AM 67-24

REACTION TIME AS A FUNCTION OF FLASH LUMINANCE AND DURATION

Mark F. Lewis, Ph.D.
and
Henry W. Mertens

Approved by

J. ROBERT DILLE, M.D.
CHIEF, CIVIL AEROMEDICAL INSTITUTE

Released by

P. V. SIEGEL, M.D.
FEDERAL AIR SURGEON

November 1967

FEDERAL AVIATION ADMINISTRATION
Office of Aviation Medicine

ACKNOWLEDGMENTS

The authors would like to thank Faye K. Ashby who assisted in the collection of data, and Becky Johnson and Ronald Morris who served as patient subjects.

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REACTION TIME AS A FUNCTION OF FLASH LUMINANCE AND DURATION

I. The Problem

Because of the high speed of modern aircraft, pilots must respond quickly to signal lights from the ground or other aircraft during night flight. The present study was concerned with the relation of reaction time to flash luminance and duration. The study was directed at the limiting case where the operator knows the position in space where the flash appears and where the behavior required of the operator is very simple.

The relation between simple reaction time and the effects of stimulus luminance and duration has been inadequately investigated. Only a few studies have been concerned with the effect of stimulus duration on simple reaction time.

Froeberg[1] used stimuli of 3, 6, 12, 24, and 48 msec and obtained an inverse relation between reaction time and stimulus duration. Wells[2] used stimuli of 12, 25, 64, 144, and 1000 msec at a luminance below 0.5 mL and reports fastest reaction times for the 25- and 64-msec flashes, with slower reaction times for stimuli that were either shorter or longer than these optima.

Baumgardt & Segal[3] investigated reaction time to stimuli of 50 and 250 msec at a luminance of 1700 nits (534 mL), with the two durations presented in alternating blocks of ten trials each. Comparisons between the means for successive blocks showed faster reaction times for the 50-msec stimulus.

Raab, Fehrer, & Hershenson[4] have criticized the above studies on several grounds. They point out that the reaction times obtained by Baumgardt & Segal[3] to the 250-msec flash were in every case shorter than the stimulus, a circumstance that obscures the relation, since reaction time could not be influenced by that part of the flash which followed the occurrence of the response.

Referring to Johnson's rationale[5] for reaction time experiments and Jarl's demonstration[6] that the presentation of stimuli in homogeneous blocks yielded effects not obtained when all stimuli were presented in random order within a session, Raab, Fehrer, & Hershenson[4] also criticized both the Wells[2] and the Baumgardt & Segal studies for presenting the stimuli in blocks of trials at the same duration; thus, they attribute the results at least in part to the method of stimulus programming.

Raab *et al.*[4] replicated the Baumgardt & Segal experiment and, at a higher luminance level, achieved the same result. They also obtained reaction times to stimuli of 10, 25, 50, 100, 250, and 500 msec at luminances of 0.30, 30, and 3000 ft-L. In the latter experiment, durations were randomized within sessions at single luminance levels, but with luminances counterbalanced over sessions. Although reaction time was found to be inversely related to luminance, no effect due to duration was obtained.

In a later study, Raab & Fehrer[7] obtained reaction times to stimuli of 0.5, 1, 2, 5, 10, and 20 msec at luminances of 0.3, 3, 30, 300, and 3000 ft-L. Again, durations were randomized within sessions at a single luminance and luminances were counterbalanced across sessions. For the two highest luminances, duration had no effect on reaction time. For the 3 and 30 ft-L flashes, reaction time increased over the range from 5 to 0.5 msec duration. At 0.3 ft-L, reaction time was inversely related to duration over the entire range investigated. At all durations, reaction time increased as luminance decreased. From these data, Raab & Fehrer concluded that the critical duration for reaction time (defined as the flash duration beyond which prolongation of the stimulus has no effect on reaction time) is less than 0.5 msec for luminances greater than 300 ft-L, and increases with decreasing luminance to about 10 to 20 msec at a luminance of 0.3 ft-L.

