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PHASIC HEART RATE CHANGES IN CHOICE REACTION TIME TASK : EFFECT OF IMPERATIVE STIMULUS OMISSION

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An experiment is reported to examine the effect of omitting imperative stimuli in choice reaction time task on phasic cardiac response during variable foreperiod determined by the subject's R-R intervals of nine beats. Male undergraduate volunteers received a visual warning stimulus signalling the presentation of one of four auditory imperative stimuli at the end of a 9-beat foreperiod in the practice session, followed by the extinction session without the imperative stimuli. The presentation of the warning stimulus was done under monitoring of prestimulus heart rate baseline with the aid of a microcomputer. Based on scoring of HR data, subjects were dichotomized to labiles and stabiles.

The results indicated that: 1) phasic cardiac response during variable foreperiod was monophasic, depending upon response requirements, 2) such a phasic response tended to decrease in its magnitude as the trials proceeded, 3) omission of the imperative stimuli relsulted in the recovery of cardiac response, 4) larger visceral responses obtained by the choice reaction time procedure did not prompt overt responding. It was suggested that there would be a screening mechanism underying an expectancy function responsible for a cardiac evoked response.

A number of peripheral variables as well as EEG often undergo phasic changes in repsonse to a given stimulus, and the direction and magnitude of these changes can be modified, depending upon not only attributes of this stimulus per se, but properties of an imperative stimulus (IS) preceded wigh a warning signal, the presence of response requirements and so forth. In the studies of evoked cardiac response, patterns of acceleration and deceleration have often been tied to such psychic processes as attention, expectancy, or orientation (Hahn, 1973; Graham & Clifton, 1966). A series of researches like those seen in Laceys (e.g., 1974) and Obrist (1981) centered around the elucidation of the mechanism underlying the integration of cardiac activity, especially indexed by heart rate (HR), and somatic responses. Then, it was the decelerative HR change named D_2[3]

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3. Alphabets representing a phasic HR response were adopted from Gatchel & Lang (1973)

component immediately before an IS which they have been particularly interested in, with different views on the functional or instrumental aspects of HR-reaction time (RT) relationship. This type of deceleration is a typical response recognized by two-stimulus paradigms with longer foreperiod approximately from 4 sec to 12 sec (Bohlin & Kjellberg, 1979).

Besides D_2 component, the preceding accelerative "A" is also a response component characteristic of phasic HR change, following initial deceleration (D_1) with its manifestation being small or unstable. Each occurrence mechanism underlying both components has been pursued in conjunction with fundamentally the same cognitive and somatic factors as those of D_2 component. The morphology of evoked cardiac response, though it can be modified due to the differences in experimental conditions such as modality of warning stimulus (WS) and a foreperiod duration, has been often found in the simple RT task (e.g., Lacey & Lacey, 1978). However, the tasks of choice RT and classical conditioning do not always lead to the biphasic figure time-locked in two-stimulus situation; e.g., the first deceleration (D_1), generally regarded as an orienting response (OR) to WS, is frequently absent (Bohlin & Kjellberg, 1979).

There seem fundamentally two viewpoints on the mechanism underlying phasic HR changes in two-stimulus paradigms. On one hand, there are a few standpoints emphasizing that autonomic activities have some causal effect in enhancing motor performance (Germana, 1969; Lacey & Lacey, 1974; 1978). Autonomic responses will play an instrumental role in preparation for efficient overt behavior, making bodily anticipatory adjustments possible. This suggests that efficient performance will result from some autonomic response, e.g., cardiac deceleration.

In contrast some consider that cardio-vascular activities can be elicited quite independently of whether or not WS produces any disposition towards overt response. Obrist's cardiac-somatic hypothesis (Obrist, 1981) states that when HR is primarily under vagal control, HR changes in parallel with somatomotor activity because of the integrating mechanism within central nervous system. This implies that phasic HR change, concomitant with somatic activities reflects attentional processes. Sokolov (1963) had already proposed a related hypothesis, the "neuronal model of stimulus" to explain orienting responses. This model is assumed to have a matching mechanism detecting a difference between incoming stimulus and representation of prior stimulus. The appearance of orienting responses involving phasic cardiac changes, is attributed to incongruent impulse resulting from the difference. Therefore, this mechanism is sensitive to perceptual and collative variables like novelty as Berlyne (1960) pointed out. The primary function of orienting responses is to raise the sensitivity of sense organs to deal with any incoming stimuli, i.e. autonomic and somatic activities facilitate the perception.

