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# Effects of Exogenous Changes in Heart Rate on Facilitation of Thought and Resistance to Persuasion

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Two experiments were conducted to examine the effects of an accelerated heart rate on information processing and resistance to persuasion. Experiment 1 addressed the effects on cognitive performance of manipulating heart rate exogenously for brief periods of time. Fourteen subjects wearing implanted demand-type cardiac pacemakers performed reading comprehension and sentence generation tasks while their heart rate was either accelerated or not accelerated. Results revealed that performance was better when heart rate was accelerated than when it was not accelerated. Experiment 2 addressed the effects on counterargumentation and resistance to persuasion of manipulating heart rate using the cardiac-pacing technique employed in Experiment 1. Subjects read highly involving counterattitudinal communications while their heart rate was either ostensibly or actually accelerated. Accelerated heart rate resulted in the generation of more total thoughts and counterarguments than did basal heart rate; resistance to persuasion was related significantly to the number of counterarguments generated. The methodology used provides a means by which social psychologists can study the effects on social processes of actual but unperceived changes in physiological processes.

Much of our social behavior is affected by the state of our physiological systems. The important work on this issue by social psychologists has been concerned with the effects on cognition and behavior of *perceived* changes in the functioning of the autonomic nervous system (ANS; e.g., Detweiler & Zanna, 1976; Schachter, 1964; Valins, 1966). However, little has been done with respect to the effects of *actual* but *unperceived* changes in ANS functioning. Methodological rather than theoretical problems seem responsible for this empirical deficit (cf. J. Lacey, 1967; J. Lacey & B. Lacey, 1974). Recently, a technique has been found (Cacioppo, 1977) that may alleviate the latter shortcoming. The purpose of this article is to describe this procedure as well as to demonstrate that heart rate influences cognitive elaboration. This will be done in two ways: (a) by showing that performance on an intellectual task requiring cognitive elaboration is enhanced by increased heart rate (Experiment 1) and (b) by showing that when resistance to persuasion depends on cognitive elaboration, greater resistance (counterarguing) occurs with high heart rates (Experiment 2).

## Cardiac Activity and Information Processing

Angell and Thompson (1899) were perhaps the first to conclude that performing complex cognitive tasks led to an accelerated heart rate. Somewhat later, Darrow (1929a) dis-

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tinguished between stimuli that led to "excitation of sensory end organs causing immediate physiological effects but calling for no extensive association of ideas" from those that led to "excitation in which the stimulation of sensory end organs is but incidental to the initiation of associative processes" (p. 185). He concluded from a review of the literature that (a) momentary sensory stimulation was accompanied generally by a decelerated heart rate and (b) "ideational stimuli" were associated with an accelerated heart rate. This review and an experimental study by Darrow (1929b) were followed by a lull of almost three decades in this area of research (J. Lacey, 1959; J. Lacey & B. Lacey, 1958).

Contemporary investigations of cardiovascular psychophysiology have included (a) monitoring heart rate during the anticipation and performance of a wide variety of cognitive (e.g., sentence generation) and sensory (e.g., viewing flashing lights) tasks (see J. Lacey, 1959; J. Lacey, Kagan, B. Lacey, & Moss, 1963; Obrist, 1963); (b) the measurement of the differences in heart rate change during performance by individuals who differ dispositionally in their mode of processing task information (e.g., Blatt, 1961; Kagan & Rosman, 1964); (c) the manipulation of attributes of the task while monitoring heart rate (e.g., Cacioppo & Sandman, 1978; Campos & Johnson, 1967; B. Lacey & J. Lacey, 1974; Tursky, Schwartz, & Crider, 1970); (d) monitoring heart rate *and* somatic activity during the anticipation and performance of tasks, often under varying levels of motivation (e.g., Elliott, 1974; Obrist et al., 1974); and (e) monitoring sensory thresholds, reaction time, or cognitive and attitudinal responses following endogenous changes in heart rate (e.g., Cacioppo, Sandman, & Walker, 1978; Sandman, McCanne, Kaiser, & Diamond, 1977; Surwillo, 1971).