Use of the term "critical duration" by Raab & Fehrer[7] was criticized by Lewis[8] because Raab & Fehrer failed to show agreement with Bloch's law for constant reaction time criteria. Lewis also suggested that both luminance and duration should be randomized within sessions. In Lewis' experiment a stimulus of 8-msec duration was matched in luminance (10 mL) to one stimulus of 2-msec duration, and matched in energy to another stimulus of 2-msec duration (40 mL). The obtained reaction time distributions indicated that stimuli of equal energy but unequal duration yield equivalent reaction time distributions, a finding at variance with the data of Raab & Fehrer.[7] Lewis concluded that for constant reaction time distributions, Bloch's law is valid.

The current experiment attempted to extend Lewis' finding to a greater range of luminances and durations.

II. Method

Subjects. The subjects were a man and woman undergraduate at the University of Oklahoma. Both were emmetropes. Both were screened for color vision deficiency on a battery including the A.O.-H.R.R. and Dvorine Plates, the Farnsworth-Munsell 100 hue test, and an anomaloscope examination. No evidence of color deficiency was found. Both were paid an hourly wage.

Apparatus. A Maxwellian view optical system, previously described,[9] was designed to deliver a 0.5° stimulus to the fovea. Fixation was assisted by four broken red lines in the form of a cross around the test spot. Equipment for generating flashes and for control of flash luminance and duration were identical with the equipment used in a previous study;[9] the same calibration procedure was used as before. Reaction time was measured from flash onset to release of a microswitch requiring 110 grams of force for depression. Reaction times were recorded from a Hewlett-Packard Model 523CR Electronic Counter.

Procedure. Experimental sessions began with a seven minute period of dark adaptation following which the subject adjusted the intensity of the fixation lines until they were just visible. The following instructions were then read to the subject:

"When you hear the ready signal, sight through the tube and fix your gaze on the center of the cross. When ready, press and hold down the switch. You will hear a noise for a period during which a flash will appear in the center of the cross. As soon as you see the flash, release the switch as quickly as possible. On some trials no flash will appear. Release the switch only when you see a flash. Do you have any questions?"

If there were no questions, the experimental session was begun. The experimenter initiated each trial by giving the subject a ready signal consisting of a short 1000 Hz tone. When prepared, the subject pressed the switch which delivered white noise to his earphone. The stimulus was then presented after a foreperiod which varied from 1 to 3 seconds, in steps of 0.5 second, and which was randomly assigned to the trial. The white noise was terminated when the subject responded to the stimulus by releasing the switch. Each trial was followed by a 20 second intertrial interval.

The 86 stimuli ranged in luminance from 7.9 to 15,850 mL and in duration from 2 to 1024 msec. These stimuli and nine blank trials were presented once in each of two random series used in an experimental session. The blank trials differed only in that no visual stimuli were presented. No responses were obtained on blank trials.

At the beginning of each experimental session, 10 practice trials were given. The stimuli for practice trials always had a luminance of 7943 mL and a duration of 512 msec. Foreperiod duration was varied as in experimental trials.

Both subjects were given six practice sessions before data collection began. The subjects, RM and BJ, were given 24 and 26 experimental sessions, respectively, and there were corresponding numbers of 48 and 52 reaction times obtained for each stimulus. After the practice sessions, the time required for each daily experimental session was approximately 1.5 hours.

III. Results and Discussion

The median reaction time was determined from the distribution of reaction times (see appendix) for each stimulus. For each subject median reaction time is shown as a function of luminance with flash duration as a parameter in Figure 1. Although there are several prominent reversals, the reversals do not appear to be systematic. Reaction time appears to be a decreasing, negatively accelerated function of flash luminance. It is not clear that there is any effect due to flash duration.

