Journal of Experimental Psychology
1969, Vol. 79, No. 1, 122–128

REFRACTORY PERIOD OF C-REACTIONS[1]

PAUL BERTELSON AND FRANÇOISE TISSEYRE

Université libre de Bruxelles

On each trial the presentation of a letter calling either a key-pressing response or abstention (Donders' c-reaction) was followed, after an interstimulus interval (ISI) varying at random over the range 0–700 msec., by the onset of one of two lamps calling for the pressure of one of two keys. The problem was to know if the second reaction would be delayed more after positive than after negative first stimuli. Experiment I, where two stimuli, one positive and one negative, were used for the c-reaction, gave ambiguous results. It seemed possible that the instructions and the payoff system had led some *S*s to prepare selectively for the positive stimulus. To make this strategy more difficult, four stimuli, two negative and two positive, calling for the choice between one of two keys, were used for the c-reaction in Exp. II. Each of the four *S*s had longer delays after the positive first stimuli. It was concluded that analysis of the stimulus and execution of the response contribute independent components to the refractory period. Also, the data from the positive trials were found to be in general agreement with a single channel interpretation of refractoriness but not with the strong version assuming no overlap of occupation times, and confirmed earlier suggestions that some residual capacity is still available during the refractory period.

The major part of the work on the psychological refractory period (PRP) (for recent reviews see Bertelson, 1966; Smith, 1967) has dealt with sequences, mostly pairs, of reactions. Some authors, however, have started to study what happens to the reaction to the second of two signals when operations other than the organization of an immediate response are called forth by the first signal. Fraisse (1957) and Davis (1959) have found that refractory delays can be caused by a signal calling for no reaction, which can simply be ignored. Rubinstein (1964) has shown that refractoriness should be expected when the two signals are identical so that the one calling for the reaction can be identified on the basis of order only, but that it can be avoided when different sensory modalities are involved.

Taken together, these results suggest that the fact of having to analyze the signal is critical in causing refractory delays, not the fact of having to respond. On the other hand, there is some suggestion that delays are longer when the first stimulus must be responded to than when it can be ignored. This was shown most clearly by Fraisse who compared the two conditions with two independent groups of *S*s. Davis obtained comparable delays under both conditions, but his *S*s did both conditions in parallel, i.e., on alternate sessions, and good evidence of transfer effects was found. It is thus possible that analysis of the signal and organization of a response contribute independent components to refractory delays.

It seemed that information regarding the respective roles of analysis of the signal and of organization of the response in causing refractory delays could be gained by studying the case of Donders' (1868) c-reaction. In that experimental situation, some of the possible signals call for a reaction, others do not. At first sight, this type of classification could impose varying demands on central analysis mechanisms depending on the possibility of filtering out the negative stimuli at some peripheral level. The problem in the present study was not to examine the conditions for peripheral filtering. It was decided from the start to use a situation where negative stimuli would presumably require analysis time in order to examine whether responding involved additional time.

[1] This work has been partially subsidized by the Belgian Fonds de la Recherche fondamentale collective under Contract 612. The paper was presented at the meeting of the Experimental Psychology Society, Oxford, England, July 1967. The help of W. G. Koster of I.P.O., Eindhoven, in providing programming facilities is gratefully acknowledged.

negative S_1 where he had correctly abstained from responding, he was told "right." On double trials, nothing was said about the RT to S_2. When an error occurred in either the first or the second reaction, no information regarding speed was given.

Results and Discussion

The RTs were analyzed for trials where both reactions were correct only. In fact, mistakes, whether reactions to the negative S_1 or wrong responses to S_2, amounted to only 1.4% of double trials. Figure 1 shows, separately for each *S* the mean correct RTs to the positive S_1 and to S_2 following either the positive or the negative S_1.

For every *S*, the second RT shows a clear increasing gradient at short ISIs after the two categories of S_1. As expected, the negative S_1 was not filtered out and was the source of definite refractory delays. But when the comparison is made between delays caused by positive and negative S_1, a striking variety of outcomes appears. The *S*s 2 and 3 have longer RT_2's following the positive S_1 at short ISIs, but *S*1 shows exactly the opposite result and *S*4 shows no difference. The differences which are apparent in Fig. 1 for *S*s 2, 3, and 4 at the level of the overall means are observed on every separate session.