Both views, according to Higgins (1971), are similar to each other in that they assume that the adaptive value of this autonomic activity is basically anticipatory in nature. At any rate the interpretation of the functional significance on the HR pattern remains a matter of dispute, particularly with respect to deceleratory component prior to the IS.

This investigation employs the choice RT task, much the same as the previous study (Hatayama, Yamaguchi & Ohyama, 1981) which requires *S* to select one correct response out of four alternatives. Then, our primary concern was to investigate how omission of an IS during the extinction session will have an effect on an evoked HR response. The working hypotheses in this experiment were as follows:

Phasic HR response during the foreperiod can not be produced without a WS. If component "A" is associated with acquisition of stimulus significance in WS, the magnitude of HR acceleration will be gradually increased in the course of acquiring four types of responding in this experiment.

Further, if the secondary deceleration is a response component reflecting an "expectancy" process, first of all the magnitude of D_2 will be increased in the earlier trials of "extinction" session; next, it will decrease gradually with continued "extinction" trials because the functional significance of the D_2 process ought to be that of sensory enhancement in the light of Sokolov's OR concept.

In the present experiment particular consideration was given to a timing of WS presentation as well as to idiosyncratic patterns in HR response which *S*s will show. On the former a technique was devised of presenting the WS under such conditions as the pacemaker was subject to considerable parasympathetic or vagal restraint (Obrist, 1981) by a computer-monitoring of successive instantaneous HRs just before the WS. For the latter, an attempt was made to dichotomize into labile and stabile responders, based upon the number of response occurrence during the practice session.

The procedure with an IS omission during the extinction session is of critical importance for verifying the hypothesis in this experiment. Before this extinction testing, *S*s undergo a practice session in order to commit correct key-pressings to memory. This procedure aims at making OR initiation easy immediately after the practice session, maximizing the surprisingness effect associated with novelty.

METHOD

Subjects: The subjects were 13 male Tohoku undergraduates recruited from College of General Education and were paid. Of these 13, 2 were eliminated because of excessive movement artifacts during the experiment. The remaining 11 *S*s constructed the sample.

Apparatus: A NEC TK–80 BS microcomputer was used to control the presentation and timing of stimuli, and the polygraphical recording system was mainly composed of a Nihon Kohden RMP–6008 preamplifier, a San-ei Recti-Horiz-8K type recorder, and a Sony NFR–3915 FM data-recorder. This system continuously monitored *S*'s heart beat, respiration, EMG, presentation of signals, and responses to stimuli. These data were simultaneously stored on FM magnetic tape. Nihon Kohden disposable Ag-Agcl electrodes with electrode paste were used for both heart beat and EMG recording.

Two HR electrodes were placed over the lower rib cage, while the EMG electrodes were placed over the ventral forearm muscle bundles of both hands. The HR was monitored by a Nihon Kohden AT–600 G tachograph and the computer. Breathing was monitored through a Nihon Kodhen Model SR–115S.

The warning stimulus was a red light and the imperative stimuli, 4 tones, were the output of a kikusui 418B oscillator. These were presented through the LED and a speaker mouted vertically in an opaque bakelite case (190×130×50 mm), placed on the table about 50 cm before *S*'s eyes. The IS tones were set at either 1,000 Hz or 50 cm befor *S*'s eyes. The IS tones were set at either 1,000 Hz or 2,000 Hz ,due to the experimental condition of stimulus presentation. In the practice session, RT was the time from IS onset to the *S*'s key-pressing of the correct lever, with the pressing turning off the IS.

*S*s were seated in a chair at the table on which were placed the right and left microswitches with the hinge lever, 26×4 mm, set freely at the convenient position for *S*'s responding.

Procedure: *S*s were requested to answer a post-sleep questionnaire prior to the connection of electrodes. This questionnaire was used to check the quantitative and qualitative aspects of last night sleep, the presence of drug administration, and so forth. The data obtained indicated that all *S*s were satisfying an administrative requirement to participate in this experiment. Recording and control apparatus was located outside a soundproof chamber, where all recording was made.