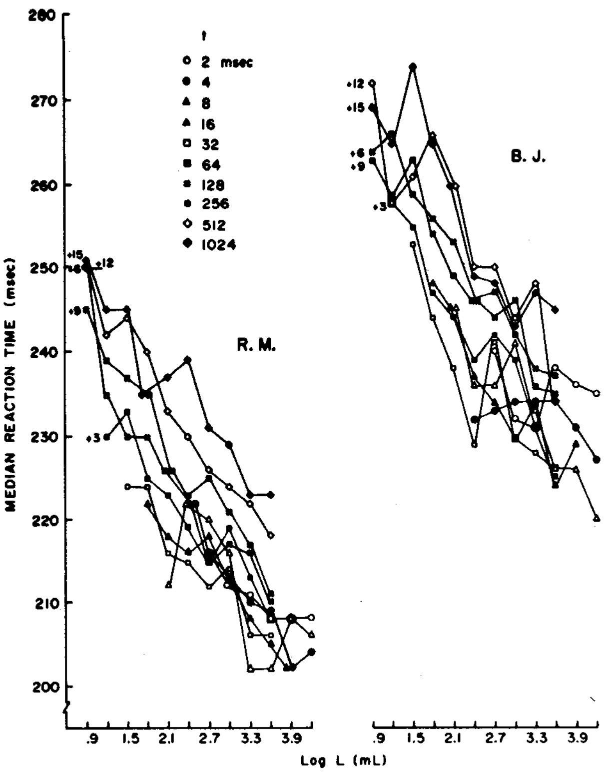

FIGURE 1. Median reaction time as a function of log luminance with flash duration as a parameter. For clarity, some functions have been shifted along the ordinate by an amount shown to the left of the function. Data for subject RM are on the left; for subject BJ, on the right.

In Figure 2 the same data are plotted as a function of flash duration with flash luminance as a parameter.

Although there is considerable noise in the data, reaction time does not appear to be systematically influenced by flash duration at any of the luminance levels examined.

Because of the apparent lack of stimulus duration effects on the reaction times obtained, the data have been averaged across durations to clarify the luminance effect (Figure 3).

Figure 3 shows that reaction time is a negatively accelerated function of flash luminance for both subjects.

The results of the current study support the findings of Raab, Fehrer, Hershenson[4] and of Raab & Fehrer[7] that reaction time is independent of flash duration at high luminances over the range of durations investigated. The current

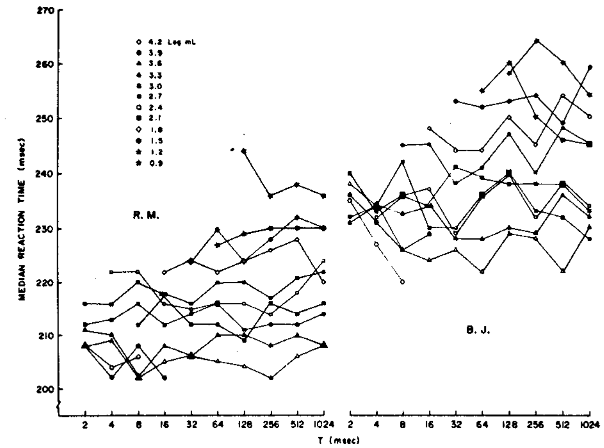

FIGURE 2. Median reaction time as a function of flash duration with flash luminance as a parameter. Data for subject RM are on the left; for subject BJ, on the right.