### *Methodological Considerations*

Although heart rate has been found generally to covary with the cognitive complexity, or difficulty, of a task (e.g., Cacioppo, 1977), the biological basis of this association has been and continues to be debated. The Laceys (J. Lacey, 1967; J. Lacey & B. Lacey, 1958) have formulated a neurophysiological account of the variations of heart rate observed during these tasks. They have speculated that, ceteris paribus, an accelerated heart rate is associated with and facilitates cognitive elaboration, whereas a decelerated heart rate is associated with and facilitates sensory reception. Obrist and his colleagues (Obrist, Gaebelein, Shanks, Langer, & Botticelli, 1976; Obrist, Webb, Sutterer, & Howard, 1970), however, have contended that the observed changes in heart rate are accompanied by changes in somatic activity, both of which are mediated by a common central nervous system (CNS) integrating mechanism. Unfortunately, most of the research with humans on which these writers base their arguments is correlational rather than experimental.

Several design strategies might be adopted to provide information about the effects of changes in heart rate on information processing. For instance, heart rate might be varied exogenously without the individual's knowledge, to determine if changes in heart rate are sufficient for altering information processing; [1] or physiological activity except for heart rate could be varied systematically to determine if changes in heart rate are necessary for altering information processing.

The first strategy was adopted in the present research. In Experiment 1, cardiac-pacing techniques were employed to accelerate heart rate during the performance of two cognitive tasks (reading comprehension and sentence generation). These procedures involve only minimal risks; nevertheless, the research was conducted in a clinical setting under the supervision of a cardiologist. Unfortunately,

[1] Exogenous manipulations of heart rate are more appropriate for investigating causal relationships between changes in heart rate and cognitive/sensory behavior because (a) exogenous manipulations of heart rate can be accomplished without the subject knowing when and in what direction heart rate was varied, thus circumventing the confounding effects of the subject's knowledge or belief of heart rate changes (cf. Valins, 1966); and (b) if behavioral effects are observed to result from an exogenous change in heart rate, then causal direction of the observed association is established.

this setting contained no resources for the measurement of any physiological process besides heart rate, but previous research has demonstrated that paced changes in heart rate (within the range of rates employed in the present research—i.e., 72–88 beats per minute) are unaccompanied by significant changes in normal visceral, somatic, or cardiac-output responses (e.g., Gill, Jakobi, Morton, & Wechsler, 1975; Karlof, Bevegard, & Ovenfors, 1973).

The selection of heart rates for investigation and the length of the experimental sessions in this research also were restricted. The pacemaker worn by each subject had been implanted for at least 3 months and was necessary to maintain heart rate in most instances at 72 beats per minute (bpm).[2] Except for surgical procedures, paced heart rate could be changed only by the use of a magnet, which, when placed properly, immediately accelerated and maintained heart rate at 88 bpm. Thus, although it would have been desirable, the effects of a decelerated heart rate on performance could not be studied in this research. And time limitations restricted the type and number of tasks on which observations could be made.

Complex cognitive tasks were chosen for the present study because of the theory and research that suggest that an accelerated heart rate should facilitate performance on these tasks (e.g., J. Lacey, 1967; J. Lacey et al., 1963). The sentence generation task has been used in previous research and was found to be associated with an accelerated heart rate (J. Lacey et al., 1963). A task similar to reading comprehension was employed by Spence, Lugo, and Youdin (1972): Subjects were instructed to attend to, and were later asked to recall, sentences reflecting a certain theme while they listened to a 17-minute passage from a clinical interview. Spence et al. found that subjects displayed a decelerated heart rate (presumably denoting sensory intake) followed by an accelerated heart rate (presumably denoting cognitive elaboration or encoding) during the presentation of thematic sentences that were subsequently recalled. This waveform was distinct from those displayed in the absence of thematic sentences and in the presence of unrecalled thematic sentences. Since the present procedure allowed the subject to take as long as he or she wished to read the passages (hence, allowing subjects to control sensory intake by their allocation of reading time to items), we expected that an accelerated heart rate would facilitate the cognitive elaboration, or encoding, of the stimuli and thereby improve reading comprehension.