A possible explanation for these puzzling results lies in the way *S*s reacted to the instruction to be fast in the first reaction. It has been amply demonstrated, in the case of choice reactions, that *S*s can prepare selectively for one particular stimulus, as, e.g., when that stimulus comes more frequently than the other ones, and so obtain faster reactions to that stimulus at the cost of slower reactions to the other stimuli (e.g., Fitts, Peterson, & Wolpe, 1963). It is not unlikely that something similar can happen with c-reactions. In the present experiment, *S*s were rewarded for responding fast to the positive S_1, and it was thus clearly in their interest to prepare for that stimulus. This would have caused longer analysis times for the negative stimulus and may have cancelled, completely in *S*s 1 and 4 and only partially in *S*s 2 and 3, an opposite effect on refractory delays of having to respond to positive S_1. Large individual differences have already been observed in the size of the effects of selective preparation on choice RT (Bertelson & Barzeele, 1965). Following this reasoning, it was thought that

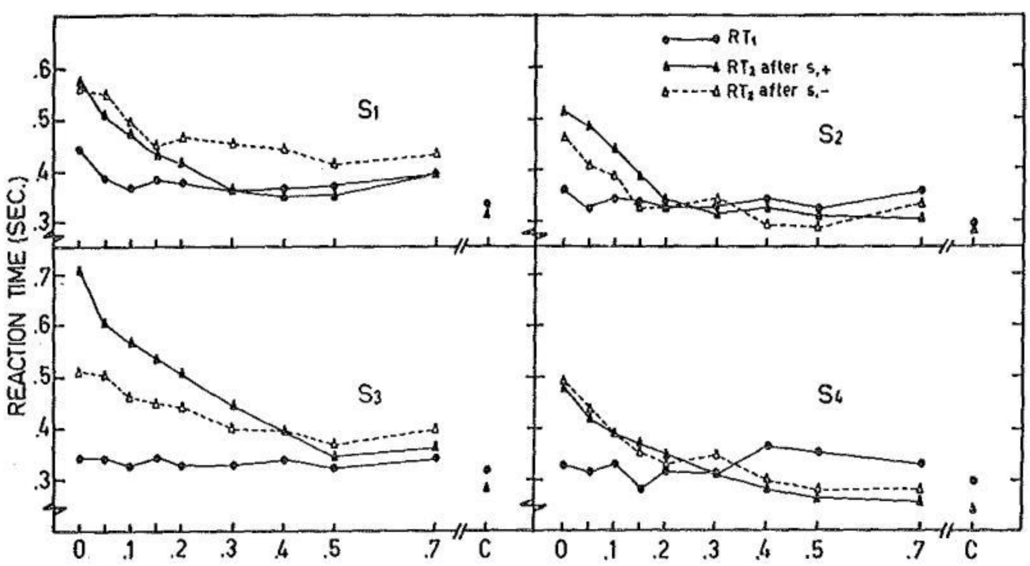

FIG. 1. Mean correct reaction times as functions of the interstimuli interval in Exp. I, Sessions 2–5. (*Circles:* RTs to positive stimuli in the [first] c-reaction. *Triangles:* RTs in the [second] b-reaction; filled: after positive first stimuli; open: after negative first stimuli. C = single trials.)

The same data, mean RT_2 over the range 0–200 msec., are given for pairs of successive sessions in Fig. 3. With the exception of *S*5, the difference between the two categories of RT_2 decreases with practice. In any case, it is clear that the difference between the results of this experiment and those of Exp. I are not due to the more extensive training received by *S*s.

The error data appear in Table 1. There are remarkably few errors on double trials, either in the first or the second reaction, except for the second reactions following positive first signals at long ISIs. The RTs on these trials are shorter than those observed at the same ISIs after negative first stimuli, but they have thus been paid for by a fall in accuracy. A similar tendency was already present in Exp. I. On control S_1 trials, *S*s tend to be much more inaccurate than in the first reactions of double trials: they make more false reactions to negative stimuli and more errors in their reactions to positive stimuli. This effect is correlated with the gain in RT which is apparent in Fig. 2. A less cautious strategy on isolated S_1 trials than on first reactions of double trials has already been observed in the case of pairs of b-reactions (Bertelson, 1967). Such findings make one doubt the usefulness of "control" single trials in refractoriness experiments.

