Mass Reaction Time: Measurement of the Speed of the Nerve Impulse and the Duration of Mental Processes in Class

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The "reaction time" subtraction technique is of both historical and current importance in psychology. It was used by Helmholtz in 1850 to demonstrate the speed of the nerve impulse, and it is a major tool of modern research in cognitive psychology. In-class or at-home reaction time demonstrations are typically difficult to arrange because they require use of reliable millisecond timers, and they require many trials in order to stabilize and reduce the variability of individual reaction times. We propose here two new variants of the reaction time technique which overcome these problems. They take advantage of the fact that summing over a series of reaction times, each less than a second, yields a time interval that can be measured easily with a stop watch or wristwatch. Because this total reaction time is summed over a large number of component times, the variability of the resulting value is lower than the variability of the individual times.

The basic procedure for in-class use is to chain a group of people (ideally 20 or so) together so that they must perform some task in sequence. When person n completes the task, he signals person n+1 who then completes the task, and so on. An alternative procedure that can be used in the student's home involves chaining tasks together (e.g. Neisser, 1963). In this way, instead of having to deal with the short times for a particular mental process, one can determine the time needed to complete this process n times.

Measurement of the Speed of the Nerve Impulse

In-class Form. The logic of this demonstration follows directly from Helmholtz's 1850 experiment. Simple reaction time to a pinch of the ankle is compared to simple reaction time to a pinch of the shoulder. The difference between these times should be an estimate of the time for the nerve impulse to traverse the equivalent of the distance between the ankle and the shoulder. Between ten and twenty students are needed for this experiment. Each student grasps the ankle of his neighbor (this can be arranged with a minimum of acrobatics if the person at the end of a row of seats links with the person in front of him). Subjects are instructed to close their eyes and to simply squeeze their neighbor's ankle as soon as their own ankle is squeezed. The last person in the series is instructed to yell "Stop" when he feels squeezed. The experimenter starts the series by tapping the ankle of the first subject with the starting pin of a stop watch, thus starting the stop watch and the squeeze simultaneously. The experimenter stops the watch on the agreed signal from the last person (i.e., the "Stop" signal). The same sequence of events must be then repeated several times, until the mass reaction time decreases and stabilizes. In our experience, six to ten trials suffice. Following this, the same procedure is repeated with shoulder squeezing. (These initial practice trials provide useful data from which the instructor can plot a learning curve [see Figure 1].) Two ankle and two shoulder trials can then be run in a counterbalanced order (e.g. ankle, shoulder, shoulder, ankle). Appropriate divisions and subtractions yield an ankle vs. shoulder mean time difference for a typical subject, which is divided into an estimate of the average ankle to shoulder distance for the subjects.

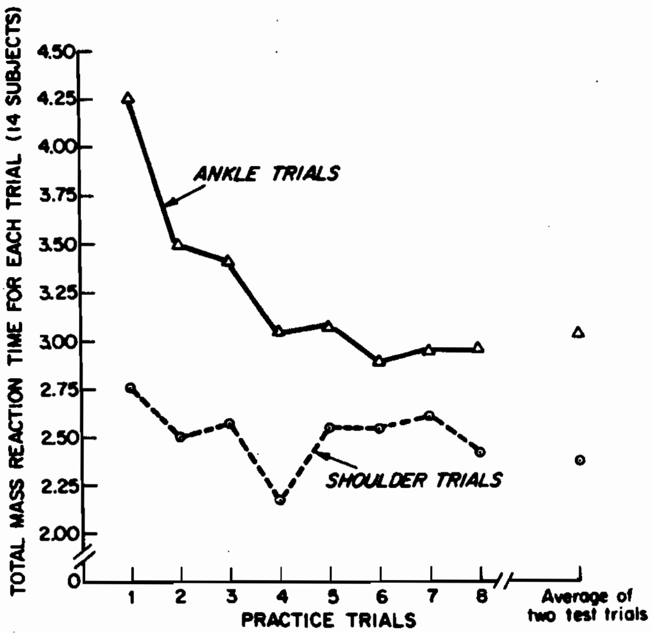

Figure 1. Total mass reaction time for shoulder and ankle trials during practice and test trials of the speed-of-nerve-impulse demonstration. The procedure included eight ankle practice trials followed by eight shoulder practice trials. Following this, test trials were run in the order ankle, shoulder, shoulder, ankle.