## Experiment 1

### *Method*

*Subjects.* Eighteen healthy and articulate outpatients at a large midwestern university hospital volunteered to participate in the experiment. Each subject had worn a permanently implanted demand-type cardiac pacemaker for at least 3 months prior to participation in the experiment. All subjects were examined by a cardiologist and, immediately afterwards, were given a pretest by the experimenter. Four subjects were not included in analyses: (a) One could not read; (b) one was extremely nervous and refused to follow instructions once the experiment had begun; (c) one was reading a. passage when her daughter entered the testing room and began speaking with her; and (d) one was replaced because the placement of the magnet to increase heart rate could not be determined by the experimenter. The remaining 14 subjects completed the pretest satisfactorily: Each displayed (a) a basal heart rate of 72 bpm when a capped magnet was placed over a reed of the pacemaker, (b) an accelerated heart rate of 88 bpm when an uncapped magnet was placed over a reed of the pacemaker, and (c) an inability to identify the intervals during which heart rate was accelerated (as determined by questions asked of the subject during the pretest).

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[2] Cardiac Pacemakers, Inc. (CPI) was the manufacturer of the pacemakers. The demand-type pacemaker is characterized by its pacing of a person's heart rate at a constant rate when natural pacing produces a rate below the preset level of the cardiac pacemaker. To our knowledge, this is the only pacemaker that provides a nonsurgical means of altering heart rate simply, exogenously, and without the subject's awareness. The preset level of the CPI pacemakers used in the present study was 72 bpm. The subjects employed in Experiments 1 and 2 required cardiac pacing when seated to attain a heart rate of 72 bpm.

Importantly, subjects in the present experiments were unable to report accurately when and how frequently their pacemaker was pulsing their heart. This finding is consistent with that of Nowlin, Eisdorfer, Whalen, and Troyer (1971); they reported subjects were unaware of paced changes in heart rate that exceeded 110 bpm.

Subjects were told to discontinue their participation at any time they wished. Four subjects left after their completion of the first series of tests (i.e., the reading comprehension test); reasons for leaving included feeling fatigued, feeling nervous, and being late for another appointment.

*Materials and apparatus.* Two types of cognitive tests were administered. The instructions, example passage and questions, and four test passages and questions were selected from a college-level reading comprehension test for use in the first portion of the experiment. In the second portion of the experiment, a sentence generation task was employed. The task involved spending 90 sec generating sentences that (a) consisted of exactly five words, (b) made sense, (c) had good grammatical structure, (d) consisted of at least three words not contained in a previous sentence, and (e) began with the same letter. (The letter for the practice trial was *O*; the first test-trial letter was *E*; and the letter used for the second test trial was *A*.) An Apollo stopwatch was used to time subjects during the tasks, and a CPI horseshoe magnet was used to manipulate heart rate.

*Design.* A 2 × 2 factorial design was used. Heart rate (basal vs. accelerated) served as a within-subjects factor, and the order in which heart rate was varied served as a between-subjects factor. The tasks were administered in the same sequence to all subjects. However, half of the subjects (a) read the first and third passages of the reading comprehension test and (b) performed the first test trial of the sentence generation task with a basal heart rate of 72 bpm; these subjects (c) read the second and fourth passages of the reading comprehension test and (d) performed the second test trial of the sentence generation task with an accelerated heart rate of 88 bpm. The heart rate of the remaining subjects was varied in the opposite sequence during the tasks. Subjects were assigned randomly to the order condition. (Passages served as an additional within-subjects factor for the analyses of the reading comprehension measures.)