The experiment consisted of two sessions. Of the first of them, 28 practice trials, earlier 12 trials were those in which *S* was given advance knowledge about an IS prior to beginning a trial, and given information of either "true" or "false" in performance after key-pressing, given to provide familiarization with the experimental procedure. The remaining 16 trials of choice RT task were just the same as earlier, except that the advance knowledge was eliminated. Each trial consisted of WS (1.3 sec in duration) followed after the ninth beat from WS onset by one of 4 IS tones produced by making a difference in intensity to two pure tones differing in pitch: 90 dB and 74 dB of 1,000 Hz tone, 78 dB and 63 dB of 2,000 Hz in SPL. The presentation order of them was randomized in each *S*, according to a predetermined design. For the second session of 15 trials, the WS alone was presented, with IS omitted.

The *S* was instructed to choose one definite response from 4 ways of responding to a given IS. Next, he was told that if the presented tone was lower, then he should prepare for responding with his right hand and press the right microswitch only once as fast as possible when it was louder, and in turn do so twice successively when less loud; if its tone was the higher, his response had to be given with his left hand in such a way as to press the left switch twice when louder, and to do so only once when less loud. Such four modes did we have by changing the key-press repetition either once or twice and by making four combinations which were composed of two kinds of pitch and loudness. One of these modes was randomly assigned to each *S*, according to a predetermined schedule.

Throughout both sessions, HR baseline immediately before a foreperiod was monitored to determine a time point of the WS presentation by the computer: the condition presented was that the number of instantaneous HR below 75 bpm was more than 6 HRs within 12 beats just before the WS. This procedure was devised to avoid the WS presentation under emotionally elevated level of arousal and phasic excessive body movements.

Scoring: Raw heart beat was initially converted into R-R intervals by the computer, which was programmed to measure the intervals between successive R waves in 5 msec. HR changes were quantified in a beat-by-beat analysis for each *S* on each of the 43 trials for both sessions. These measurements consisted of a continuous sample of HR beginning 6 beats prior to WS onset and ending 6 beats following at IS presentation. Based on this sample, difference scores were derived from averaging 5 HR values just before the WS, and then continuously subtracting this prestimulus HR level from each of successive 9 HR values during the foreperiod and from 6 values following an IS onset. These scores, by taking into account the difference from resting baseline, were modified as an adjusted difference scores by subtracting a baseline value, which was the mean of 3 samples obtained in the same computational procedure as experimental sessions from arbitrary points of post-experimental resting recordings, from the original difference scores per trial.

Each *S*'s RT on each of the practice session was read, online, at a sampling time of 0,5 msec. By scanning the key-pressing and the EMG traces on the Recti-Horiz, it was possible to determine whether *S* had made a correct response or not.

Of the data in the practice session, those of earlier 13 trials were excluded from the results.

RESULTS

Dichotomy of labile and stabile types of cardiac responses[4]: Since there seemed to be a greater difference between *S*s in response occurrence described as evoked HR changes during the foreperiod, *S*s were dichotomized into labiles and stabiles on the basis of frequencies of response occurrence in the practice session.

HR changes during a foreperiod were classified into 3 types of response, with different weighed scores for different response types; A type was given weight, 3 which has a definite acceleration pattern followed by decleration immediately prior to an IS,

4. The method of identifying evoked HR responses involves a technique that can detect a response pattern when it is occurring within the spontaneous, ongoing cardiac activity. In this study, a set of baseline data was matched against the data obtained in each trial using a product-moment correlation method. For the present, the correlation coefficient about 0.4 was regarded as an index to judge no response because HR change in this case had little shown a pattern time-locked to two-stimulus situation. This is, however, not an entirely satisfactory procedure. Then, HR pattern recognition through visual inspection was made as well, with particularly paying attention to facilitatory change during the foreperiod and subsequent deceleration pattern immediately before an IS.