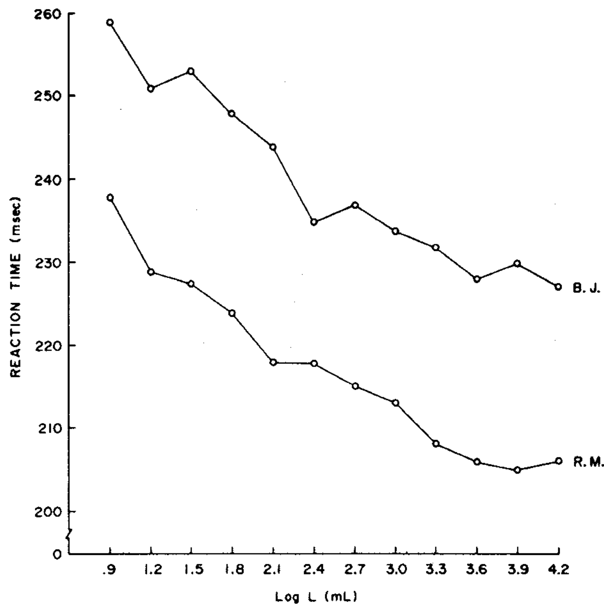

FIGURE 3. Median reaction time as a function of log luminance. Data are averaged across durations shown in Figure 1. Data for subject RM are on the left; for subject BJ, on the right.

study fails, however, to replicate the effect of duration obtained at lower luminances by Raab & Fehrer[7] and by Lewis.[8] Additionally, examination of the reaction time distributions obtained in the current study casts doubt on the validity of Lewis' earlier conclusion[8] that Bloch's law holds for constant reaction time distributions.

The data support the suggestion (implicit in Raab & Fehrer's discussion[7] and explicitly stated by Kahneman[10]) that it is incorrect to speak of the critical duration for Bloch's law without stating the criterion response, i.e., Bloch's law holds for a constant response criterion up to some critical duration. The critical duration is not, however, independent of the response criterion. The current data, together with those of Raab, Fehrer, & Hershenson[4] and Raab & Fehrer[7], suggest that for reaction time criteria the critical duration, if it exists, is extremely short. It must be noted that in the absence of a demonstration that Bloch's law holds for reaction time criteria, the "critical duration" discussed above is not necessarily the critical duration of Bloch's law. Rather, it is the duration at which reaction time becomes independent of stimulus duration and this need not be identical with the duration at which the integration of energy for a constant reaction time criterion ceases.

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APPENDIX

Distributions of reaction times in response to onset of visual stimulus. Points shown in each figure are the interpolated deciles of each distribution. Distributions for single durations are presented in each figure. Data for each subject are presented separately.