*Procedure.* Subjects were tested individually while sitting calmly at a table in a quiet room. The experimental tasks were described, and an example passage and questions for the reading comprehension test were administered. Once subjects understood what they were to do and were relaxed with the procedure, the reading comprehension test was administered.

Either a capped (basal heart rate) or uncapped (accelerated heart rate) magnet was placed over a reed of the subject's pacemaker while he or she read each practice and test passage.[3] Immediately following the subject's response that he or she had completed reading the passage, the magnet was removed, the next page of the booklet was presented, and the subject answered the multiple-choice questions about the passage just read. Subjects were allowed to take as long as they wished to read each passage and answer the subsequent questions, but subjects were not allowed to return to a passage once they had reported having read it. Four passages and multiple-choice tests constituted the reading comprehension test.

Next, the nature of and instructions for the sentence generation task were explained. Subjects practiced the procedure until the requirements of the task were understood. Each subject's heart rate was monitored, and either a capped or uncapped magnet was placed over the pacemaker during the 90 sec in which sentences were generated. At the onset of the trial, the experimenter announced the letter with which each sentence was to begin, and during the trial, subjects listed the sentences on ruled paper as they generated them.

*Dependent variables.* The percentage of the questions for each passage that was answered correctly served as the measure of reading comprehension; the time that was spent reading each passage was also recorded and analyzed.

The dependent measure of the sentence generation task was calculated in the following manner: (a) Each sentence that was generated in accordance with all of the instructions listed was assigned a value of 1.0; (b) sentences with errors were assigned a value of $(1.0 - .2X)$, where $X$ denoted the number of errors (0 was the least a sentence could be assigned).[4] The total points accumulated served as the measure of cognitive performance.

## *Results and Discussion*

Fourteen subjects completed the reading comprehension task, and 10 of the 14 subjects completed the sentence generation task. A multivariate analysis of variance was conducted for the cognitive performance of the 10 subjects who completed the experiment; the dependent measures were the percentage of correct answers in the reading comprehension test and the number of points accumulated in the sentence generation task. The analyses indicated that accelerated heart rate facilitated performance, $F(3, 6) = 5.63$, $p < .05$.

Univariate analyses of variance revealed

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[3] Since pacemakers are sometimes implanted in other than the upright position, location of the reed was determined by monitoring heart rate while placing the magnet on the skin over the upper and lower portions of the implanted pacemaker. When placement of the magnet resulted in an accelerated heart rate of 88 bpm, the placement was marked with a felt pen. Heart rate was also monitored during the pretest and test intervals. In all instances, heart rate did not vary from the paced levels.

[4] The person who scored the sentences was blind to the experimental conditions to which the subject had been assigned.

that (a) reading comprehension was better during accelerated heart rate ($M = 48.68\%$) than during basal heart rate ($M = 39.33\%$), $F(1, 12) = 5.24$, $p < .025$, one-tailed comparison; (b) performance of the sentence task was improved marginally by accelerated heart rate ($M = 3.88$) compared to basal heart rate ($M = 3.27$), $F(1, 8) = 2.87$, $p < .08$, one-tailed comparison; and (c) reading time was not affected by heart rate or order ($F$s $< 1$).

A significant Heart Rate × Order interaction, $F(1, 12) = 51.68$, $p < .01$, for reading time signified that the second and fourth passages of the reading comprehension test ($M = 78.1$ sec) took longer to read, on the average, than did the first and third passages ($M = 45.4$ sec). Since this interaction was not significant for the percentage of correct answers on the reading comprehension test ($F < 1$), these results indicate that reading time did not affect the role of heart rate on cognitive performance in the present study.

