MECHANISMS OF HUMAN AUDITORY LOCALIZATION

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13. ABSTRACT

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The second experiment replicated, with improved methods, an earlier experiment which measured the accuracy of auditory localization with and without pinnae. The findings were striking and conclusive: in the absence of head movement, pinnae even someone else's pinnae, appear to be necessary for accurate auditory localization.

The third experiment compared the effectiveness of different stimuli in an auditory localization task. We expected that increasing the informational content of the stimulus would improve localization performance. However, the findings were inconclusive.

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Abstract

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THE ROLE OF THE PINNA IN AUDITORY LOCALIZATION * II

Batteau (1968) has proposed that the pinna plays a critical role in auditory localization, attention, and speech intelligibility. We have performed a series of localization experiments (Freedman & Fisher, 1968) which lend support to this theory. In the first of our experiments, we compared localization performance for a group of college student observers under three different conditions: listening with own pinnae, artificial pinnae, and no pinnae. Although the results were convincing and statistically significant in demonstrating the importance of the pinna, the method of by-passing the pinnae left something to be desired. We were using MSA muffs which seal tightly around the listener's external ear. These muffs were drilled to pass a small tube which led directly into the auditory canal. Unfortunately, this procedure (a) expanded the effective interaural axis significantly, (b) possibly introduced resonances in the tubes, and (c) created acoustic reflections off the hard shell of the muff.

Because of the great theoretical and practical significance of this experiment, we felt that it was important to replicate it anyway and also to employ an improved technique for by-passing the pinna.

Procedure

Six college student paid observers (Os) were used. They had all participated in previous experiments in this series and so were trained in our procedures. Each O participated in two of the three experimental conditions in a single session in a balanced design. Each O had two experimental sessions judging the odd-numbered locales on one day and the even-numbered locales on the other day. He made five judgments at each stimulus position.

The observer was seated in an adjustable chair within a light-tight

acoustically treated room. His head was restrained by a tight but comfortable plastic band attached to the headrest of the chair. At the first session, an audiometric test using the Grason-Stadler Bekesy type audiometer (Model 800) was administered. Ascending, pulsed, pure tone signals were presented through a loudspeaker directly in front of O. Recorded at slow speed, hearing thresholds were measured on the Hearing Level Compensation curve of the audiometer. Instructions to O for the audiometric test were such as to emphasize that he should depress the attenuator button as soon as he thought he heard the stimulus and release it as soon as he no longer thought he heard it. Any O having an estimated (visually) threshold value of 80db or higher was rejected.

A shaft perpendicular to the center of O's interaural axis and suspended from the ceiling, provides the center of rotation of a 10 ft. boom one end of which carries the sound source. This boom is motorized so that E can set it to any point 360° in azimuth; white noise masks the noise of the boom motor. The localization stimulus was a tape recording of a single male talker reading alternately from an anatomy textbook and from The Neuropsychology of Spatially Oriented Behavior. This tape was played backwards to minimize any tendencies to listen for content rather than for position. The stimulus was presented continuously until O made his final response.

Sixteen equidistant positions in azimuth were used for stimulus presentation. Each O was taught the verbal designations of the positions and had a brief pre-experimental training session. During training he was instructed to keep his eyes closed and his head still while he responded by naming the apparent position of the sound he heard and pointing at it. He was then allowed to open his eyes to check after each response. During testing O responded only verbally and received no feedback information.

After training, O was blindfolded, his head restraint was adjusted, and the room lights were extinguished.

There were three test conditions:

(1) Own Pinnae (OP)--no restriction or occlusion of O's ears.

(2) Artificial Pinnae (AP)--molds were made for both of each O's ears using Silastic 502 RTV Silicone Rubber Compound. These molds filled the convolutions and the back of O's own pinnae leaving only a small opening opposite the auditory canal. Casts of human pinnae (Emerson and Cumings Stycast 2850GT) were fitted to the RTV molds with short tubes extending into O's auditory canals.

(3) No Pinnae (NP)--same as AP except that pinna casts were not used.

Free-field audiograms were made for each O in the AP and NP conditions.

Results

Figures 1A, 1B, and 1C are scattergrams indicating the relationship between True Stimulus Position and Subject's Report for each response under each experimental condition. It is obvious that O's perform similarly under the two pinna conditions (OP and AP) but are considerably less accurate under the NP condition. Simply counting the errors (each response taken as right or wrong) points this up:

Per Cent Correct	
OP	= 58.4%
AP	= 53.1%
NP	= 39.1%

The OP and AP results are not significantly different from one another (t test) but the NP results are significantly inferior to each of the other two.

