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SIMPLE REACTION TIME – EVIDENCE FOR TWO AUDITORY PATHWAYS TO THE BRAIN

V. T. WYNN
Department of Physics, University of Exeter
Exeter, England

INTRODUCTION

One of the well accepted facts about simple reaction time distributions is that they are not of the usual Gaussian form (Broadbent, 1971). Over a period of six years about one third of a million reaction time responses have been obtained which cast some new light on such distributions and which suggest that the skew form of distribution might be evidence for the presence of two separate pathways from the ear to the brain.

METHOD

Responses of a finger, foot and the clenching of teeth on a microswitch were made to auditory and visual stimuli. The visual stimulus was produced by the application of an external trigger voltage to a stroboscope (Strobotac Type 1531-A). The stroboscope was mounted in a soundproof box with a double glazed window and the subject's ears were plugged and covered to block out any trace of the click produced by the firing of the discharge tube. The intensity of the flash was varied with the aid of a polaroid attenuator.

The auditory stimulus was the click produced by the stroboscope. The flash was concealed by placing the stroboscope in a lightproof box. In addition two other click generators were used to check the results; one was the click produced by the rapid closing of a mechanical relay and the other was generated by feeding a 2-msec rectangular voltage pulse into a set of headphones. Attenuation of the first two click generators was obtained by covering them with various layers of sound absorbing material (cotton wool). Attenuation of the third generator was accomplished by varying the amplitude of the voltage pulse fed into the headphones. In each case the intensity of the clicks was monitored by measuring the amplitude of the voltage pulses produced in a microphone placed at the position of the subject's head. A further series of responses was obtained at different intensity levels by picking up the click produced by the mechanical relay in the microphone, amplifying it up and feeding it into the headphones. The results were consistent no matter which way the click was generated or presented to the ear (or ears).

The method of triggering the stimulus differed from the usual practice in that it was phase linked to S's own electrocardiogram (ECG). This procedure was followed in an attempt to reduce the moment to moment spread in reaction times by minimizing the effect that the baroreceptors of the arterial system are thought to have on the central nervous system (or even on the auditory sense itself) (Birren et al, 1963; Wynn, 1973; Saari et al, 1976). Although the reduction in the width of a distribution plot of reaction time responses was found to be small using this technique, the triggering of the stimulus by a particular reference point in the ECG provided a useful means of varying, in a slight way, the time between the presentation of each reaction time stimulus. The stimulus was applied at approximately 5 sec intervals. This was achieved by arranging for each reaction time response to prevent the ECG reference point from triggering the stimulus until after a constant delay of about 5 sec. The onsets of either the P, R, or T peaks of the ECG were extracted using electronic comparators and gating circuits. The results described below were obtained using only the R peak as the trigger even though the other two reference points produced the same type of results.

The number of responses which was recorded at any one session varied from 600 to 2,000.

RESULTS

The results indicate that for a well practised individual a frequency histogram of the response times can be thought of as being composed of one, or under some conditions, two partially resolved Gaussian curves.

In the response to the auditory stimuli of differing intensities the histograms were observed to vary from a Gaussian to a skew distribution. The skew distribution, however, could be separated easily into two Gaussian components. Fig. 1 shows, on the left hand side, one example of a frequency histogram for 10,000 responses to an auditory stimulus of one intensity. This histogram was constructed by adding together responses from several sessions in which the mean reaction times for each session differed by no more than 1 msec. The dotted lines are the suggested Gaussian components. The main peak was extracted by the well known and simple symmetry technique in which the assumption is made that the smaller peak affects only the lower near side of its neighbor to any appreciable extent. The minor peak was then obtained by subtracting the isolated major peak from the rest of the histogram.

The second histogram in Fig. 1 shows the distribution curve for 1000 reaction time responses to a visual stimulus (flash) of one level of intensity. This latter Gaussian distribution was observed for flash intensities covering a range of approximately 70 db; and although the width of the histogram varied with intensity the distributions remained as a single Gaussian throughout. (N.B. The widths measured in this report are all measured half-way up the Gaussian curves.)

