The interaction of ITI interpolated stimuli and ISI on classical conditioning of the nictitating membrane response of the rabbit[1]

RITA E. SNYDER AND JAMES D. PAPSDORF, *DEPARTMENT OF PSYCHOLOGY, THE UNIVERSITY OF MICHIGAN, Ann Arbor, Mich. 48104*

ITI presentations of a white noise burst had little effect on conditioning rates of Ss trained at a 350 msec ISI, while producing a considerable decrement in the conditioning rates of Ss trained at a 750 msec ISI. These results are discussed in terms of variable, ISI-determined, ITI consolidation rates.

Problem

The purpose of the present investigation was to determine whether the marked attenuation in conditioning rates produced by ITI interpolation of short white noise bursts (Papsdorf & Kettlewell, 1968) is influenced by ISI duration. Schneiderman & Gormezano (1964) obtained significantly more rapid conditioning of the rabbits' nictitating membrane response with an ISI of 250 msec than with one of 500 msec. In an as yet unpublished investigation from the Michigan laboratory (Pennes and Papsdorf, manuscript in preparation) the frequently observed depression in human eyelid conditioning rates which accompany 50% reinforcement schedules (e.g., Meiselman & Moore, 1965) was also found with conditioning of the nictitating membrane response, but only at such relatively non-optimal ISIs as 600 and 1200 msec. On the contrary, Ss trained at a 200 msec ISI conditioned as rapidly on a 50% reinforcement schedule as did the continuously reinforced animals. Since, in the Papsdorf & Kettlewell (1968) investigation, the interpolated stimulus depression was obtained with Ss conditioned at the 600 msec ISI, we decided to determine whether the depression would be present or, paralleling the above unpublished observation, absent in Ss trained at a more optimal ISI.

Subjects

The Ss were 32 albino rabbits, 80-100 days old, obtained through the facilities of the Animal Care Unit of The University of Michigan, and maintained on ad lib food and water.

Procedure

The apparatus and procedure employed in classical conditioning of the nictitating membrane response of the rabbit has been described in detail by Gormezano (1966). Forty-eight h after delivery S was placed in a Plexiglas restraining box, the inferior and superior lids of the right eye were retracted with tailor hooks stitched to an adjustable Velcro strap, and a muzzle-like assembly supporting a photo-electric transducer was positioned on Ss head. Movements of the nictitating membrane were monitored electrographically by mechanically coupling the transducer to a small nylon loop previously sutured into the membrane. S was then placed in a deactivated, sound-attenuating chamber for a 15 min habituation session. Twenty-four h later the 32 Ss were randomly assigned to the 4 cells (N = 8) of a 2 by 2 factorial design having ISI levels of 350 and 750 msec orthogonal to the presence (D) or absence (C) of a 5 sec burst of 85 dB white noise occurring 30 sec after CS onset. On each of the subsequent conditioning sessions, given daily for seven days or until S attained the 85% CR level on two consecutive sessions, Ss received 15 CS-US pairings at an ITI of 60 sec. The CS, a 93 dB 1000 cps tone, was presented for 450 or 850 msec with the US, a 3.0 mA 60 cps shock delivered to a point approximately 12 mm posterior to the right temporal canthus, overlapping the last 100 msec of CS presentation. CRs were defined as a 1 mm or more deflection of the oscillographic recording pen occurring 50 msec after CS onset and up to the moment of US presentation.

Results

Figure 1 plots the percentage CRs across the seven conditioning sessions for each of the four groups with their mean performance over the seven sessions plotted in the Inset. In the construction of this graph as well as in the subsequent data analysis the extrapolated performance level for a S attaining criterion prior to the seventh session was arbitrarily given the value attained by that S on the second criterion session. As examination of the figure indicates, ITI presentation of white noise bursts had little effect on conditioning rates at the 350 msec ISI, while producing a marked depression in the acquisition curve of the 750 msec ISI group. F-test comparisons of the control and experimental means over the seven conditioning sessions yielded no significant difference at the 350 msec ISI (F = .08) with a significant difference present at the 750 msec ISI (F = 6.70; df = 1/36; p < .05).

Discussion

The observation that ITI interpolations of "white noise" bursts produce deficits in conditioning rates which may be obviated by training with a more optimal ISI can be presently accounted for by at least two theoretical positions: (1) A larger reactive inhibition to associative strength ratio in the 750 msec ISI white noise Ss; (2) a faster rate of ITI consolidation in both of the 350 msec ISI groups. With respect to the former hypothesis, as there is a slightly greater frequency of white noise-elicited ITI blinking in the interpolated stimulus groups, it could be suggested, in accord with Hull (1943) that the level of reactive inhibition, though equal in the two experimental groups, is, in comparison to their amounts of associative development, relatively greater for the 750 msec ISI Ss. However, as it was previously reported (Papsdorf & Kettlewell, 1968) that a white noise burst occurring 50 sec into a 1 min ITI produced less of a depression than one occurring 30 sec into the ITI, the reactive inhibition hypothesis, as well as other time-decaying inhibitory effects, would not appear to be applicable.