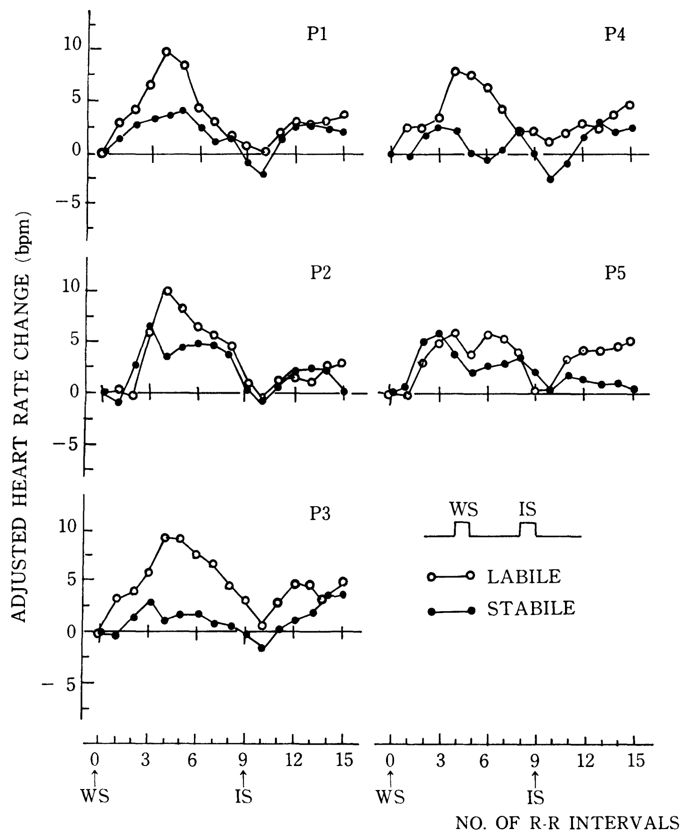

Fig. 1. Mean amplitudes of phasic cardiac responses following WS onset over 5 successive trial blocks for both labile and stabile subjects in practice session.

Table 1. *F* values based on trend analyses defined according to practice and extinction sessions (represented by trial block, 1 and 5)

		Practice		Extinction	
		Trial Block		Trial Block	
		1	5	1	5
Labile	Linear	7.04*	0.57	6.67*	1.21
	Quadratic	9.21**	8.77**	10.95**	0.04
	Cubic	4.19*	0.52	1.25	2.07
Stabile	Linear	8.21**	1.34	0.72	2.34
	Quadratic	7.56**	1.54	7.96**	0.01
	Cubic	0.29	0.48	0.32	0.16

dfs are 1, N–1 for ANOVA of each trend component, i.e., 1 and 40 for labiles; 1 and 50 for stabiles.

* $p<.05$, ** $p.<01$

B type weight, 2 with a monotonic increase pattern or a decrease, and C type weight, 1 with no response. The mean of the weighted response scores for all *S*s was 36.2 with a standard deviation of 6.8; the median was 36.0. Labile *S*s in HR response were defined as those who scored above the median and stabile *S*s below the median on the occurrence score of HR response. Among the 11 *S*s, 5 *S*s were above the median (labiles) and 6 were below (stablies).

Heart Rate

The data of phasic HR responses were separately analyzed in both sessions.

Practice session: Average adjusted difference scores were derived at every block of 3 trials from the data of the 14th to the 28th trial. The cardiac responses following WS onset are shown in Fig. 1 over 5 successive trial blocks for both labiles and stabiles. A single curve for each of labiles and stabiles was condensed from the 5 curves to assess the common trends of 10 data points following WS onset as a whole. The most significant trends in the composite curve during practice were the linear and quadratic components (linear ($F(1/40)=14.27$, $MSe=31.84$), quadratic ($F(1/40)=118.26$, $MSe=263.85$) for labiles and linear ($F(1/40)=12.02$, $MSe=26.04$), quadratic ($F(1/40)=30.73$, $MSe=66.56$) for stabiles). The waveform of these responses was monophasic, consisting of an initial acceleration and a deceleration.

