Signal detection during watchkeeping in relation to heart rate

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Heart rate (HR) was investigated in relation to signal detection in 56 subjects during the performance of an hour-long watchkeeping task. The subject's task was to observe the hand of a large clock as it traveled in 6.6° steps around the face of the clock and to detect the occurrence of "double jumps"—instances when the hand moved through twice its usual distance. It was hypothesized that HR at the time a double jump occurred would be lower when these signals were detected than when they were missed. Findings showed HR to be no different for the two conditions.

Lacey (1967), Lacey, Kagan, Lacey, and Moss (1963), and Lacey and Lacey (1958, 1970) have formulated a hypothesis in which feedback from cardiac-system events is said to influence central nervous system functioning. According to their theory, heart-rate (HR) and blood-pressure changes are capable of facilitating or inhibiting cortical excitability through afferent excitation from baroreceptors located in the carotid sinus and the aortic arch. The hypothesis is directionally specific in that decreased HR is thought to result in facilitated cortical excitability, whereas increased HR is considered to have inhibitory effects. Translated into the realm of behavior, these relationships predict that decreased sensory sensitivity will be associated with elevated HR, and vice versa.

The results of a number of tests of the hypothesized relationship between HR and sensory sensitivity have been inconsistent and inconclusive. In a signal-detection task, Edwards and Alsip (1969) presented near-threshold auditory signals during periods of spontaneously high and low HR but failed to find differences in the number of correct detections. Saxon and Dahle (1971) reported that their subject's auditory thresholds to a 100-Hz tone were significantly less acute when HR was elevated by vigorous exercise prior to taking the threshold measurements. But Elliott and Graf (1972) have seriously questioned the validity of their findings, since the effects of the increased body noise resulting from exercise on the determination of auditory thresholds were not ruled out or adequately taken into account. Finally, Schell and Catania (1975) obtained visual thresholds during HR decelerations produced by a 60-dB warning tone, and found that the HR decelerations were greater on trials when the stimulus was detected than when it was missed.

The distinguishing feature of Schell and Catania's (1975) study is their use of a warning signal preceding the presentation of the threshold stimulus. It

could be argued that their finding was the result of a differential response to the warning signal and that the apparent relationship between HR and sensory sensitivity is spurious. To avoid the possible confounding effects of a warning signal, the present study investigated HR levels in relation to signal-detection during the performance of a watchkeeping task. Following Lacey's theory, we expected that paying close attention to the task would cause HR to decelerate. This being the case, we should expect HR to be lower when signals are detected than when they are missed.

METHOD

Subjects

Fifty-six healthy males having a mean age of 58 years were the subjects of the investigation. They were selected from a larger group of 106 subjects, who performed the watchkeeping task on the basis of the percentage of signals that were detected. Only subjects who detected at least 30% but not more than 70% of all the signals presented were included in the study. This meant that the same subjects missed between 30% and 70% of the signals presented and, hence, insured that HRs for the two conditions were computed from a sufficient number of trials to be reliable.

Procedure

Subjects performed an hour-long watchkeeping task in which they monitored the movements of a pointer as it moved in discrete 6.6° steps, one every second, like the hand of a large clock. At long and irregular intervals, the pointer traveled through twice the usual distance in the same amount of time, and these "double jumps" served as the "signals" in the experiment. Twenty-three double jumps were presented in the course of the 1-h-long test, and the subject's task was to signal whenever he detected a double jump by pressing a response key. Details concerning the task have been described previously by Surwillo and Quilter (1964).

An electrocardiogram (EKG) was picked up from two electrodes attached to the left and right sides of the subject's chest. The EKG was fed into a Waters Conley Instantaneous Heart Rate Indicator, which was connected to one channel of an inkwriting oscillograph that recorded HR in bpm. Other channels recorded the raw EKG itself, the initiation of the double jumps, and the signal from the subject's response key. For purposes of the present

experiment, the interval between the two beats that a signal happened to fall in and the interval coming immediately before it were taken as measures of HR. The latter measure was designated the presignal beat and the former, the postsignal beat. These values were read directly from the chart to the nearest bpm. Average values of HR for detected signals and missed signals were computed for each of the 56 subjects.