Together, these results indicate that heart rate accelerated peripherally is sufficient to facilitate performance of a difficult cognitive task when the change in heart rate is brief (e.g., 30–90 sec) and ongoing physiological activity reflects a normal state.[5]

## Experiment 2

Previously, multiple sessions of discriminative operant training have been employed to modify heart rate while subjects maintained a relatively constant level of somatic and respiratory activity (Cacioppo et al., 1978). The results revealed that individuals generated more counterarguments and were more resistant to persuasion when heart rate was accelerated than when it was decelerated. It appeared that brief accelerations of heart rate when unaccompanied by large increases in somatic activity produced resistance to persuasion by stimulating the cognitive elaboration of and responding to the counterattitudinal communication. Thus, it was expected that the brief increase in heart rate produced by using cardiac-pacing techniques would facilitate thought production (e.g., counterargumentation) and, ultimately, resistance to persuasion. The purpose of Experiment 2 was to provide a direct test of this hypothesis.

### Method

*Subjects.* Twenty-four healthy and articulate outpatients at a large midwestern university hospital volunteered to participate in the experiment. Experiment 2 was conducted in the same setting and in a similar manner to Experiment 1. As before, subjects were examined first by their cardiologist and by an experimenter who was unaware of the experimental hypotheses. Each subject displayed (a) a basal heart rate of 72 bpm when a capped magnet was placed over a reed of the pacemaker, (b) an accelerated heart rate of 88 bpm when an uncapped magnet was placed over the reed of the pacemaker, and (c) an unawareness of the intervals in which heart rate was manipulated. Two subjects were deleted from analyses because the experimenter failed to follow the experimental procedure correctly.

*Materials and apparatus.* Subjects were given the first half of the reading comprehension test employed in Experiment 1 during a preliminary examination and instruction period. These stimuli constituted the materials used in the preliminary task. Materials for the experimental task were developed in pilot testing with four elderly subjects; communications were developed that were highly involving and counterattitudinal. The advocacies selected were that (a) all Social Security and Medicare programs be eliminated and (b) the drinking and voting age in Ohio be lowered to 13 years of age.

CPI horseshoe magnet again was used to close the reed in the pacemaker and thus raise heart rate, and an Apollo stopwatch was used to time reading intervals.

*Design.* A 2 × 2 factorial design was used. Heart rate (basal vs. accelerated) served as the within-subjects factor, and the order in which heart rate was varied (basal–accelerated vs. accelerated–basal)

[5] To assess if it was necessary to vary heart rate within a constant pattern of peripheral nervous system activity to affect cognitive performance, a portion of the experiment was replicated using college undergraduates who had no pacemakers. They either stood or lay down while performing a reading comprehension task; these postural variations caused not only heart rate to differ but also respiration, muscle tension, and blood pressure. In this situation neither reading time nor reading comprehension was affected by the heart rate of the subject during the performance of the task. One should be cautious in comparing these results with the previous experimental results because of the noncomparability of the subject samples. Nevertheless, these studies together suggest that increased heart rate facilitates cognitive performance, particularly if the increase is relatively independent of major changes in physiological activity.

served as the between-subjects factor. Again, the stimuli were presented to all subjects in the same sequence.

*Procedure.* The procedure was similar to that used in Experiment 1 except that subjects engaged in a longer preliminary task to all adaptation to the experimental procedures prior to the administration of the experimental task. Subjects were tested individually while sitting at a table in a quiet room. Subjects were told that they would first read two passages and answer questions about the content of each passage; afterwards, they would hear two advocacies, and their opinions about each would be solicited.

The preliminary task was then begun. Two passages of the reading comprehension test were administered. During the performance of the preliminary task, (a) heart rate while a capped and uncapped magnet was placed over a reed of the pacemaker was again determined; (b) task requirements were clarified; and (c) all subjects were assured that the changes in their heart rate were not hazardous to their health. (Greater precautions were taken in the present experiment than in Experiment 1 because of the involving nature of the experimental task.)