Every intrasubject comparison without exception shows more correct responses with OP than with AP and more correct responses with AP than with NP.

(1) Looking at Front-Rear confusions we found that O's never confused position 1 with position 9 when listening with their own pinnae (OP), but did so 3 times with the artificial pinnae (AP) and 16 times with no pinnae (NP).

(2) Analysis of Front-Rear confusions may profitably be extended to include the positions immediately adjacent to straight ahead (position 1) and straight behind (position 9). Comparisons now are even more revealing:

(a) In the OP condition listeners never reported (i.e., confused) position 2 as 8, 9, or 10 but did so 10 times with NP and once with AP.

(b) In the OP condition listeners never reported position 16 as 8, 9, or 10 nor did they do so with NP, but they did 5 times with AP.

(c) In the OP condition listeners never reported position 1 as 8, 9, or 10 but did so 16 times with NP and 3 times with AP.

(d) Pooling these data gives zero confusions with OP, 26 confusions with NP, and 9 confusions with AP.

(3) As an indication of "cone-of-confusion" problems without pinnae, we may look at several off-center Front-Rear confusions:

(a) In the OP condition listeners never reported position 3 (Right-Front) as 6, 7, or 8 (Right-Rear) but did so 17 times with NP and 11 times with AP.

(b) In the OP condition listeners never reported position 15 (Left-Front) as 10, 11, or 12 (Left-Rear) but did so 13 times with NP and 10 times with AP.

(c) These data may also be pooled: zero confusions with OP, 30 with NP, and 21 with AP.

Discussion

This is the fourth in a series of experiments concerned with the role of the pinna (see Freedman, 1968, for review of this work). The first experiment

demonstrated that, in the absence of head movement, pinnae, even somebody else's pinnae, appear to be necessary for accurate auditory localization to occur. Second, we demonstrated that a single pinna may be sufficient for localization. Third, by expanding the interaural axis we showed that the pinna transformation may be sufficient with the accustomed binaural time difference cues confounded. Finally, we have replicated our first experiment with somewhat better methods producing even more striking and convincing results. These experiments taken together strongly support the theoretical work of Batteau (1968) and his electronic demonstrations. The findings not only implicate the role of the pinna in directional hearing but cast serious doubt upon the relevance and significance of experiments which manipulate fine interaural differences between stimuli presented through earphones as well as upon theories based on such experiments.

At the very least, the pinna transformation provides significant and important information for auditory localization; at the most, it is the dominant factor.

References

Freedman, S. J. (Ed.) The neuropsychology of spatially oriented behavior. Dorsey Press, Homewood, Ill., 1968.

Batteau, D. W. Chapter 7 in above. Listening with the naked ear. pp. 109-134.

Freedman, S. J. and Fisher, H. G. Chapter 8 in above. The role of the pinna in auditory localization. pp. 135-152.

AUDITORY LOCALIZATION TO STIMULI OF VARIED INFORMATIONAL CONTENT

Although speech is sometimes used as a stimulus in auditory localization experiments, it is far more common to used pulsed white noise, clicks, or sine waves. We expected that increasing the informational content of an acoustic stimulus would make it easier to localize accurately. The commonly used types of stimuli, we felt, may not be sufficiently informative to permit listeners to make consistently accurate responses.

An experiment was therefore devised to measure the effect of varying the informational content of stimuli in an auditory localization task.

Procedure

Using the method worked out in previous experiments in this series (see pp. 3-5 above) we tested 5 observers using three different stimuli:

(1) Pulsed white noise--pulses lasting for 0.12 millisec. occurred repetitively every 1050 millisec.;

(2) Male talker--a tape-recorded male voice reading alternately from a textbook of anatomy and from Freedman and Fisher (1968);

(3) "Babble"--a tape-recording of five talkers each reading from different material simultaneously.

During testing the stimulus continued to sound until the observer made his final response.

Each observer participated in four sessions in a partially balanced design. Responses were given by naming the apparent position of the stimulus.

