Absolute identification of azimuthal sound location and judgment of auditory circular direction.

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1. INTRODUCTION

As reported at the last CAA-ACA annual meeting, a program of research on auditory circular direction has revealed that the proximity between audio sources determines whether a sound appears to move from one audio speaker to another in a clockwise (CW) or counterclockwise (CCW) direction. More specifically, the directed vector takes the shortest distance between the two sound sources. A similar finding in the pitch domain has been observed by Shepard, 1964. In addition, as is typical of localization data, front-back confusion is often prevalent, as early described by Toole (1970). Thus, if listeners tend to hear sounds from only the front or back hemisphere, tones from sources in the ignored hemisphere will be re-located to the mirror-imaged position in the preferred hemisphere. This conception was consistent with three proposed models of directional judgments. The Circular Model assumed that listeners could hear sources in 360 degrees. The Front Model assumed that listeners heard sources located in the front hemisphere. The Back Model assumed that the listeners heard sources located in the back hemisphere. The trajectory data were fit best by one of the models, however, the best-fit could only be determined post priori. The aim of the present study was to predict the best-fit model a priori on the basis of the ability to locate individual sources in an absolute identification paradigm.

To the best of the authors' knowledge, the present study is the first to relate absolute identification results to judgments of trajectories (CW/CCW directional judgement) created by separate audio sources. Listeners were tested in absolute identification of the location of 12 circumcranial sources and subsequently carried out the task of direction judgment of all possible pairs of the 12 sources. To determine the stability of the individual location judgments, the absolute identification task was then repeated. For each listener, errors in absolute identification provided evidence of their degree of front-back confusion. Error patterns should help predict the applicability of the previously developed Circular, Front, and Back theoretical models of the trajectory data (Cohen et al., 2001). Results of the analysis would confirm one of two possible outcomes. The first is that the absolute identification error pattern for each listener will provide an a priori basis for predicting which of the models is most appropriate for the directional data of that listener. The second is that the two different tasks, absolute identification of individual sources versus the task of direction judgement of a pair, engage different spatial auditory processes.

2. METHOD

Subjects. There were 16 male and 16 female subjects ranging from 18 to 42 years of age. One half of each of the gender groups had more than 4 years experience playing a musical instrument. Hearing level, tested with Digital Recordings AUDIO-CD™ was within normal limits in the range 1 - 4 kHz.

2.1 Apparatus.

In a single-walled sound-attenuated room (Eckel), 12 small Koss speakers (12 x 8 x 8 cm) were spaced at intervals of 30-degrees around an azimuthal circumference of the largest circle (diameter 119 cm) that could be accommodated by the room. The speakers were 1.5 m off the floor, roughly at ear level for an individual seated in the centre of the circle. A multiplexing switch directed an audio signal to one of the 12 speakers. The signal was a complex tone composed of 10 octaves of 22.5 Hz with an envelope that approximated a Gaussian function. Each signal was 250 ms in duration.

2.2 Procedure.

Listeners were tested individually, seated centrally within the circumference of the 12-speaker array, facing a corner of the room subtending speaker 1 and interacted with a computer screen using a cordless mouse.

Part 1. Absolute Identification. Listeners were presented with 11 blocks of 12 trials. Each block consisted of presentation of the tone from each of the 12 speaker locations in a random order. The listener was required to indicate from which location the sound was emitted by moving the cursor to the analogous position represented on the computer screen. Testing time was approximately 10 min.

Part 2. CW/ CCW Direction Judgments. Each listener was presented with a block of (12 x 11) 132 pairs of successive tones, such that all possible successive pairs of the 12 speakers were represented. The intertone interval within a trial was 450 ms. On each trial, the listener judged the direction of the sound around his or her head represented as CW or CCW on a computer screen. The trial block took about 10 min. There were 3 successive blocks in a session, such that each pair was represented 3 times for a total of 396 trials in approximately 30 min.

Part 3. Absolute Identification. Part 3 repeated the procedure of Part 1 for 10 blocks of trials.

3. RESULTS

3.1 Absolute Identification.

Fig. 1 illustrates the mean per cent correct for each tone for all listeners for Parts 1 and 3. Performance is poorest

for the speakers behind the head and performance improves on the 2nd block. Overall improvement (mean % correct on the first set was .52 and on the second set .65) and selective improvement on the back speakers was also noted. The mean percent correct for each speaker for the pre- and post- test were entered into a repeated measures ANOVA having one factor of speaker position and one factor of time (pre/post). The effect of location was significant, F (11, 330) 42.66, p < .0001, with a strong quadratic trend, F (1, 30) 83.77, p < . 0001.