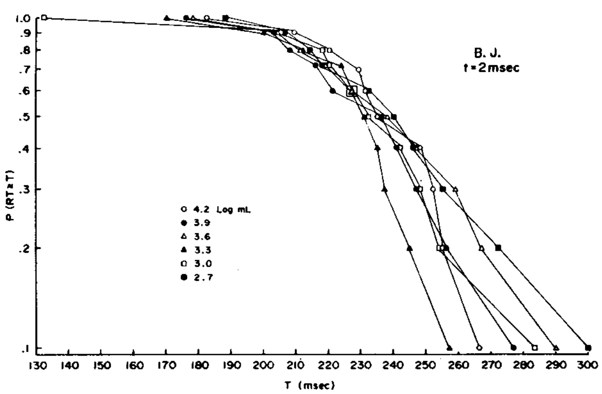


FIGURE 1A

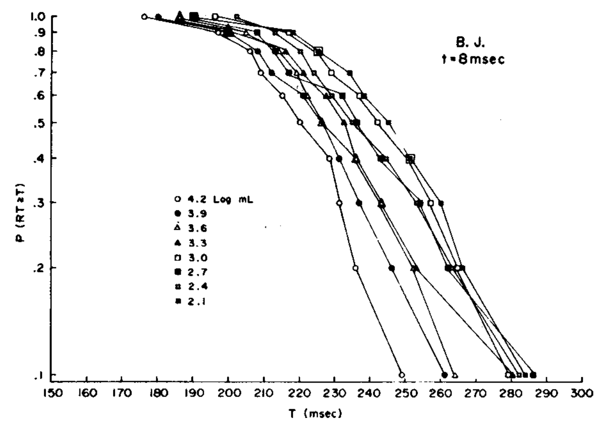


FIGURE 3A

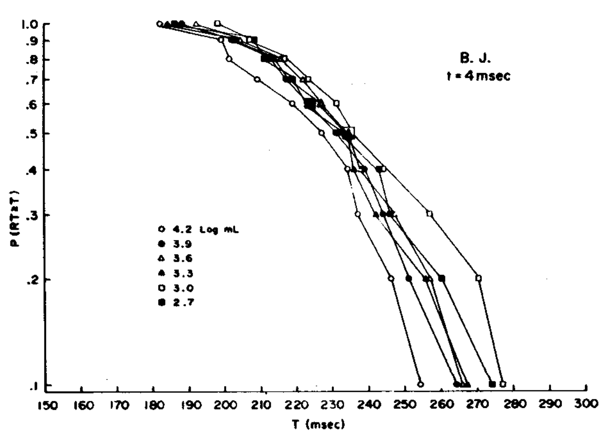


FIGURE 2A

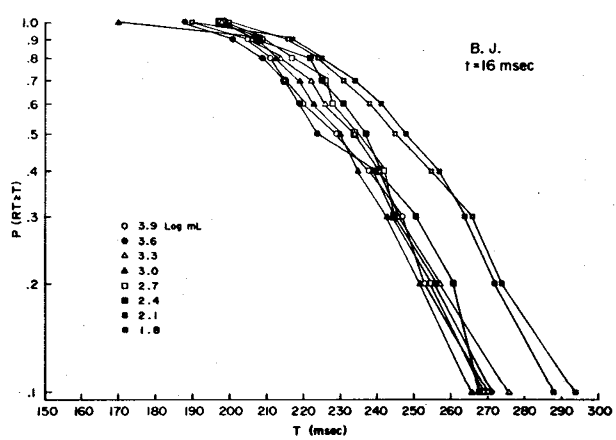


FIGURE 4A

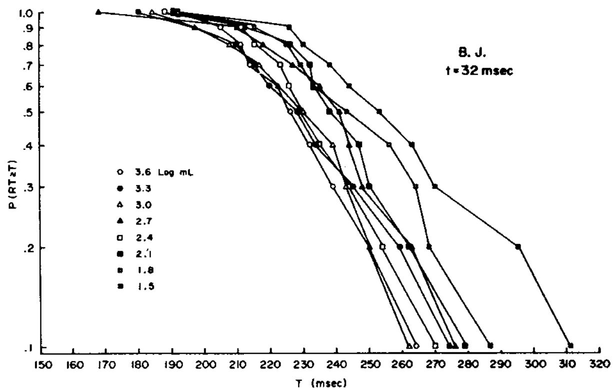


FIGURE 5A