Results

The responses for each of the three conditions were correlated with the test positions (Spearman rho). Responses to the male talker correlated 0.98, responses to the pulsed white noise correlated 0.93, and the correlation for

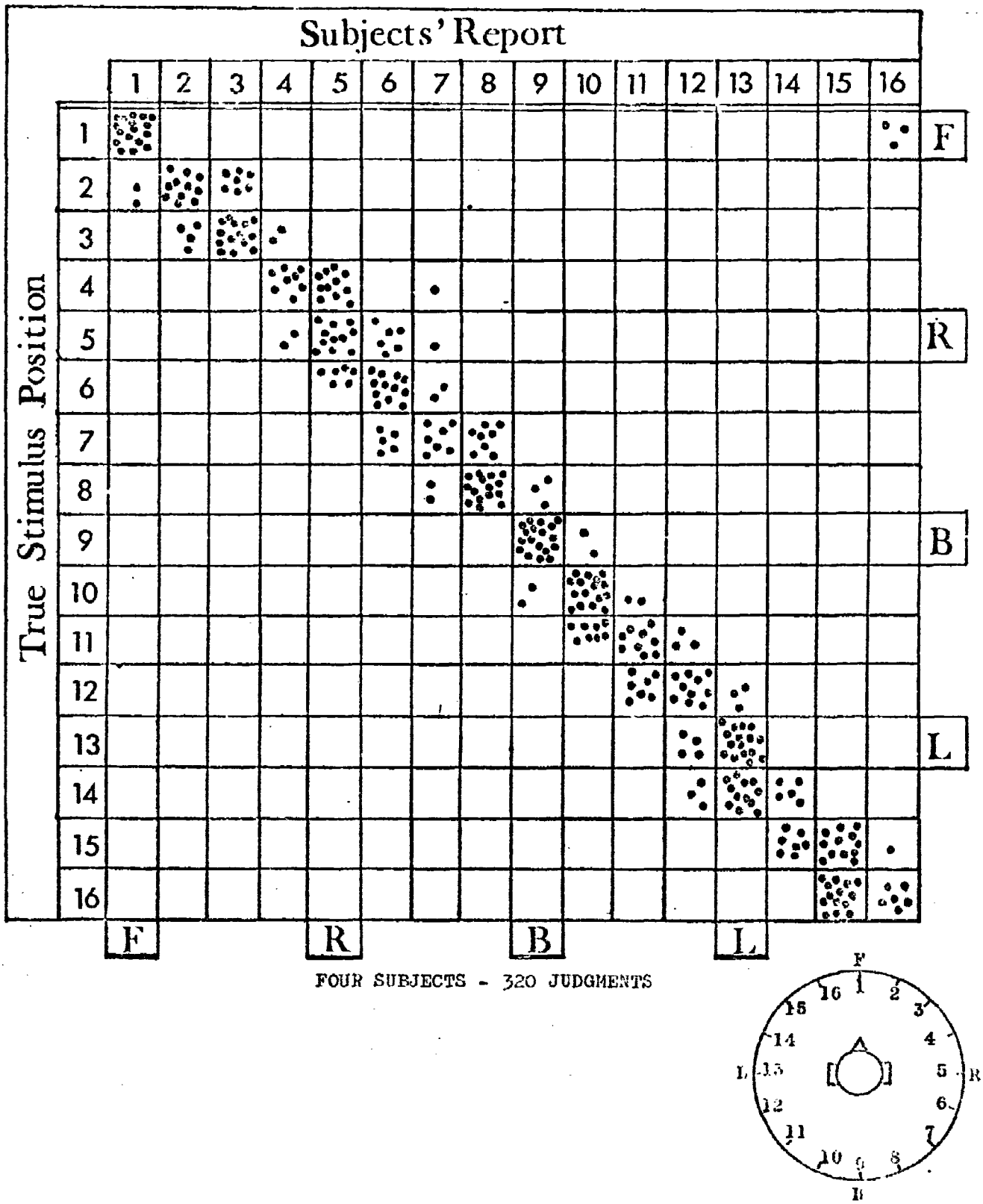
"babble" fell in between. While the rank order of magnitude for these correlations conforms to our hypothesis, the differences between the correlation statistics were not statistically significant. Further, analysis of variance indicated that the conditions (varying stimuli) did not contribute significantly to the observed variance in response. Spearman Rank Correlation Coefficients for size and number of errors among the three experimental conditions were not significantly different.

Discussion

The hypothesis that increasing the informational content of a stimulus would improve auditory localization performance was tested with three different stimuli. No significant differences in performance with 5 observers were found. While we are encouraged to continue with this line of research, findings thus far must be considered inconclusive.

