ACTA NEUROBIOLOGIAE EXPERIMENTALIS

Acta Neurobiol. Exp. 1996, 56: 209-213

The evoked cardiac response as a function of cognitive load in subjects differing on the individual difference variable of reaction time

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Abstract. We report research on different phasic evoked cardiac responses associated with differences in cognitive activity. These were examined in relation to a stable individual difference variable, mean simple reaction time (RT). Individual means on RT were found to be sufficiently stable over a 10 month period to consider them as individual functional characteristics. Subjects were divided into two subgroups on the basis of the first measure of their individual mean RT (above and below the group median). Each subject received 10 innocuous auditory stimuli with randomly varying interstimulus intervals. Stimuli were presented in one of two conditions defined by instructions allowing them to ignore (irrelevant condition), or requiring them to count the stimuli (relevant condition). A main effect of instruction was obtained in the evoked cardiac response. The initial heart rate deceleration was significantly larger in the irrelevant condition and a later acceleration was significantly larger in the relevant condition. Short-RT subjects had smaller heart rate changes to the irrelevant stimuli. The data are discussed in terms of the intensity of stimulus processing (both physical and cognitive) as a factor which may be related fundamentally to stable individual differences in RT.

Key words: evoked cardiac response (ECR), heart rate (HR), individual differences, reaction time (RT)

INTRODUCTION

The relation between cardiac-cycle changes and information processing activity has been well established in some situations. In a simple reaction time (RT) task the stimulus has to be encoded first. Next, the preparation for the response occurs. Each of these two successive phases of information processing is associated with a specific component of the evoked cardiac response (ECR). The first is associated with a heart rate (HR) deceleration and the second with an HR acceleration. The level of motor performance in an RT task depends on the course of the underlying information processing. The physiological correlates of information processing have two main dimensions: timing and intensity. These two dimensions characterize the pattern of the physiological response to experimental variables. In this study we attempt to investigate whether people differentiated by RTs present different patterns or time-course of the phasic HR response in general terms. We concentrate on the pattern or course of the transient biphasic ECR of HR change (a pattern of a single autonomic component) in a simple cognitive task rather than in the RT task itself. The establishment of such a general difference in autonomic response patterning would signal a systemic pattern difference.

Two main factors influence the pattern of an autonomic response: the particular stimulus situation and the characteristics of the individual. By using an adequate experimental procedure it is possible to distinguish two types of patterns reflecting these factors: a stimulus-situation pattern and the individual-response pattern.

The ECR elicited by an innocuous stimulus requiring cognitive processing is essentially a biphasic response. When no task requirements are imposed upon the subject (only innocous stimulus which means irrelevant stimulus) most often a simple early deceleratory cardiac response occurs. Increased stimulus significance (relevant stimulus), produced by instructions to respond to the stimulus in some way (e.g. to count the stimuli), generates a largely acceleratory HR response, usually with some initial HR deceleration. Thus, the biphasic picture of the ECR consists of an initial deceleration followed by an acceleration (Barry 1987).

The initial HR deceleration, ECR1, is identified as a primary bradycardia. The Laceys have shown that brief stimuli prolongate the cardiac cycle in which the stimulus onset occurs and also the subsequent cardiac cycle. After those two slower heart beats, a return towards the baseline occurs. This reflex bradycardia was considered by the Laceys as a correlate of an "early process of stimulus registration" (Lacey and Lacey 1980). The accelerative component of the ECR, ECR2, which is affected by variation of stimulus significance, may be treated as a correlate of an experimentally defined set of mental processes (Kaiser et al. 1993). Thus, the biphasic ECR may be described as the sum of two independent response components.

Some simple manipulations of situational demands, e.g., increasing the significance of the stimulus by instructions, have clear effects on the ECR, generating HR acceleration. This effect is related to stimulus significance in terms of signal value. Signal value associated with a stimulus is definable in terms of what the subject does after the stimulus onset (e.g., counts the stimuli) (Barry 1982).

There are two, in some meaning classical, theories of the function of cardiac activity. Lacey et al. (1963), on the basis of the idea of "directional fractionation" (fractions of the total somatic response pattern may respond in opposite directions), went on to argue that HR decreases (deceleration) reflect attention to external events - "stimulus intake", while HR increases (acceleration) reflect internally concentrated mental processes such as thinking - which require "environmental rejection". Obrist (1976) distinguished two situations: "passive coping" and "active coping". In the first of these the organism has little control over the environment, as for example when a person perceives stimuli which occur regardless of his action. In this condition the heart is under the control of the vagus nerve of the parasympathetic nervous system (PNS). In the latter case action is required of the person. Here the heart is under sympathetic nervous system (SNS) control and HR acceleration occurs. Obrist stressed the importance of the fact that changes of HR and muscle activities covary and that this covariation is produced by the same brain mechanism.

In the more recent literature an alternative interpretation of ECR components was provided by Barry (1987), who regards the initial deceleration as reflecting stimulus registration and the accelerative component as reflecting cognitive load.