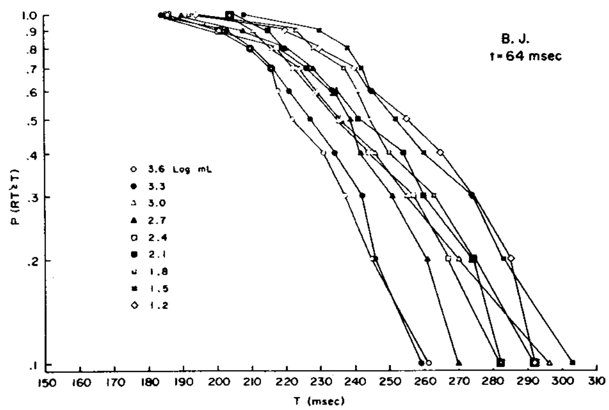


FIGURE 6A

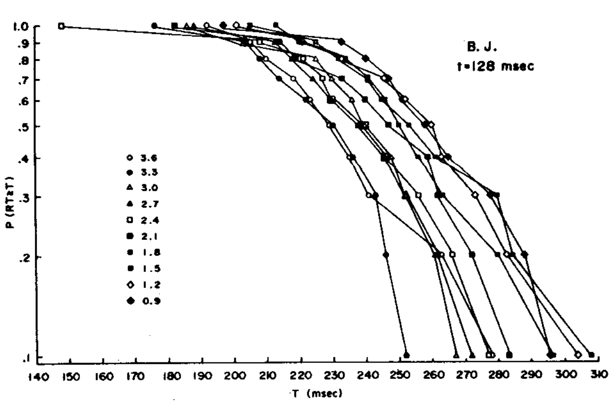


FIGURE 7A

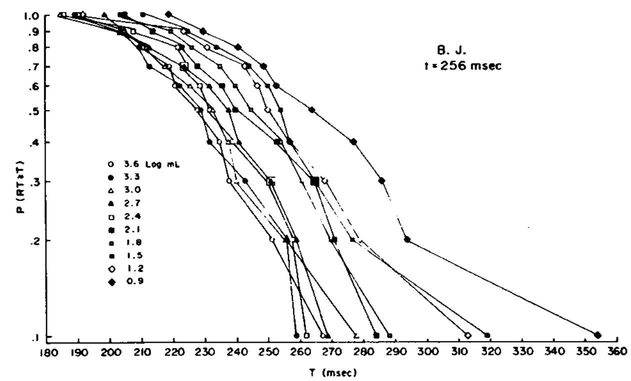


FIGURE 8A

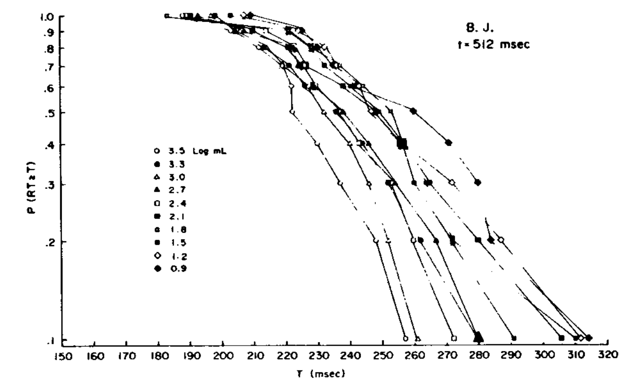


FIGURE 9A

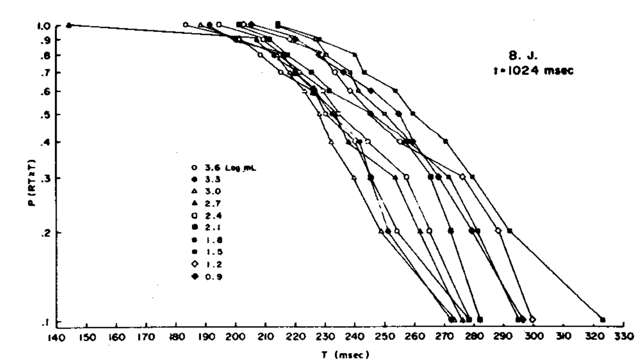
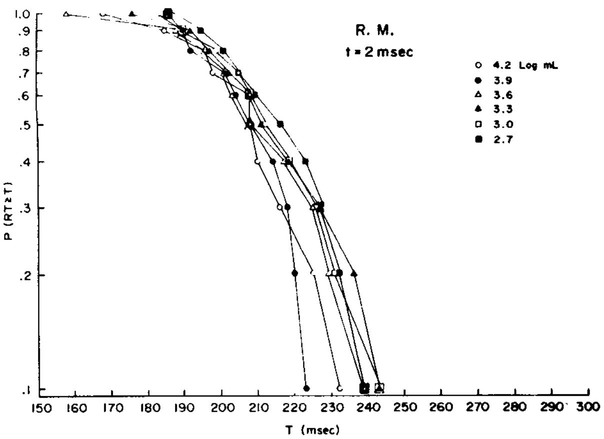