RESULTS

The findings are summarized in Table 1. Contrary to expectation, HR for the signals-detected condition was numerically higher than HR for the signals-missed condition. A *t* test (two-tailed) for correlated means failed to reject the null hypothesis, suggesting that HR is no different for the two conditions. It made no difference whether the presignal beats or the postsignal beats were used in the analysis.

Performance data showed that more signals were missed toward the end of the watchkeeping session. Since HR showed a tendency to decrease throughout the latter 45 min of watchkeeping, it could be argued that our failure to reject the null hypothesis was the result of lower HR values being paired with the signals-missed condition. This, however, proved not to be the case. During the first 15 min of watchkeeping—when HR showed no decrease with time—average HR for the signals-missed condition (pre 73.8 bpm, post 73.9 bpm) and the signals-detected condition (pre 73.7 bpm, post 73.9 bpm) also did not differ by *t* test.

To determine whether age of the subjects might be a factor in the outcome, the experimental sample was split at the median and the HR data for each group were analyzed separately. Table 2 summarizes these data. Except for the fact that HR was nearly 9 beats

slower in the old subjects, there were no significant differences between the signals-detected and signals-missed conditions in either group.

DISCUSSION

The present findings are in agreement with those reported by Edwards and Alsip (1969). Our study, of course, differs from their experiment in that HR was treated as the dependent variable. Thus, while Edwards and Alsip (1969) inquired whether an observer detected more signals when HR was low than when it was high, we asked whether HR was lower when signals were detected than when they were missed. Both studies showed that HR and success in signal detection are unrelated.

If we assume that the subjects were paying close attention when they detected signals but were not when they missed them, Lacey's theory is clearly not substantiated by the present data.¹ The decelerated HR which the theory hypothesizes to accompany increased cortical excitability is said to occur in the beats coming directly before a signal (Lacey & Lacey, 1974). Since HR was measured immediately prior to the signal, the present experiment would seem to be an adequate test of the theory.

One limitation of this study may derive from the need for our subjects to maintain vigilance over a long period of time. How this factor may have affected the outcome vis-à-vis the theory, however, is unknown. It is also possible that the hypothesized relationship between HR and signal detection was attenuated by age changes in cardiovascular function. But the fact that no differences were found when the sample was split into old and young groups would seem to rule this out.

It may be that Lacey's theory holds only when HR changes are evoked by a warning signal preceding the signal to be detected. At least this seems to be one way of reconciling Schell and Catania's (1975) results with the present findings and with those reported by Edwards and Alsip (1969). If this was so, the changes in HR as reported by Schell and Catania (1975) might be simply a part of the general attentional process (Obrist, Webb, & Sutterer, 1969; Obrist, Webb, Sutterer, & Howard, 1970a, b). Should this prove to be the case, the idea of a causal relationship existing between HR and sensory sensitivity would be strongly put into question.

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Table 1
Heart Rate During Watchkeeping in Relation to Signals Detected and Signals Missed

	Signals Detected	Signals Missed
Percent of total (23) Signals	55.6	44.4
Heart Rate (bpm):		
Presignal Beat	72.9	72.2
Postsignal Beat	73.3	72.7

N = 56

Table 2
Heart Rate (bpm) During Watchkeeping in Young* and Old** Subjects for Signals Detected and Signals Missed

	Old Subjects		Young Subjects	
	Signals Detected	Signals Missed	Signals Detected	Signals Missed
Presignal Beat	68.6	67.7	77.2	76.6
Postsignal Beat	69.0	68.3	78.0	77.0

**M* = 43.1 years, *N* = 28

***M* = 72.3 years, *N* = 28

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NOTE

1. Since our group consisted only of persons who correctly detected between 30% and 70% of the signals, all of the better performers were excluded from the experiment. It might be argued that only good signal detectors show the sought-for effect and that the failure to find it was due to our selection of poorer performing subjects. To provide some evidence relevant to this issue, the HR data associated with missed and detected signals were analyzed for persons who correctly detected between 74% and 96% of the signals. Average HR in these subjects ($N = 34$) for the signals-detected and signals-missed conditions was 76.4 and 76.0 bpm for the presignal beat, 76.6 and 76.3 bpm for the postsignal beat. As the HR values for the two conditions did not differ significantly from each other, these data also failed to substantiate the theory.

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