There are some common standpoints in Lacey's, Obrist's and Barry's theoretical interpretations of the function of decelerative and accelerative components of the evoked cardiac response. They all regard the ECR as a physiological indicator which reflects higher activity of the brain. Both Lacey and Barry regard deceleration of HR as a correlate of a "stimulus intake/registration process", while all three theorists interpret HR acceleration as a correlate of the mechanism of mental performance.

The question is whether people who are reliably characterized by faster or slower RT present a specific level of intensity of the HR correlate of stimulus intake and/or the HR correlate of mental performance. A specific level of the intensity dimension of ECR1 and/or ECR2 would be interpretable in terms of individual characteristics related to motor performance.

METHOD

Subjects

Forty technical college students, 19 years old, were subjects. They did not receive money for their participation in the experiment. Participants claimed not to use any medication and declared themselves to be healthy.

Individual RT data were obtained on two occasions separated by a 10 month interval. On each occasion subjects were asked to react to changes of stimulus intensity by pushing a button as quickly as possible. Subjects received 64 auditory stimuli with 1,000 Hz frequency and 2 s duration, with an intensity change from 60 dB to 50 dB and *vice versa* in the middle of the stimulus. Individual data from the first and second RT measurements were moderately consistent (stability coefficient, rtt=0.62, $P<0.001$). Subjects were divided into two groups using the median value of individual RT means obtained in the first RT experiment as a criterion.

Apparatus

Heart rate and respiration were recorded from the same SandW standard electrodes connected to an SandW/BIAZET ECG and Respiration device. The output from an R-wave peak detector was used to compute R-R intervals in ms. Measures of cardiac activity were calculated in terms of mean values of HR at 0.5 s intervals for 30 s epochs commencing 20 s before each stimulus.

Corresponding values of respiratory activity were obtained, and used in off-line analyses to correct the HR for respiratory sinus arrhythmia (Barry et al. 1993, 1994).

Procedure

Each session lasted 30 minutes. Subjects were seated in a comfortable armchair in an air-conditioned, electrically- shielded, sound-isolated chamber which was separated from the recording equipment. The subjects received 10 innocuous auditory stimuli (60 dB, 1,000 Hz, 1 s duration, 20 ms rise/fall times), with interstimulus intervals randomly varying between 40 and 60 s. Stimuli were presented in one of two conditions, defined by instructions that there was no task involving the stimuli (irrelevant condition) or by instructions to count the tones (relevant condition).

RESULTS

The mean evoked cardiac responses from the relevant and irrelevant conditions are shown in Fig. 1. It can be seen that the response in the irrelevant condition was a simple deceleration, identifiable as ECR1. In contrast, the response obtained in the relevant condition is seen to be dominated by the ac-

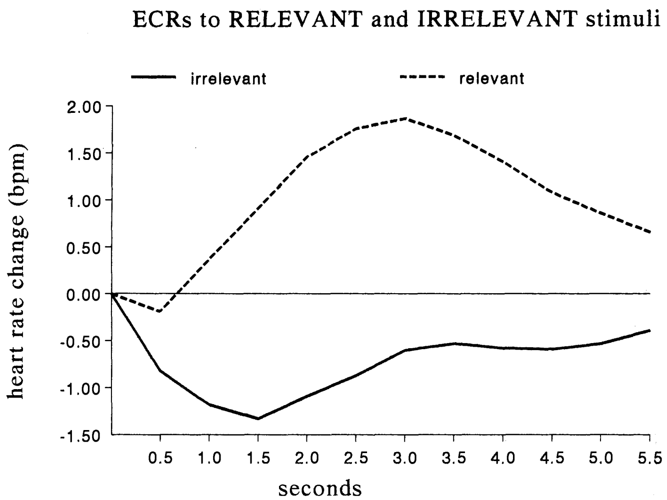

Fig. 1. Mean evoked cardiac responses from the relevant and irrelevant conditions. HR changes from the immediately- prestimulus value are shown. The stimulus onset occurred at time 0.

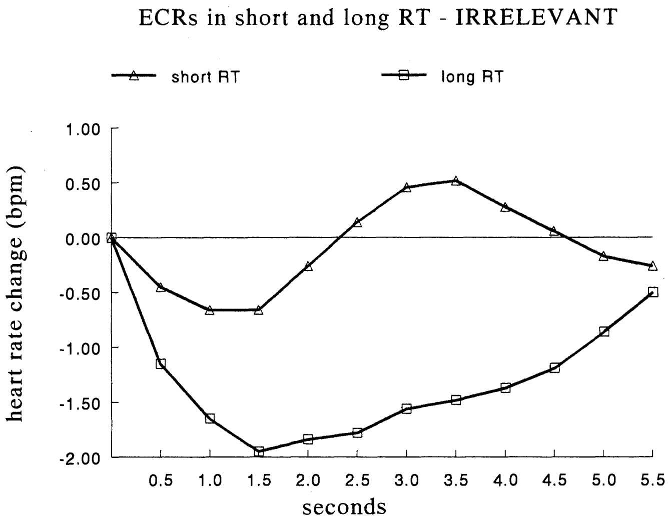

Fig. 2. The decelerative ECR1 from the irrelevant condition, separated on the basis of the subjects' scores on RT measurement.

celerative ECR2. These data points were submitted to a two-way repeated-measures ANOVA examining the factors of time-points (12 values) and condition (relevant/irrelevant). Within time-points, simple trends (linear, quadratic and cubic) were examined. There was a significant interaction between condition and quadratic trend over time, $F(1,36)=17.25$, $P<0.0005$, indicating that the response patterns differed significantly between the conditions.