Concerning the curves over successive blocks, the peak acceleration seen between beat 3 and 6 decreased gradually, especially in labiles. Table 1 summarizes the results of trend analyses per block for both practice and extinction sessions, represented by block 1 and 5. From this table it was indicated that in the practice session the significant components, all but the quadratic in labiles, diminished over subsequent blocks. Table 2 presents the correlation coefficients per block calculated over the 15 data points from the data for two kinds of cardiac curves, to evaluate the extent of concordance for both waveforms. The coefficients from the 3rd block on were low in the practice session. These results revealed that there was habituation of anticipatory cardiac responses, which was more noticeable in stabile subjects.

Table 2. Product moment correlations for cardiac responses in each trial block between labile and stabile subjects

Trial Blocks	Practice	Extinction
1	.78	.55
2	.76	.89
3	.37	.82
4	.18	.62
5	.32	.01

Extinction session: In the same manner as in the practice session extinction trials (not accompanied by IS) were divided into 5 blocks of 3 trials. The first and second blocks (E1 and E2) in Fig. 2 showed that the HR responses to WS tended to increase in

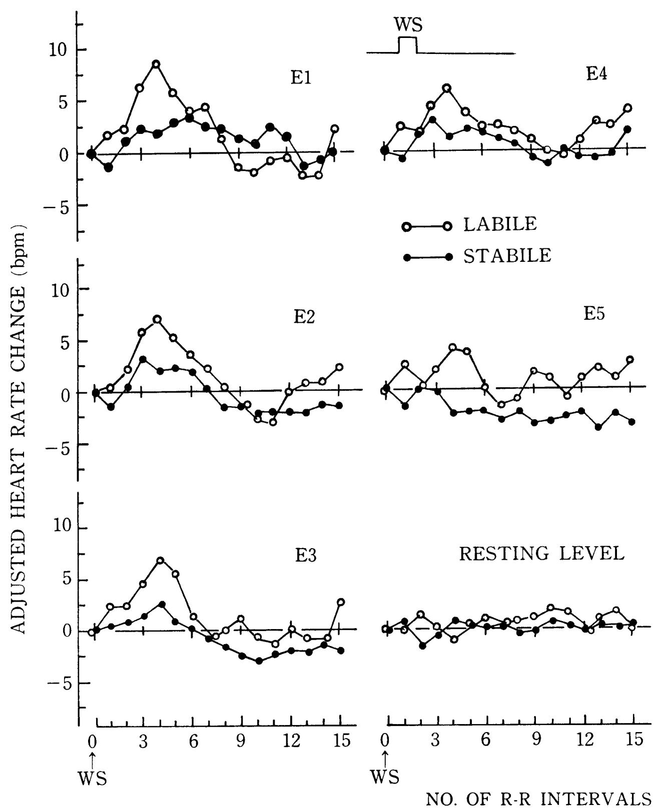

Fig. 2. Mean amplitudes of phasic cardiac responses in extinction session with IS omission.

peak acceleration. This was first confirmed by trend analysis (Table 1) demonstrating reappearance of significant linear and quadratic components. Further, the mean adjusted HR scores for P5 and E1 were compared in a pair-wise manner over the 10 data points following the WS with the Wilcoxon sign rank test to evaluate the immediate effect of withholding IS on response magnitude. Significant ranking was obtained for labile subjects ($T=1$, $p<.01$), with the stabiles, however, remaining just below the level of significance ($p=.05$). These results suggested that removal of Is would cause to recover cardiac response with a sharp acceleration.

The gradual decreases of peak acceleration were seen also in this session subsequent to the 3rd block. Especially, no evoked cardiac responses were found from the E5 block in Fig. 2, similar to resting level. This impression was again made certain by trend analysis, which showed no significant components (Table 1). The transition of the waveform of HR responses over the extinction session was found to be similar to each other in two types of subject groups because of the higher coefficients of correlation for 4 blocks except for E5 seen from Table 2, though the shapes were different in the magnitude of change.

Reaction Times

All RTs obtained from the practice session were transformed into common logarithm and the performance was evaluated using a two-factor ANOVA with repeated measures on one factor (trial block) described in Winer (1971). Average RT, converted to standard T-scores, appeared to be somewhat longer in the labiles than in the stabiles. This difference, however, was not statistically significant, with the exception of significant between-subject difference for which $p=.05$.