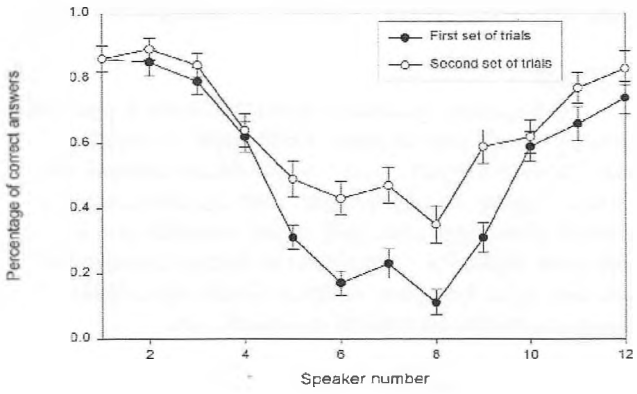

Figure 1. Mean % correct identification as a function of location and session (speaker 1 is directly ahead of listener).

There was a significant interaction between repetition and location, F (11,330) = 5.94, p < .0001. There were no significant effects of musical training or sex of listener, but mean performance for males (.63) exceeded that of females (54) (p < .07).

3.2 Part 2. Direction as a function of CCW rotation.

As in previous work (Cohen et al., 2001), three models were applied to each of the 3 sets of 132 trials per listeners and to the total 396 trials per listener.

The best-fit models were distributed among Circular and Front with a tendency for increased applicability of the Circular Model with time in the task (applicability of the Cirucular model was 13 of 32 listeners for Block 1, and 16 for Block 3). The size of the correlation increased with block, indicating a stabilizing of the listener's hearing strategy.

3.3. Prediction of Best-fit Trajectory Models From AJ data.

It was reasoned that those listeners who did well on the front speakers but poorly on the back speakers could be the same listeners whose trajectory data were best fit by the Front model. Similarly, those who did well on the front and back speakers in the absolute identification (AJ = absolute judgment) task would be those for whom the Circular Model was the best fit. To test this hypothesis, predictors of the best-fit trajectory model were developed from the AJ performance data as follows: performance on 12 speakers, speaker 1, speaker 7 and then all groups of speakers symmetrical round these two points: the 3 front, 5 front, and 7 front and the 3, 5, and 7 back. Only the back speakers proved to have high absolute correlations with the model values, positive correlations with the Circular model and negative correlations with the Front model. Predictions were derived separately for the two blocks of absolute judgment data. Higher correlations arose from the second set of data, and the highest correlations were for the 3rd set of trajectory data. The first set of AJ data correlated most strongly with the first set of trajectory data (Block 1).

Correlation of 2 of the AJ predictors with Circular Model Fits				
	Set 1 (pre)		Set 2 (post)	
Predictor	Back 5	Back 7	Back 5	Back 7
Block 1	**.55**	.52	.63	.58
Block 2	.44	.44	.73	.67
Block 3	.40	.43	**.83**	.80
All 3	.47	.48	.80	.75

Multiple recognition of the separate predictors on the Circular and Front correlations raised the predictability but not dramatically. The superior applicability (yes or no) of Circular over the Front model was predictable for 87.5 % of the listeners (28 out of 32).

4. DISCUSSION

Earlier, perceived direction of auditory motion has been shown to be influenced by proximity of sound sources. The present study adds to the picture by verifying that tendencies to hear sounds in one contribute to these direction judgments, in particular the applicability of a circular or front or back model. In terms of the initial question, it is clear that auditory-location identification data and auditory circular direction judgments tap similar underlying processes, at least for most listeners.

REFERENCES

Cohen, A. J., Lamothe, M. J. R., MacIsaacs, R., Fleming, R., & Lamoureux, M. (2001). Does proximity govern judgments of auditory direction in the azimuthal plane? *Journal of the Acoustical Society of America, 109*, No. 5, Pt. 2, pMUa3 Abst.

Shepard, R. N. (1964). Circularity in judgements of relative pitch. *Journal of the Acoustical Society of America, 36*, 2346-2353.

Toole, F. (1970). In-head localization of acoustic images. *Journal of the Acoustical Society of America, 48*, 943-949.

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