Figure 2 shows the decelerative ECR1 separated on the basis of the subjects' scores on individual means of RT. Slower scorers showed an enhanced deceleration. The data underlying the decelerative response was submitted to a two-way analysis over group and time-points (12 values). The time factor included simple trends. The response pattern was defined by a significant cubic trend over time points, $F(1,19)=14.28$, $P<0.001$. There was a significant interaction between quadratic trend over time and RT score, $F(1,19)=6.18$, $P<0.025$, confirming the significance of the ECR1 difference shown in Fig. 2.

The data underlying the accelerative components from each group were submitted to a similar two-way ANOVA over time-points (1-12) and group (faster/slower RT), with simple trends included in the time factor. The accelerative response was characterized as a significant quadratic trend over time points, $F(1,17)=22.50$, $P<0.001$. There was no significant difference in this ECR2 component as a function of RT performance.

DISCUSSION

In this study we obtained the biphasic ECR in response to innocuous auditory stimuli as was described in the Introduction. In Figure 1 can be seen clear evidence of the decelerative ECR1 obtained under task-irrelevant conditions. Under the relevant conditions, in which subjects had to count the stimuli, a largely accelerative response, identifiable as ECR2, was obtained. The instructional manipulation between the relevant and irrelevant conditions led to significantly different responses in line with our predictions. The deceleratory ECR1 component was found to differ significantly as a function of individual RT. Slower subjects (with longer RTs) showed an increased deceleration in their ECR1 (see Fig. 2).

The deceleratory ECR1 component of the evoked cardiac response has been associated with an early stage of sensory processing, involving stimulus intake (Lacey 1963) or stimulus registration (Barry 1987). The enhanced ECR1 found with slower subjects thus may be interpreted in terms of a greater perceptual engagement with environmental stimuli. This finding of enhanced ECR1 in the slower subjects thus confirms the suggestion of an association between individual RT and an early processing stage of sensory perception.

There was no significant difference as a function of individual RT for the accelerative ECR2 component obtained under instructions to count the stimuli. This component of the evoked cardiac response is interpreted as a marker of cognitive load or mental performance, reflecting (in this experiment) the subject's effort involved in the counting of the stimuli. The present results indicate that, despite different ECR1s, there are no differences in the acceleratory HR correlate of the task performance associated with different RT performances.

It may be concluded that the stimulus registration stage of information processing of long RT individuals is more extensive than that of short RT individuals. Such an enhancement of the stimulus processing may be advantageous under some circumstances. However, it would be expected to impair performance in those situations where rapid responding is required, such as in the RT task. These data suggest that a stable individual difference characteristic - speed of RT performance - may have its origin in differences in the extent to which some aspects of stimulus processing are carried out in individual subjects. Further exploration of this finding, perhaps looking for the convergence of psychophysiological and psychophysical measures, would appear to be important to the understanding of the origin of some performance aspects of individual differences.

REFERENCES

Barry R.J. (1982) Novelty and significance effects in the fractionation of phasic OR measures: a synthesis with traditional OR theory. Psychophysiology 19: 28-35.

Barry R.J., Tremayne P. (1987) Separation of components in the evoked cardiac response under processing load. J. Psychophysiol. 1: 259-264.

Barry R.J., Wortmann L.H. (1994) Validation of a correction procedure for the removal of respiratory sinus arrhythmia from single trial cardiac activity. Intern. J. Psychophysiol. 18: 93.

Barry R.J., Wortmann L.H., Salter G. (1993) Correction of single trial cardiac activity for respiratory sinus arrhythmia. Intern. J. Psychophysiol. 14: 113.

Kaiser J., Barry R.J., Bener J., Mrozowski E. (1993) Evoked cardiac response after correction for respiratory sinus arrhythmia: effect of task. Intern. J. Psychophysiol. 14: 130.

Lacey B.C., Lacey J.I. (1980) Cognitive modulation of time-dependent primary bradycardia. Psychophysiology 17: 209-222.

Lacey J.I., Kagan J., Lacey B.C., Moss H.A. (1963) The visceral level: Situational determinants and behavioral correlates of autonomic response patterns. In: Expression of the emotions in man (Ed. P.H. Knapp). International Universities Press, New York.

Obrist P.A. (1976) The cardiovascular-behavioral interaction - as it appears today. Psychophysiology 13: 95-107.

Paper presented at the 2nd International Congress of the Polish Neuroscience Society; Session: Psychophysiology of cognitive functions