We have performed this experiment on eight separate occasions, resulting in values between 15 and 50 meters/second on each occasion (the expected range would be about 6 to 122 meters/second [Milner, 1970]). Figure 1 shows both the learning curves and final test measurements of one such demonstration. It should be noted that because each measurement takes less than ten seconds to obtain, the total of 12-25 measurements needed does not take a great deal of class time.

At-home Form. The at-home version of this experiment requires only six students: five participants and one experimenter. The logic of the experiment is the same as that described above, but easily measurable time values are obtained by cycling four times around the five participants. That is, each participant grasps his neighbor's ankle or shoulder (depending on the type of trial), forming a circle. The squeezing is initiated by the experimenter, as in the in-class version. The fifth person in the cycle is instructed to signal "Stop" the fourth time he is squeezed. This procedure was used in an at-home experiment with a class of introductory psychology students and their roommates or other friends. Students were instructed to carry through a series of five practice trials and then to run four critical tests as described above. The mean estimate of nerve impulse speed for the fifteen participating groups was 32.7 meters/second (within the expected range) with a standard deviation of 17.4 meters/second. One group reported an unreasonably slow rate of below 6 meters/second (none were negative). On the high end, the maximum value was 83.2 meters/second, again within the normal range.

Measuring the Time for More Complex Mental Processes

In-class Form. The basic nerve-impulse-speed design can be extended to measure more complex mental processes with one modification. Many reaction time experiments of cognitive processes require subjects to choose between two (or sometimes more) response alternatives. To perform such experiments using the mass reaction time technique, one must provide each subject in the chain with a method of choosing between at least two alternative responses. We illustrate this technique with an experiment that measures the time it takes subjects to scan through a memorized list of target letters in order to determine if a probe stimulus letter is a member of that set (e.g. Sternberg, 1966). Before each trial, subjects are told two, three, or four randomly chosen target letters which they must hold in memory. They close their eyes, and a large stimulus letter is written on the blackboard in front of them. On a signal from his neighbor, a subject opens his eyes, determines whether the letter on the board is in the target set, and signals his neighbor in the following way: Each subject is instructed to hold his index and middle finger above the forearm of his neighbor, and to poke the neighbor's arm with his index finger if the stimulus is in the target set, or with his middle finger if it is not. Because the fingers are not actually touching the neighbor's skin before each trial, the neighbor has no way of knowing which decision his predecessor made when he is touched. The experimenter can observe the response which each subject makes and thus can ensure that no errors are made (subjects should be exhorted to make no errors, and trials with more than one error should be excluded). A trial is initiated by the experimenter who signals the first subject to open his eyes, and who simultaneously starts a timer. It ends when the last subject yells "Stop." This procedure, when used with ten to twenty subjects, results in an easily measurable time interval.

We performed this experiment in class with a group of twenty-one subjects in the chain. The critical test trials of the experiment were preceded by thirty practice trials, ten each with a different target set size. These practice trials were followed by twenty-five test trials; for fifteen of these (five for each memory set size), the stimulus letter was a member of the target set. For ten trials, it was not. These latter negative trials were discarded in the data analysis. The negative trials are needed minimally to keep the students honest—that is, to keep them from consistently responding with their index fingers. Once the fifteen critical positive mass reaction times are collected, they are divided into three groups, according to the size of the memory set. The five reaction times within each group are averaged and this average is then divided by the number of people in the chain. These overall means are graphed in Figure 2 below, as a function of memory set size.