Discussion

This investigation was mainly designed to examine the effect of omitting the imperative stimuli in choice reaction time task on phasic HR response during the foreperiod. In a similar way to the previous study (Hatayama et al., 1981), a monophasic pattern of cardiac response was seen under the choice RT procedure with four alternatives in the practice session. This pattern consists of an initial acceleration and subsequent deceleration preceding an imperative stimulus onset. However, the first deceleratory component, generally regarded as an orienting response, was not found in either session. Although there is some possibility that such an initial deceleration was absent because of the warning LED stimulus with low intensity, it appears to be difficult to confirm the presence of this component without dealing with resting control rather than pre-WS level in view of at most one-or-two beat deceleration as Bohlin et al.'s (1969) review showed.

In both practice and extinction session the amplitude of HR responses tended to decrease gradually with continued trials. Removal of imperative stimuli in the extinction session led to an increase in response magnitude. Thus, such a decrement in both sessions will seem to be due mainly to habituation of cardiac response to the repetitive series of events. Then, habituation in the practice session, more rapid in stabiles, occurred in spite of the presence of motor response requirements and a certain degree of time uncertainty at a foreperiod. However, such changes of response magnitude were not related with any improvement of RT performance, though labiles might have tendency to decrease RTs in the latter half of this session. These results suggest that initial acceleration is not due to a stimulus significance of WS acquired in process of learning the response mode, but rather to a sort of sensory facilitation to IS uncertainty warned by the light. This view seems to agree with those of Higgins (1971) and Lawler, Obrist & Lawler (1976) in that HR acceleration is a function of the stimulus uncertainty of WS rather than a function of response preparation. There is some possibility that the more accelerated response seen in labiles may have been connected with the longer RT, i.e., deterioration in performance. If it is the case, the initial component "A" HR response is seen to reflect a process for organization of pre-motor set, or for paying attention to the expected IS.

HR deceleration just prior to an IS was evident in the present study, without slowing below baseline. Though such a deceleration reliably showed the anticipatory response pattern time-locked to IS, the degree of deceleration was not related with efficacy of motor response. This finding is compatible with our previous study's (1981), pointing out that the situation for choice reaction time with 25% certainty did not produce significant cardiac-motor relationship. Further, it was noticed that reaction time for the CRT task preceded with WS was almost identical to that for the CRT task without WS; i.e., this showed again that HR response just before IS would not be connected with efficacy of motor performance. However, the situation for the so-called simple reaction time where S could have prepared the response informed beforehand for the IS did produce a significant negative correlation between HR deceleration and reaction time (Hatayama, et al., 1981). This suggests that cardiac-motor relationship, which has been discussed from a few viewpoints like visceral feedback afferentation (Lacey, 1967), respone requirements at IS (Simons, Öhman & Lang, 1979; Coles & Duncan-Johnson, 1975), may fit between RT and deceleration below baseline generated under RT task with relative simple response requirements. Consequently, such a below-baseline deceleration may play some causal role in response facilitation.

Concerning HR deceleration prior to the IS, we observed it also in the extinction session. This means that anticipatory HR deceleration is likely to be obtained in the absence of response requirement at IS. Thus, demands on overt responding ought to be unable to be the single determinant of deceleration. In addition, the fact that dishabituation of cardiac response occurred at the earlier stage of extinction session will indicate the existence of an expectancy function, according to Sokolov (1969) and Öhman (1979). As seen in the present study, since the HR response to all stimuli utilized is considered to be learned, it follows naturally that such a function will result from a screening mechanism capable of comparing the sensory input with the *S*'s memory to determine the appropriate autonomic response.

To sum up, phasic cardiac response during the variable foreperiod defined by the *S*' R-R intervals will be monophasic, depending upon response requirements at the imperative stimuli. Such a phasic response tends to decrease in its magnitude with continued trials regardless of the presence or absence of an IS. The fact that omission of the IS resulted in dishabituation of cardiac response suggests the existence of an expectancy function. It is inferred from these findings that initial component "A" will be related mainly to the process of sensory enhancement, and anticipatory decelerative component "D_2" following "A", to a screening mechanism. The SRT situation characterized by the reduced dependability to such an internal mechanism will probably produce the larger below-baseline deceleration, leading to a significant cardiac-motor relationship.

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