FIGURE 1A.

OWN PINNAE

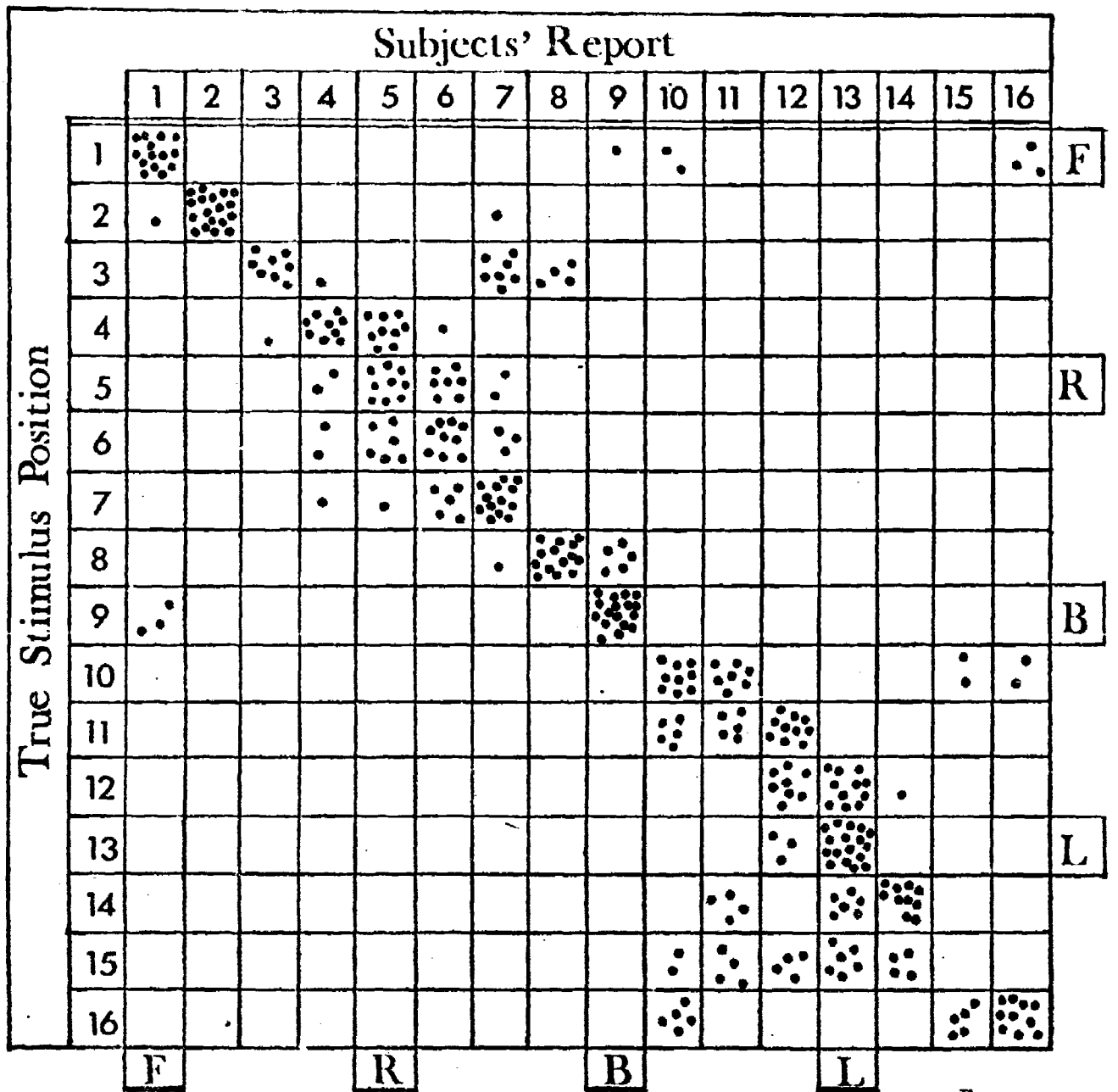


FOUR SUBJECTS - 320 JUDGMENTS

FIGURE 1B

11

ARTIFICIAL PINNAE



FOUR SUBJECTS - 320 JUDGMENTS