Subjects then performed the experimental task. Subjects were informed that two proposals pertinent to them were under consideration and that messages had been prepared to explain the proposals. Subjects read each advocacy at their own speed. After reading each, subjects were given 2.5 min. to list everything about which they had thought while reading (thoughts were reported aloud by speaking into a tape recorder) and were asked to rate their agreement with the advocacy.[6]

*Dependent variables.* The tape-recorded listings of thoughts were transcribed by a judge who was unaware of the experimental hypotheses. Transcribed as a "cognitive response" was any phrase or sentence expressing a single thought or idea; although grammar was not a criterion, a subject's pauses and voice inflections were used in a few instances to determine whether a phrase or a group of phrases was a single thought or idea. The total number of thoughts and ideas listed served as a measure of the amount of cognitive responding.

A second judge, unaware of the experimental conditions to which a subject was assigned, scored the transcribed cognitive responses. Each response was scored as favorable, unfavorable (i.e., counterargument), or neutral/irrelevant toward the advocacy.[7] A third judge, who also was unaware of the experimental conditions to which subjects were assigned, spot-checked the scoring of cognitive responses. The second and third judges agreed completely on the scoring of the responses. (This was due largely to the uniform nature of the responses generated—see discussion below).

The subjects were asked, "How much do you agree with the proposal that you just read about?" after listing their responses to each advocacy. Subjects responded to the question using a 15-point scale in which 1 was labeled "disagree completely" and 15 was labeled "agree completely."

Although there were procedural differences among the subjects during the preliminary task of this experiment, the percentage of questions answered correctly and the reading time were also monitored and analyzed.

## *Results*

Twenty-two subjects completed the preliminary and experimental tasks. Multivariate analyses of variance were performed for the set of eight dependent measures; heart rate and order served as the criteria. The analyses revealed that heart rate affected cognitive and affective response, $F(8, 13) = 3.17$, $p < .05$. Univariate analyses of variance were then performed. The means are summarized in Table 1.

*Preliminary task.* Neither heart rate nor order affected reading comprehension or reading time during the preliminary task. Heart Rate × Order interactions were found for both reading comprehension, $F(1, 20) = 7.39$, $p < .05$, and reading time, $F(1, 20) = 11.65$, $p < .01$. These effects denoted only that the first passage was read more quickly and comprehended less completely than the second passage (see Table 1). This result is due possibly to the subjects' apprehension

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[6] Subjects were asked to verbally report everything about which they thought during their reading of the advocacy, because pilot testing indicated subjects had noticeable difficulty in writing. This difficulty was also noted during Experiment 1, and may possibly account for the attenuated effects of heart rate on the performance of the sentence generation task observed in Experiment 1.

[7] The procedures employed for scoring were adapted from Petty and Cacioppo (1977) and Cacioppo and Petty (1979). Statements directed against the advocated position that mentioned specific unfavorable consequences, statements of alternative methods, challenges to the validity of arguments in the message, and statements of affect opposing the advocated position were counted as counterarguments. Statements in favor of the advocated position that mentioned specific favorable consequences, statements eliminating alternatives, statements that supported the validity of the message, and statements of positive affect regarding the advocacy we scored as favorable thoughts. All other statements were classified as neutral/irrelevant thoughts.

Table 1
*Summary of Cognitive Measures for Preliminary and Experimental Tasks, Experiment 2*

| | Heart rate | | | |
|---|---|---|---|---|
| | Basal (72 beats per minute) | | Accelerated (88 beats per minute) | |
| Measure | Order 1 (Message 2) | Order 2 (Message 1) | Order 1 (Message 1) | Order 2 (Message 2) |
| Preliminary task | | | | |
| Reading comprehension | 41.73 | 26.36 | 19.73 | 38.91 |
| Reading time | 96.73 | 47.54 | 47.36 | 92.91 |
| Experimental task | | | | |
| Total thoughts | 3.82 | 3.00 | 4.82 | 3.55 |
| Counterarguments | 3.73 | 2.91 | 4.73 | 3.27 |
| Favorable thoughts | .09 | 0 | 0 | 0 |
| Neutral/irrelevant thoughts | 0 | .09 | .09 | .27 |
| Attitude | 1.67 | 3.82 | 1.91 | 3.36 |
| Reading time | 145.00 | 121.64 | 134.82 | 138.64 |

*Note.* Entries for reading comprehension are in terms of percentage of correct answers, whereas entries for reading time are in seconds. Higher means on the attitude measure indicate more agreement with the speaker's position, where 1 indicates "disagree completely" and 15 indicates "agree completely." Remaining entries designate the mean frequency observed for each type of cognitive response measured.

about the experiment and confusion about what they were to do when they started.