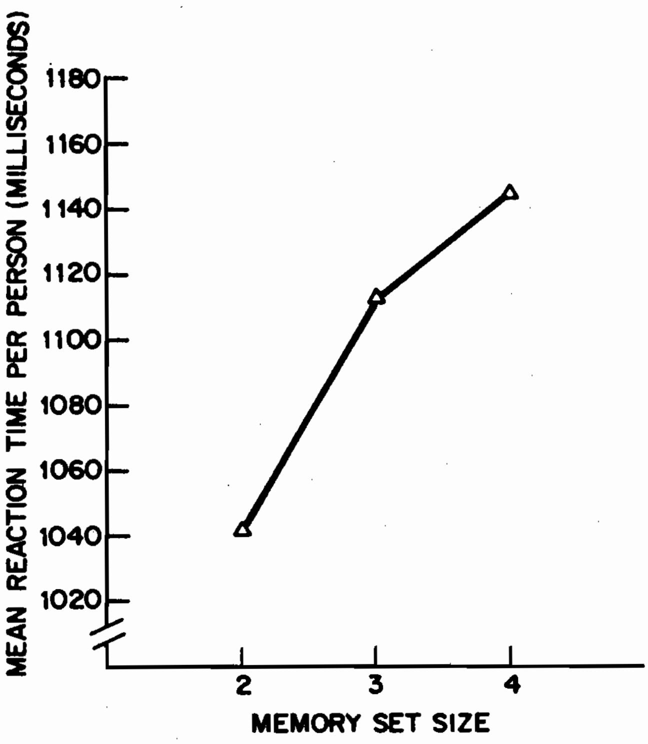

Figure 2. Mean reaction time as a function of memory set size for memory scanning demonstration.

Clearly, there is an increase in mean reaction time as a function of number of items in the memory set. Furthermore, this increase appears to be roughly linear, agreeing quite well with Sternberg's (1966) findings. We have calculated that the search rate in our experiment is approximately 52 msec. per item in the memory set (Sternberg's better controlled experiments give a typical value of 38 msec. per item).

Note that although a fair number of trials (55 in all) is required in this experiment, the actual time occupied by the experiment is not great. Each trial takes no more than 20 seconds so that the whole experiment can be completed in approximately 25 minutes.

At-home form. We have applied the same logic to at-home experiments of cognitive processes. In one case, we had our students replicate the Shepard and Metzler (1971) mental rotation experiment.[1] In this experiment, subjects are asked to judge whether two block figures are actually the same figure in different orientations, or whether they are two different figures. This task occupies some considerable time, and it is almost within the range of accurate timing on a wristwatch. However, to make it more appropriate for at-home experimentation, we had subjects obtain mass reaction times from successive judgments about three pairs of block figures. Each subject was presented with a set of three pairs of figures on each page of a mimeographed handout (see Figure 3 for an example of a sheet of this handout). He was instructed to determine whether the members of each pair were identical (except for rotation) or whether they were different from one another. After making this determination