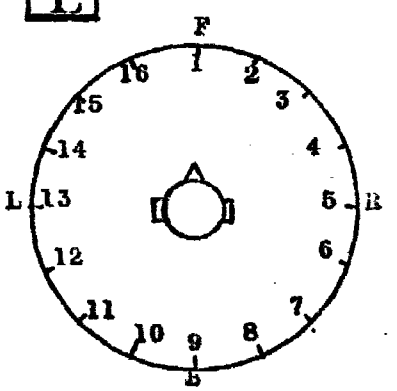
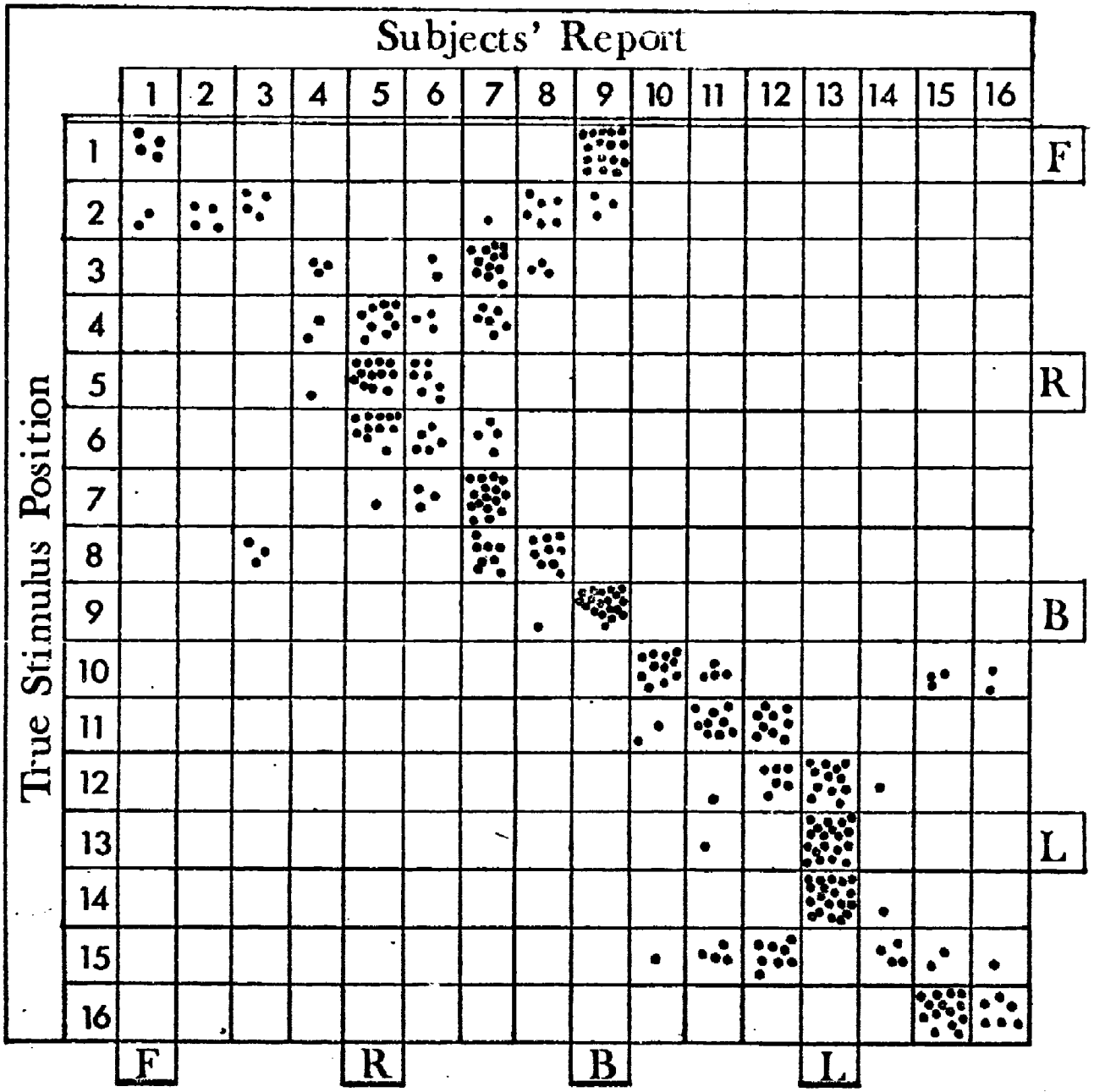


FIGURE 1C

NO PINNAE



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