The alternative formulation of ISI-determined consolidation rates is an expansion of the hypothesis that ITI consolidation occurs in conditioning of the nictitating membrane response (Kettlewell & Papsdorf, 1968). Briefly, this theory assumes that tone-shock presentation on trial N activates a population of neural elements which code this contingency and move from a vulnerable or short-term state to a less vulnerable or long-term state in the
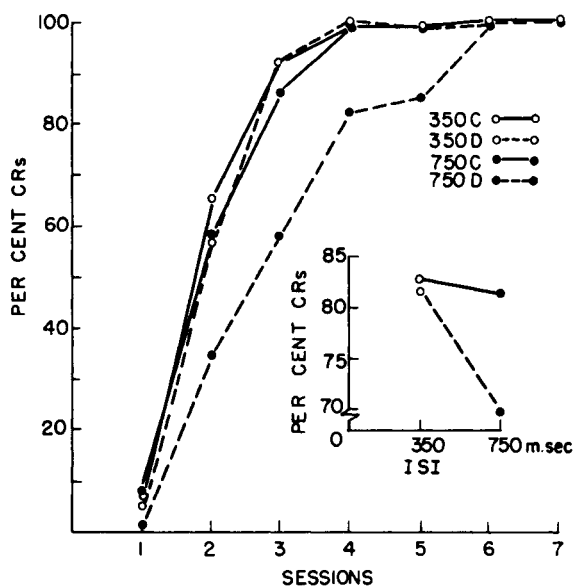

Fig. 1. Percentage CRs for all groups over the seven conditioning sessions and (Inset) collapsed across the seven sessions.

period following US offset. US presentation on trial N + 1, as well as ITI presentations of white noise bursts, terminates the consolidation process and those traces which have not yet consolidated are lost. However, another population of traces codes the tone-shock contingency of trial N + 1 and the process is reinitiated. With reference to the present results, more optimal ISIs could presumably produce more rapid ITI consolidation; thus, for example, given a 350 msec ISI, 95% of the activated traces could be consolidated 30 sec after CS onset while, for the 750 msec ISI Ss, only 50% of their traces might be consolidated by this time.

As to the possible reasons for such a relationship between ISI and ITI consolidation rate, we can, of course, at this point only speculate. John (1967, p. 62) has suggested that the reverberatory overlap of wavefronts of coherent neural activity emanating from the CS dominant focus and travelling to the US dominant focus underlies the neural basis of associative ontogenesis. John further suggests that the facilitatory effects of certain analeptic drugs on conditioning rates is attributable to increasing the number of CS-excited neural elements. Besides increasing the coherence or detectability of the reverberatory wavefronts, larger neural populations may interact in such a way that there is greater alteration in the extraneuronal microenvironment which accelerates the metabolic process involved in associative storage. This hypothesis of metabolically determined consolidation rates can also be applied to the results of the present investigation if it is assumed that the number of CS activated neurons, or degree of wavefront coherence, effectively interacting with the US dominant focus is determined by the ISI.

Another possible explanation for ISI determination of ITI consolidation rates, one which John has also considered in accounting for the facilitatory effects of certain CNS excitant drugs, is that the rate of reverberatory activity underlying consolidation may be altered by ISI duration. If the lengths (i.e., number of synapses) of the functional neural paths involved in wavefront emanations from the CS-dominant focus to the US-dominant focus are determined by the ISI, then the number of wavefront passages which proceed through these loops in a given unit of time would vary inversely with the period of CS-US separation. Thus on the assumption that each wavefront sweep adds a constant increment to associative development, consolidation would proceed more rapidly with an ISI of 350 msec than with one of 750 msec.

While the present investigation points to the possibility of ISI determination of ITI consolidation rates, only further research can establish this hypothesis; an investigation critical to its acceptance would involve not only demonstrating the presence of variable, ISI determined, ITI vulnerability gradients, but also the existence of an early ITI locus where white noise bursts produce a level of depression independent of the ISI function. Such a locus of course would reveal the time at which the ITI consolidation process has been initiated.

If the efficacy of this hypothesis is established, consideration of the alternate neural analogues proposed—differential metabolic enhancement as a function of wavefront coherence, or variable neural loop iteration frequencies—suggests another line of investigation. A factorial comparison of the disrupting effects of white noise bursts on conditioning to CS of several intensities should, if the loop length hypothesis is correct, result in no interaction since increases in CS intensity presumably augment wavefront coherence but do not alter loop length. We are presently engaged in this and related investigations at the Michigan laboratory.

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