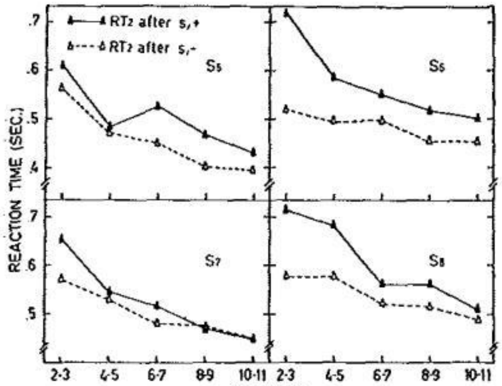

FIG. 3. Mean correct reaction times to the second stimulus at short interstimuli intervals (0–200 msec.) as functions of practice in Exp. II, Sessions 2–11. (*Filled triangles:* after positive first stimuli; *open triangles:* after negative first stimuli.)

TABLE 1

ERRORS IN PERCENTAGES: EXP. II

Trial Category	Stimulus	ISI	*S*s				
			5	6	7	8	*M*
Double	positive S_1	all	2.2	1.8	1.2	1.5	1.7
	negative S_1	all	.6	.2	.6	—	.3
	S_2 after positive S_1	0–100	.7	—	—	—	.2
		150–300	1.0	—	—	—	.25
		400–700	2.0	1.1	5.7	2.1	2.7
	S_2 after negative S_1	0–100	—	—	—	—	—
		150–300	—	—	—	.5	.1
		400–700	.5	—	—	.5	.2
Single	positive S_1	—	1.4	6.1	10.6	4.0	5.5
	negative S_1	—	2.5	1.2	1.9	—	1.7
	S_2	—	1.2	—	.8	—	.5

The *S*s 5, 6, and 8 had roughly the same RT_1 at all ISIs (Fig. 2). But *S*7 showed a definite increase in RT_1 with increasing ISI. Mean RT_1 is longer at ISIs 0–150 than at ISIs 250–700 at each of the eight sessions; the effect is significant, $p = .008$, by a simple sign test. This *S* presumably has been waiting for S_2 on some proportion of the trials.

DISCUSSION

With four stimuli the results are much clearer: significantly longer delays are observed after positive stimuli in all four *S*s. It might be objected that the difference is due to the fact that abstention occurs on 50% of the trials, whereas each positive response occurs on 25% only. There are two arguments against this interpretation. First it has been shown (Bertelson & Tisseyre, 1966), in a four-stimuli, two-responses situation, that it was stimulus relative frequency, not response frequency, that determined RT. Of course, in an experiment with three stimuli and two responses, LaBerge and Tweedy (1964) have found some evidence of a response effect beside the stimulus effect, so that the argument is not wholly conclusive. The second, and more decisive, argument is that one would expect the sort of frequency effect under consideration to increase with practice, and the opposite trend is observed.

It seems that responding contributes a detectable component to the refractory delay. The length of this component cannot be assessed from the data. The incentive to respond fast to the positive first stimuli is still present in Exp. II, and presumably *S*s still try to prepare selectively for them. The fact that RTs after these stimuli decrease with practice more than those after negative stimuli is probably due to the discovery of processing strategies

Bertelson, P., & Tisseyre, F. Choice reaction time as a function of stimulus versus response relative frequency of occurrence. *Nature*, 1966, **212**, 1069–1070.

Davis, R. The human operator as a single channel information system. *Quarterly Journal of Experimental Psychology*, 1957, **9**, 119–129.

Davis, R. The role of "attention" in the psychological refractory period. *Quarterly Journal of Experimental Psychology*, 1959, **11**, 211–220.

Donders, F. C. Die Schnelligkeit psychischer Processe. *Archive für Anatomie, Physiologie und wissenschaftliche Medizin.* 1868, 657–681.

Fitts, P. M., Peterson, J. R., & Wolpe, G. Cognitive aspects of information processing. II. Adjustments to stimulus redundancy. *Journal of Experimental Psychology*, 1963, **65**, 507–514.

Fraisse, P. La période réfractaire psychologique. *Année Psychologique*, 1957, **57**, 315–328.

LaBerge, D., & Tweedy, J. R. Presentation probability and choice time. *Journal of Experimental Psychology*, 1964, **68**, 477–481.

Rubinstein, L. Intersensory and intrasensory effects in simple reaction time. *Perceptual and Motor Skills*, 1964, **18**, 159–172.

Smith, M. C. Theories of the psychological refractory period. *Psychological Bulletin*, 1967, **67**, 202–213.

Welford, A. T. The "psychological refractory period" and the timing of high-speed performance—A review and a theory. *British Journal of Psychology*, 1952, **43**, 2–19.

(Received January 26, 1968)