A serial effect in time estimation

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When a series of reproductions of an interval of time is made without interpolation of a standard between judgements, some studies suggest that the reproductions grow progressively longer (Falk and Bindra, 1954; von Sturmer, 1966); other work implies that the duration of reproductions is constant (McGrath and O'Hanlon, 1967). In the present study, experiments using 10 sec and 60 sec intervals supported the former view. The increase in reproduction duration was a linear function of the trial number, n. The method for measuring subjective time proposed by McGrath and O'Hanlon is criticized.

One procedure by which time perception can be studied is to present S with a standard interval and to ask him to make a series of responses such that the interval between any two consecutive responses is equal to the standard.

There are at least two ways in which data from this type of experiment can be analyzed. One way is to plot the objective interval between the nth and the (n+1)th response (i.e., the duration of the nth reproduction of the standard) as a function of n. Falk & Bindra (1954) using the method of production, and von Sturmer (1966) using the method of reproduction employed this approach. In both cases the data anlysis suggested that the reproduction gradually grew longer as the experiment progressed. Standard intervals of 15 sec and 5 sec were used.

A second method is to plot the time which has elapsed between the first and the (n+1)th response as a function of n. McGrath & O'Hanlon (1967) used this method with standards from 1 to 10 min. The functions they obtained appeared linear. If the time which has elapsed up to the (n+1)th response is a linear function of n, the interresponse interval must be constant; this contradicts the results of Falk and Bindra and of von Sturmer.

The issue becomes clearer if the terminology used by McGrath and O'Hanlon is adopted. They denote objective time by t and subjective time by T. Thus if the standard is S sec, the subjective time which has elapsed at the (n+1)th response is Sn sec. Their method of analysis amounts to plotting T against t, and the resulting functions are of the form

$$t = a + bT.$$

Differentiating this equation gives

$$\frac{dt}{dT} = b$$

This indicates that the rate at which objective time increases as a function of subjective time is constant. Therefore, plotting increments in objective time corresponding to constant increments in subjective time (which is the method of analysis used by Falk and Bindra and by von Sturmer) ought to yield a straight line of zero slope. Instead a function of positive slope was found.

Conversely, the results of Falk and Bindra and of von Sturmer indicate that dt/dT increases with T. If this relationship is linear (a point taken up below), then

$$\frac{dt}{dT} = f + gT$$

Integrating this to obtain the function relating t to T gives

$$t = e + fT + \frac{gT^2}{2}$$

According to this equation subjective time and objective time have a curvilinear (quadratic) relationship.

The purpose of this paper is to resolve the conflict described above. A subsidiary purpose is to evaluate the method of measuring subjective time proposed by McGrath and O'Hanlon. They advocate fitting a function to the plot of T against t and using the derivative of this function, dT/dt, as the rate of subjective time, RST. This procedure would be of most interest if the function relating T to t were a straight line, since RST would then be a constant.

Method

In the first experiment 10 male Ss wearing opaque goggles were required to make 30 consecutive reproductions of a 10 sec interval. Judgments were made by tapping a Morse key which was linked with a pen recorder running at 5 mm/sec. The standard interval, which the Ss knew to be 10 sec, was presented once before the series of judgments was recorded. Ten seconds after the offset of the standard, the E said "Begin." The first tap was made then. Each S continued to tap once every estimated 10 sec until told to stop. Techniques such as counting were not precluded by the instructions.

In the second experiment, using another 10 Ss, 10 consecutive reproductions of 1 min were measured using a procedure which was identical to the one employed in the first experiment except that the pen recorder was run at 1 mm/sec.

Results and Discussion

Trend analyses (Edwards, 1967, ch. 15) were carried out on the data from each group. Denoting the duration of the nth reproduction by D_n it was found that the linear regression of D_n on n was significant ($F = 44.04$, $df = 1/261$). The nonlinear regression was not significant ($F = 1.38$, $df = 28/261$). The linear regression equation was $D_n = 12.353 + .052n$.

For the 60 sec group, the linear regression of D_n on n was significant ($F = 10.64$, $df = 1/81$), and the nonlinear regression was not significant ($F < 1.0$). The linear regression equation was $D_n = 65.027 + .906n$.

The regression coefficient was greater than zero in both cases, indicating that successive reproductions of a 10 sec or a 60 sec standard tend to grow longer and longer. The nonsignificance of the nonlinear trend components shows that this increase is a linear function of the trial number, n. These results agree with the findings of Falk & Bindra (1954) and von Sturmer (1966), and contradict the findings of McGrath & O'Hanlon (1967). This contradiction can be demonstrated by expressing the regression equations in terms of T and t. For the 10 sec standard

$$\frac{dt}{dT} = 1.2353 + .0052T$$

For the 60 sec standard

$$\frac{dt}{dT} = 1.0838 + .0151T$$

Integrating these equations yields

$$t = c_1 + 1.2353T + .0026T^2$$

$$t = c_2 + 1.0838 \quad + .0076T^2$$

This shows that the function relating t to T is a quadratic one, not a linear one as the report by McGrath and O'Hanlon suggests. One implication of this is that RST, which is equivalent to dT/dt, is not a very useful measure of subjective time because it is not a constant. It decreases as t increases.

One issue remains to be settled: Why did McGrath and O'Hanlon obtain plots of T against t which appeared linear? The data obtained for the present study were also analyzed according to the method of McGrath and O'Hanlon. In this case the datum for trial n was not the duration of the nth reproduction, but t_n, which was the total elapsed objective time at the end of trial n; i.e., the time from the beginning of the first reproduction to the end of the nth reproduction, marked by the (n + 1)th tap. The functions obtained in this way were equivalent to those obtained above by integration. For both groups it was difficult to discern by eye any departures from linearity. This was not surprising, since the quadratic coefficients in the functions relating t to T were very small. Trend analyses did not indicate any departure from linearity ($F < 1.0$) in either case. This was because the departures were small and the assumptions of normality and homogeneity involved in the trend analysis were not met. Cumulating the data in this way caused treatment variances to increase rapidly with increases in n. This did not happen in the first analysis.

In summary, it appears that successive reproductions of a short time interval grow progressively longer and that this increase is a linear function of the trial number, n. Because it conceals this trend, and also because RST is not independent of t, the analysis recommended by McGrath and O'Hanlon is of questionable value.

References

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