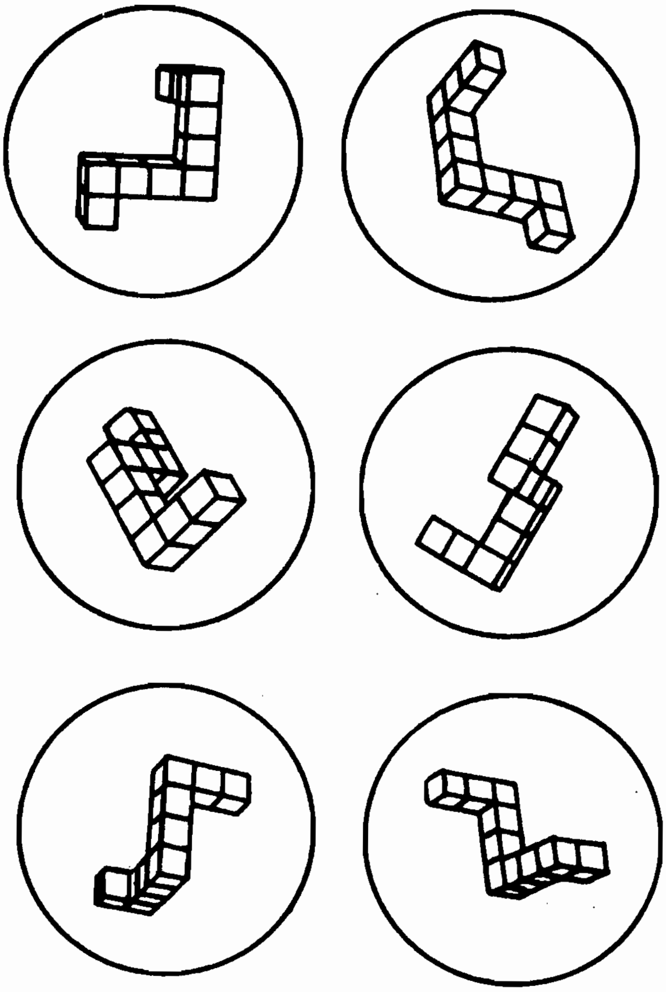

Figure 3. A typical triplet of pairs of block figures used in at-home demonstration of mental rotation effect. The members of each pair in this example are identical to one another, but differ by a rotation of 160°.

for the first pair, the subject proceeded to the next pair, and then to the final pair of the three. At this point, he determined (with a wristwatch) how much time elapsed for all three decisions. He wrote down his responses for all three pairs, and then proceeded to the next triplet of pairs. Most of the triplets of pairs included in the task contained pairs all of which were identical, although subjects were not informed of this beforehand. As with the memory scanning experiment, negative instances (in this case, different pairs), were occasionally inserted to keep subjects honest, but the triplets which contained a different pair were not included in the data analysis. We constructed the all-identical triplets so that the disparity in rotation between the pairs in any triplet was the same: some triplets contained pairs which all differed by a 40° rotation, others by 80°, others by 120°, and finally, others by 160°. In all, there were eight such critical trials in the experiment, two at each of the four degrees of rotation.

Subjects performed all the calculations in this experiment based on instructions provided in a handout which they read after they produced the data. First they identified the eight triplets which contained pairs whose members were identical to one another. Then they determined whether their responses to these triplets were correct. Any triplet in which an incorrect response was made was excluded from data analysis. For any given degree of rotation, (40, 80, 120 or 160) subjects computed the average time taken to respond "identical" to a pair by adding together the reaction times for the two triplets representing that degree of rotation and dividing by six (the total number of pairs contained in both triplets).

One hundred-twenty-two subjects performed this experiment. Though there were many perturbations in the individual data, the group data for all subjects were quite interesting, as one can see by examining Table 1. Across

Table 1
Mean Times for Mental Rotation
(Sec., Averaged Across 122 Subjects)

	40°	80°	120°	160°
Mean	6.42	8.92	10.73	12.98
S.D.	7.06	12.24	17.37	23.35

subjects there is a roughly linear increase in time with degree of rotation. The slope of the linear function best fit to these data is 18.6 degrees per second, compared to the value of 55-60° that was reported by Metzler and Shepard (1974). In view of the fact that so few trials were run in the present experiment, and that subjects were not pre-selected according to spatial ability (as were subjects used by Shepard & Metzler), this difference is not unreasonable.

Of the 122 individual data reports, 42 showed completely consistent data; that is, time increased as rotation degree increased across all three transitions (40-80, 80-120, 120-160). No subject showed the reverse pattern.

The mass reaction time technique here described thus appears to be a useful tool in demonstrating both measurement of the speed of the nerve impulse, and measurement of the durations of various cognitive processes.

References

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Notes

1. We thank Dr. Roger Shepard for supplying us with the stimulus materials used in his experiments.

2. Address requests for reprints to Dr. John Jonides, Human Performance Center, University of Michigan, 330 Packard Road, Ann Arbor, Michigan 48104.