Fig. 2 shows the way in which the histograms from the auditory triggered reaction times vary with change in stimulus intensity. The lower part of the figure is a plot of the width of the extracted main peak as a function of the mean reaction time. The upper part contains three histograms which illustrate the behavior of the two Gaussian components at the different levels of stimulus intensity. The sound pressure levels are measured relative to the threshold standard (0.0002 Newton/metre^2). The vertical arrows indicate the positions of the three

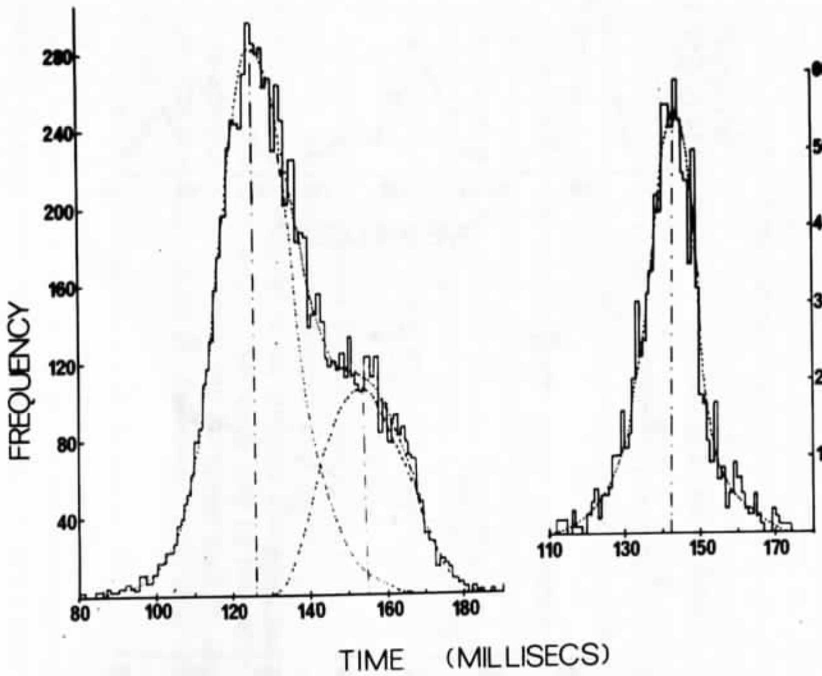

Fig. 1. On the left hand side is a frequency histogram containing 10,000 reaction time responses to auditory stimuli of one intensity level. The dotted lines indicate the presence of two Gaussian components. The second histogram shows the frequency distribution for 1000 responses to visual stimuli of one level of intensity.

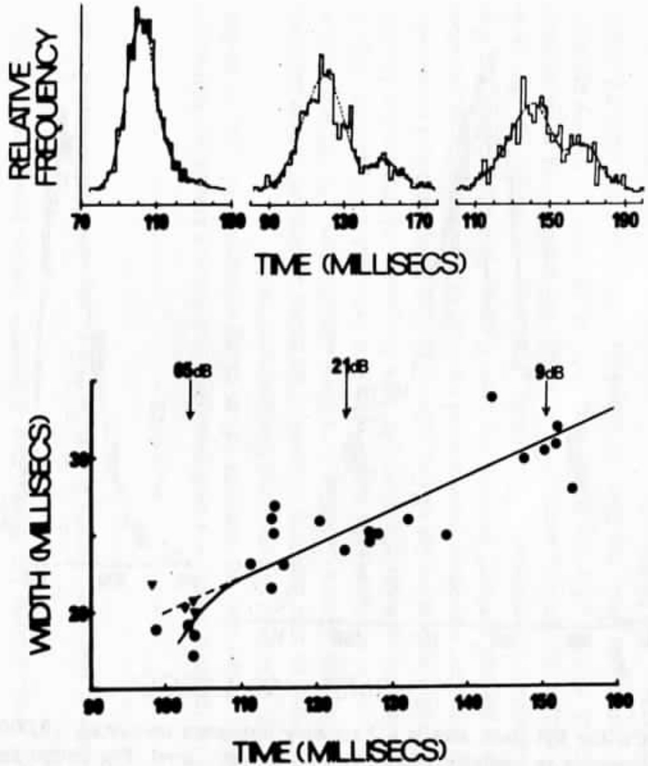

Fig. 2. The histograms show the variation in shape for the distribution of 600 reaction time responses to auditory stimuli of three different intensity levels. The lower plot depicts the width at half height of the left hand peak as a function of the mean reaction time.

intensity levels on the mean reaction time axis.

The three histograms are typical examples which show the way in which the relative populations of the two Gaussian components vary with change in intensity. As the stimulus intensity is increased the relative heights of the two peaks change. The peak with the longer mean reaction time decreases to zero whilst the other increases keeping its Gaussian shape until its left hand side reaches a limiting value of 70 ± 3 msec (S.E. of mean). Greater stimulus intensities produce a one-sided distortion of the Gaussian curve as the peak moves toward the 70 msec value. The limit induced distortion was observed in the histograms obtained from the four highest click intensities. These are seen in Fig. 2. The triangular points indicate the measurement of twice the width of the undistorted side of the histogram. The dashed line shows the extrapolation into this region. The four circular points underneath indicate the actual width.