*Experimental task.* It was hypothesized that an accelerated heart rate would facilitate cognitive responding. The analyses supported the hypothesis: More total thoughts, $F(1, 20) = 20.64$, $p < .001$, and counterarguments, $F(1, 20) = 12.36$, $p < .01$, were produced when heart rate was accelerated than when it was not accelerated (see Table 1).

It was also hypothesized that heart rate would affect resistance to persuasion. The analysis of variance provided no support for this hypothesis: No treatment or interaction of treatments affected subjects' rating of agreement with the advocacies. However, an inspection of the raw data revealed that *59%* of the subjects' responses to the attitude measure were 1 ("disagree completely"); thus, the attitude measure was probably insensitive to treatment effects. In other words, subjects were able to counterargue and reject completely the advocacies, whether their heart rate was accelerated (thus, facilitating cognitive responding) or not accelerated. Accordingly, a total of one favorable thought and five neutral/irrelevant thoughts were generated during the entire experiment. Within-cell correlations between the cognitive response and attitude measures were calculated and indicated that agreement with the advocacy was related (a) negatively with the number of counterarguments generated ($r = -.46$, $p < .05$); (b) positively with the number of neutral/irrelevant thoughts generated ($r = .42$, $p < .05$); and (c) negatively with the number of total thoughts generated ($r = -.44$, $p < .05$). Counterargumentation and total thoughts were correlated positively and highly ($r = .99$, $p < .001$), denoting that most of the thoughts generated were unfavorable toward the advocacies (see Table 1). Finally, counterargumentation and the number of neutral/irrelevant thoughts were related negatively ($r = -.35$, $p < .05$).

The positive association between the number of neutral/irrelevant thoughts generated and susceptibility to persuasion was unexpected. The production of neutral/irrelevant thoughts may indicate that a person was momentarily or partially distracted from responding cognitively to the advocacy while reading. Previous research has demonstrated that distraction during the presentation of a counterattitudinal communication increases susceptibility to persuasion by inhibiting the production of counterarguments (cf. Petty, Wells, & Brock, 1976). Thus, the generation of neutral/irrelevant thoughts during the reading of the counterattitudinal communications may have inhibited the production of counterarguments and, consequently, increased the subject's susceptibility to persuasion. As would be expected if this were true, counterargumentation and production of neutral/irrelevant thoughts were related negatively.

## General Discussion

Two experiments were conducted in which heart rate was accelerated peripherally by altering the signals transmitted by implanted pacemakers. In Experiment 1, subjects performed cognitive tasks while their heart rate was either accelerated or not, unbeknownst to them. Cognitive performance was best when heart rate was accelerated. In Experiment 2, subjects read a highly involving counterattitudinal communication while their heart rate was either accelerated or not. Accelerated heart rate led to the generation of more counterarguments and total thoughts during the reading of these communications than did basal heart rate. Moreover, resistance to persuasion was related significantly to the number of counterarguments generated.

### *A Biosocial Model of Attitude Change*

The Laceys (J. Lacey, 1967; J. Lacey & B. Lacey, 1958) proposed that an accelerated heart rate facilitates extensive processing (or cognitive elaboration). And, within the area of attitudes, evidence supports the view that the idiosyncratic cognitive responses elicited by a communication are an important determinant of the direction and amount of attitude change (cf. Petty, Ostrom, & Brock, in press). Thus, changes in heart rate may affect information processing and *thereby* alter the attitudinal or emotional response to a stimulus, even though recent evidence casts doubt on a *direct* link between affective and heart rate responses (Cacioppo & Sandman, 1978; Harris, Katkin, Lick, & Habberfield, 1976).[8] Although the present data are in accord with this formulation, the limits of the formulation should be noted also. First, changes in heart rate should have the predicted effects only in certain (describable) instances. Second, the model is mute about the effects of individual differences in basal heart rate. And third, the specific physiological mechanism involved cannot as yet be identified with great confidence. These limits are discussed next.

