task requiring listeners to make between sound judgements (Cusack et al., 2000; experiment 2).

DISCUSSION

A systematic shift of midline was not found in the neglect patients. Five of the patients showed midlines within the normal range. Patient discrimination thresholds were also found to be in the normal range. Furthermore, we found no evidence of worse discrimination performance on the left, which could otherwise have masked an underlying shift to the right.

Our results are consistent with Farnè et al. (1998) who concluded that a shift in reference frame does not always accompany neglect. Alternatively, it may be that we did not see a consistent shift due to a lack of power in the experiment. However, the lack of a reliable shift in midline here should be contrasted with the strong consistent deficit in the non-lateralised tasks that used similar sounds. Furthermore, the presence of auditory deficits on these non-lateralised tasks demonstrates that lack of midline shift is not due to our patients exhibiting a purely visual deficit. Further work might investigate the pattern of occurrence of deficits in neglect. Is there more of a dissociation between performance in the auditory and visual modalities, or between lateralised and non-lateralised tasks?

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Rhodri Cusack. E-mail:rhodri.cusack@mrc-cbu.cam.ac.uk