FIGURE 10A



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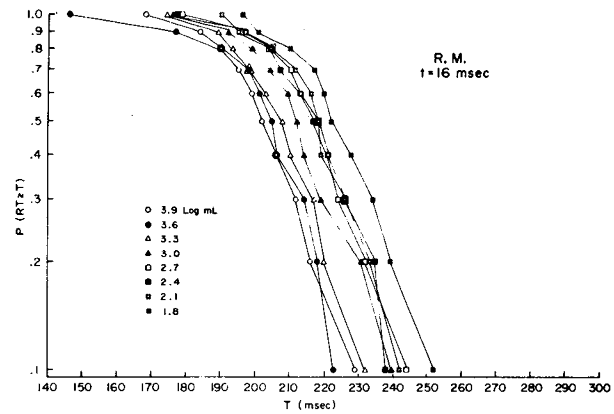

FIGURE 14A

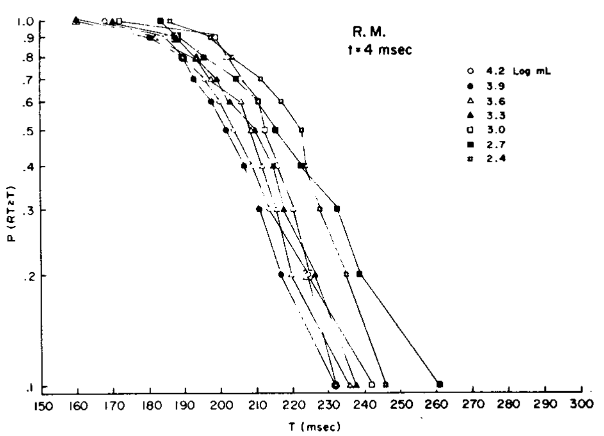

FIGURE 12A

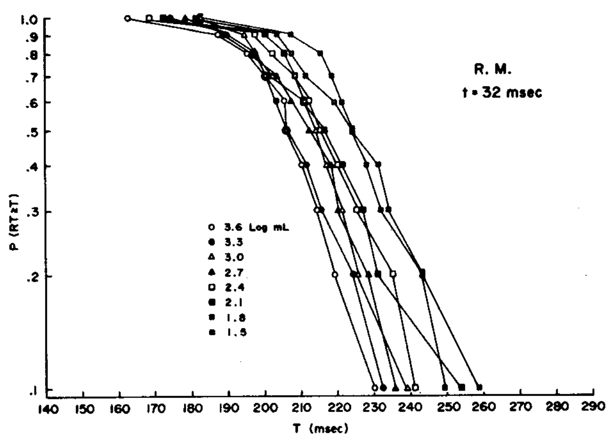

FIGURE 15A

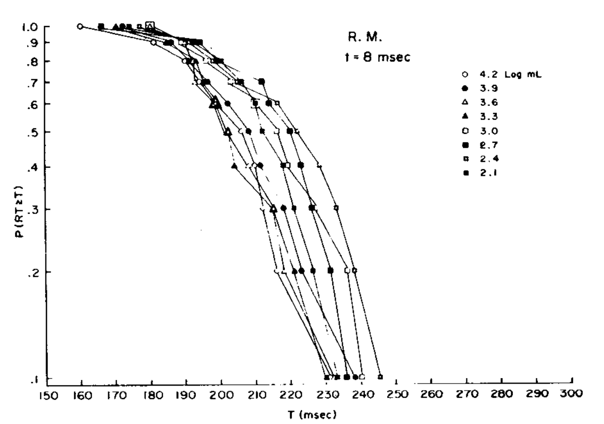

FIGURE 13A