The Laceys (1974) and others have argued that changes in heart rate may affect behavior (e.g., cognitive performance) directly *in some instances*. In other words, there are physiological conditions that may negate the psychological effects of heart rate changes (J. Lacey & B. Lacey, 1974; Obrist et al., 1970). The results of the performance during the preliminary task of Experiment 2 demonstrate that even when the physiological conditions are relatively quiescent and heart rate is varied, the effects of heart rate are easily obscured. Indeed, even when instructions were understood completely and distractions and interruptions were minimal (i.e., during the experimental task), increasing heart rate by 16 bpm resulted in the production of only an average of .78 more total thoughts per person. Hence, the more impressive aspect of accelerated heart rate is the consistency rather than the size of its effects: An accelerated heart rate facilitated the production of total thoughts in 13 of 16 subjects and had no effect on the thought production of 6 subjects. (This effect is highly significant by a sign test.)

These heart rate changes may better be conceived as altering temporarily a subarousal process rather than as altering the general arousal of the organism for the following reasons: (a) Differences in general and diffuse physiological arousal were not evident. Heart rate was accelerated exogenously, for only about a minute, independent of any visually observable changes in motor activity or respiration, and without the subject's awareness. (b) In research in which

[8] This synthesis compliments rather than contradicts present theories in social psychology (e.g., Schachter, 1964). Whereas previous research and theory have addressed the effects of *perceived* changes in ANS functioning (whether they are real or not), the present discussion refers to *actual* but *unperceived* changes in ANS functioning.

two or more physiological responses to a cognitive or sensory stimulus were recorded, low and nonsignificant correlations between these responses were often found; indeed, the responses sometimes differed in direction as well as in intensity (e.g., Blaylock, 1972). Results such as these pose problems for the concept of "arousal." And (c) the *effort* expended during the performance of a task is correlated positively with heart rate when performance requires cognitive elaboration (Kaiser & Sandman, 1975; Tursky et al., 1970), but is correlated negatively with heart rate when performance requires primarily sensory reception (Coles & Duncan-Johnson, 1975, 1977). Hence, the results of this research are explained most parsimoniously by the Laceys' analysis of subarousal processes (J. Lacey, 1967) and the formulations regarding the cognitive and behavioral effects of specific changes in heart rate (Cacioppo et al., 1978; Coles & Duncan-Johnson, 1977; J. Lacey & B. Lacey, 1970).

Finally, the Laceys (cf. J. Lacey, 1967; J. Lacey & B. Lacey, 1974) hypothesized that a negative feedback system between the baroreceptors (pressure-sensitive stretch receptors) of the aortic arch and carotid sinus and the reticular formation of the brain influences behavior. The present experimental findings are in accord with the Laceys' neurophysiological formulations. But the results cannot be considered as providing definitive evidence for the negative feedback hypothesis until actual measurements of heart rate, blood pressure, baroreceptor firing, reticular arousal, and cortical activity are obtained during intervals of sensory intake, cognitive elaboration, and baseline activity. It would be difficult to explain these data in terms of a motor effect mediated by a common CNS integrating mechanism because of the *exogenous* manipulation of heart rate. Nevertheless, these results do not necessarily constitute a disconfirmation of Obrist's (e.g., Obrist et al., 1970) position, because neither somatic activity nor oxygen consumption was monitored. In any event, the procedures employed in this study provide a means of clarifying these issues and of studying further the effects of unperceived ANS changes on attitude change and other variables of interest to social psychologists.

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