Although the width of the two peaks varied with intensity, the separation between the means of the peaks was constant. Measurements on more than 100 histograms for stimuli of different intensities gave a value for the separation of the peaks of 29.8 ± 0.5 msec.

Fig. 3 shows the variation in the relative heights of the two peaks as a function of the arithmetic mean reaction time. The mean reaction time in Figs. 2 and 3 is a function of the stimulus intensity and the abscissa covers a range of more than 65 db. Each histogram used in Fig. 3 contained 2,000 responses. The solid triangles refer to the right hand peak, the circles to the left hand peak.

DISCUSSION

The absence of a second Gaussian peak in the visual reaction time histogram places the mechanism for its production plainly in the hearing process. The presence of the two peaks in the auditory histogram, and their behavior with changes in intensity, suggest that there may be two pathways by which the sound stimulus can travel from the ear to the brain. It seems possible that a stochastic mechanism might be responsible for deciding which pathway is to be used.

In view of the constant nature of the separation between the Gaussian peaks with changes in stimulus intensity, it seems unlikely that the delayed response time of the right hand peak is part of the same mechanism which produced the variation in width with changes in intensity. It seems more plausible that the constant delay is produced by a difference in the effective length of the two different pathways. This effective length may be either a difference in real length, in conduction velocity, in the number of nerve synapses along the paths or in a combination of all three. The constancy of the gap between the peaks with change in intensity and the fact that the widths of the peaks change with intensity indicate that the mechanism that produces the latter effect must occur very early on in the hearing process.

The results so far described have been obtained using the finger as the responding member. Auditory reaction times in which the jaw and foot were used to close the timer microswitch also showed the presence of the two Gaussian distributions in each case. The peak separations in these cases, however, were dif-

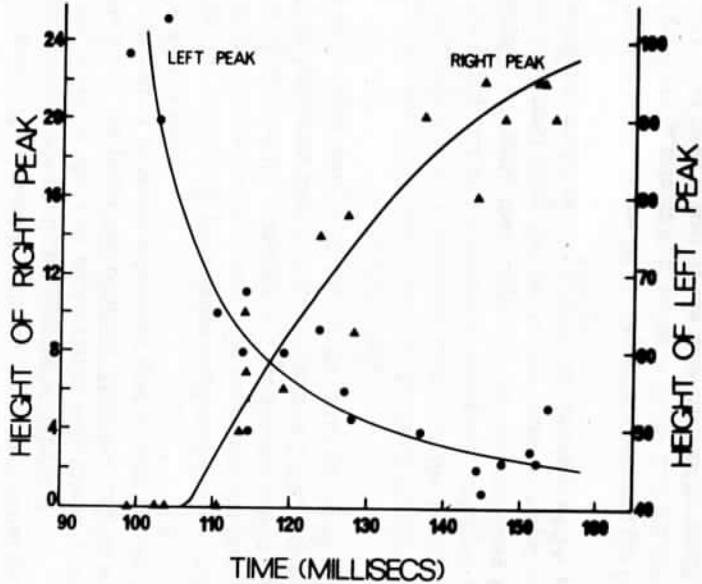

Fig. 3. Variations in the relative heights of the two Gaussian peaks as a function of the arithmetic mean reaction time. Each measurement was made on a histogram containing 2000 responses. The solid triangles refer to the right hand peak, the circles to the lefthand peak.

ferent and were measured to be 26 ± 3 msec and 41 ± 2 msec for the jaw and foot responses respectively. The widths of the histogram peaks for the jaw, hand and foot responses varied as a function of the responding member in a similar way for both auditory and visual stimuli and were in line with the increase in the separation between the two Gaussian components. This suggests that the gap between the peaks may have been increased by a dispersion process in those later brain, muscle and nerve pathways which are common to the two types of stimuli used.

The results also show that reaction time responses have a lower limit of about 70 msec for auditory stimuli and although no distortion of the visual reaction time histograms were observed the results showed that the lower limit in this latter case was less than 80 msec. Measurements on the delay time between the onset of the muscle action potentials of the forearm and the subsequent closing of the microswitch by the finger due to the action of those muscles gave a value for the delay time of approximately 35 msec. This strongly suggests that for a well trained S, and a sufficiently intense auditory stimulus, the brain can receive and respond to a stimulus in a time of less than 40 msec.

SUMMARY

The responses were recorded for many thousands of responses of a finger, foot, or jaw to either an auditory click or a visual flash. The presence of two Gaussian components in the distribution histograms obtained from the auditory stimuli, but not the visual, suggests the presence of two pathways for conveying auditory information to the brain. A stochastic mechanism may be responsible for channeling this information into either a slow or a fast pathway. For the highest stimulus intensities only the fast channel is chosen but as the intensity is reduced the probability of the information being diverted into the slower pathway is progressively increased.

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