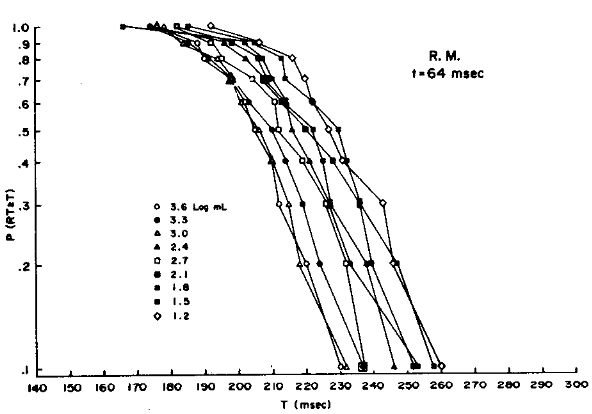

FIGURE 16A

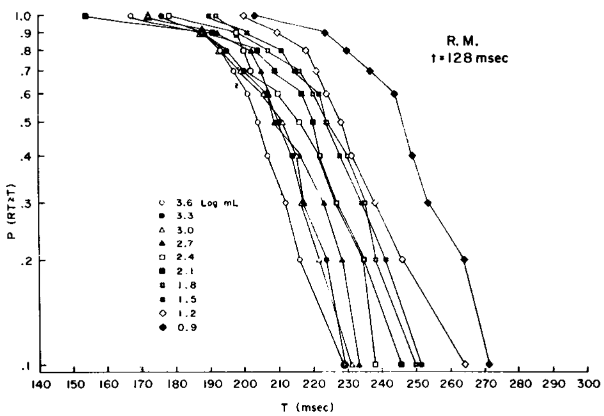

FIGURE 17A

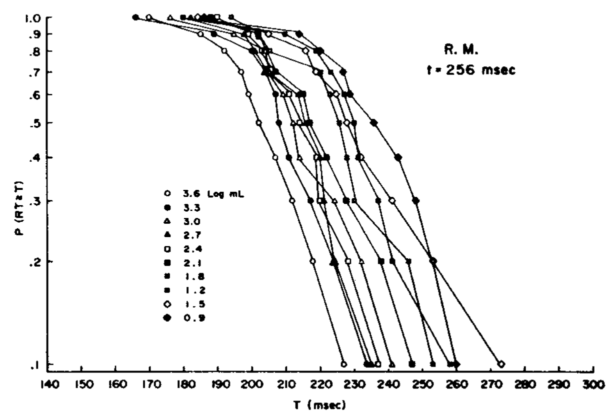

FIGURE 18A

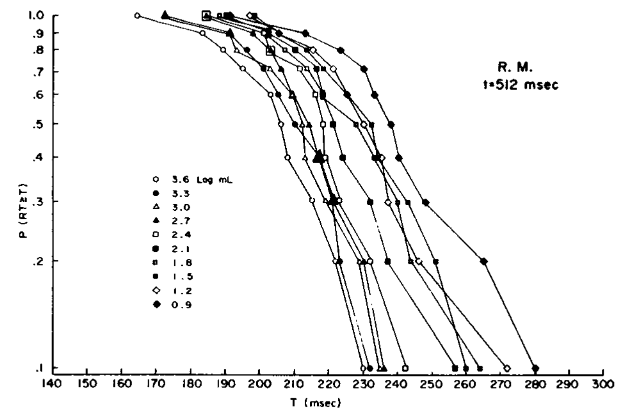

FIGURE 19A

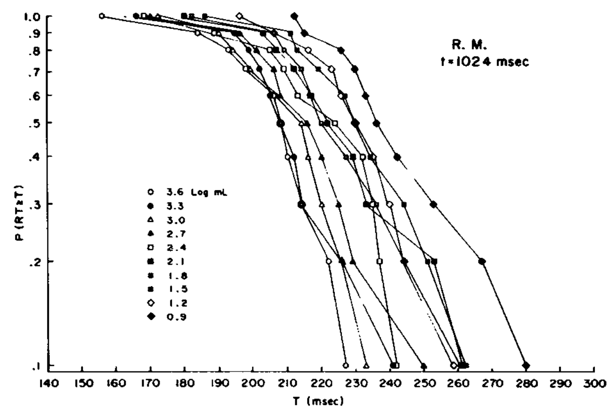

FIGURE 20A

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