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Dissociating beliefs about heart rates and actual heart rates in patients with cardiac pacemakers

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Abstract

Performance on heartbeat counting tasks is usually interpreted in terms of cardiac sensitivity. We tested the hypothesis that heartbeat counting is influenced by beliefs about heart rates by dissociating beliefs about heart rates and actual heart rates. In a within-subjects design, heart rates of 50 patients with cardiac pacemakers were set to a low (50 bpm), medium (75 bpm), or high (110 bpm) pacing rate unknown to the patients via remote control while they performed a heartbeat tracking task. Results showed that patients' heartbeat counting did not follow the shifts in their actual heart rates adequately, although their overall performance was comparable to that of young and healthy control participants. As a result, tracking scores decreased significantly in the high pacing rate condition where beliefs about heart rates and actual heart rates were most extremely dissociated. The findings suggest that tracking scores reflect beliefs about heart rates rather than cardiac sensitivity.

Descriptors: Cardioception, Heartbeat perception, Interoception, Methodology, Cardiac pacemakers

Several methods for assessing heartbeat perception have been developed in psychophysiological research (see Jones, 1994; Reed, Harver, & Katkin, 1990, for thorough reviews; for empirical evaluations see Brener, Liu, & Ring, 1993; Eichler & Katkin, 1994, Knoll & Hodapp, 1992; Ring & Brener, 1996; Schneider, Ring, & Katkin, 1998; Störmer, Heiligtag, & Knoll, 1989). The most economic and most practical method is the heartbeat counting or tracking task introduced by Schandry (1981). In this procedure, participants are asked to count their heartbeats during defined time intervals of usually less than 1 min. Performance scores are then computed based on the deviation between the number of actual heartbeats and the number of counted heartbeats. Because of its straightforwardness and practicability, the task can be applied easily in a wide range of research settings, including ambulatory and clinical contexts (e.g. Ehlers, Breuer, Dohn, & Fiegenbaum, 1995).

Some recent methodological studies, however, suggested that heartbeat counting in the tracking task might be based on beliefs about (or estimates of) heart rates rather than on cardiac sensitivity (Brener & Knapp, 1995; Phillips & Jones, 1997; Ring & Brener, 1996). Counting heartbeats the way the heart is believed to be beating rather than the way it is *felt* to be beating can normally lead to high performance scores because beliefs about heart rates can be based on a variety of internal and external cues of physiological arousal indicating actual cardiac activation. Thus, actual heart rates and beliefs about heart rates have to be dissociated experimentally without participants' knowledge (Ring & Brener, 1996, p. 542) to examine the question of whether tracking performance depends on accuracy of beliefs about heart rates rather than on cardiac awareness.

In the present experiment, we dissociated actual heart rates and beliefs about heart rates by manipulating actual heart rates in patients with cardiac pacemakers without providing them any information about this manipulation. The pacemaker was set to rates of 50 bpm (low pacing rate condition), 75 bpm (medium pacing rate condition), and 110 bpm (high pacing rate condition) via remote control while participants were supine and performed a mental tracking task of the Schandry (1981) type. Thus, we induced drastic heart rate changes while leaving beliefs about heart rates unaffected.

If patients based their heartbeat counting on constant beliefs about heart rates rather than on cardiac sensations, their counted heart rates should not follow the shifts in their actual heart rates adequately. Rather, the difference between actual and counted heart rates should change significantly in line with the pacing rate manipulations. Furthermore, tracking scores should be affected significantly by the experimental dissociation of beliefs about heart rates and actual heart rates. We also compared tracking performance of patients with cardiac pacemakers with a group of healthy, young controls to discount the possibility that patients' overall level of cardiac awareness was significantly impaired.

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Method

Participants

Fifty patients with cardiac pacemakers (26 women, mean age 71.3 years, *SD* = 17.3; 24 men, mean age 69.2 years, *SD* = 12.5) participated in the study. Patients with diabetes were excluded from the sample. Data from one male patient (aged 85 years) had to be eliminated for the low pacing rate condition because he had not completely understood the instructions at that time.

Twenty-one healthy subjects (11 women, mean age 33.17 years, *SD* = 9.92; and 9 men, mean age 26.56 years, *SD* = 7.73) participated as controls. They were recruited via local media announcements and were paid DM 30 for participation. All indicated that they were currently not under medical treatment, were not taking medication, and had no medical or psychiatric disease. Data of one male subject had to be eliminated for one trial because he had not understood the instructions correctly.

Apparatus

In the patient group, the electrocardiogram was recorded from the limbs using a six lead electrocardiogram recorder (Siemens Cardirex 62), and lead II was displayed on a single channel monitoring device (Siemens Ergoscop 841). The programmer of the pacemaker corresponded to the brand of the unit implanted (Medtronic 9790, Intermedics Rx 2000, Biotronik EPR 1000, Pacesetter APS II).

Electrocardiogram in the control group was recorded using Ag-AgCl electrodes placed on the thorax. The signal was displayed on a computer screen while R-waves per trial were detected and counted online using laboratory equipment from MedNatic (Munich, Germany) and the software package B-Scope developed by Erhard Bablok (Regensburg, Germany).

Procedures

Patients with cardiac pacemakers were asked to participate in a psychophysiological study involving a heartbeat counting task during a routine follow up examination of the pacemaker functions by the cardiologist. Because manipulation of the pacing rate is usually included in these routine medical examinations, participation in the experiment did not involve any additional medical risk or physical load. After giving their consent, patients performed two trials of 30-s duration each in every pacing rate condition (low: 50 bpm; medium: 75 bpm; and high: 110 bpm; presented in counterbalanced order) with an intertrial interval of about 3 min. The patients were instructed to “count your heartbeats silently without taking the pulse” as indicated by the verbal “go!” and “stop!” commands of the experimenter. The three pacing rates were set via remote control. To avoid abrupt heart rate changes, programming steps did not exceed 10–15 heartbeats per minute, so that it took two or three adjustments until pacing rates reached the predefined values. Actual heart rates were registered offline from the electrocardiograph. The rates deviated slightly from the programmed pacing rates in the three conditions and also displayed some variance. This variation was due to naturally occurring arrhythmic heartbeats that cannot be prevented by the pacemaker and that shorten the current interbeat interval. In addition, some patients had baseline heart rates above 60/min that could of course not be lowered by the pacemaker. For this reason, actual heart rates in the low pacing rate condition showed the most variance.

Control participants also gave informed consent prior to participation. They were given about 5 min rest before the experimental procedures were run. Apart from the heart rate manipulations, the procedures were identical to those described for the patient participants.

In both groups, numbers of counted heartbeats were recorded manually and were later transcribed for statistical analysis. All participants were supine during all procedures.

Data Analysis

We computed beats per minute for actual and for counted heartbeats. The ordinary tracking score was then computed as:

$$1 - [(|H_i - H_c|)/H_i]$$

with H_i indicating number of actual heartbeats per minute and H_c indicating number of counted heartbeats per minute. The scores were then averaged across the two trials.

We performed the following analyses. First, we compared tracking scores of controls with tracking scores of patients in the medium condition (which paralleled the control group in terms of actual heart rate best) using analysis of covariance (ANCOVA) with actual heart rate as covariate. Second, to analyze tracking performance in the patient group, we performed analyses of variance (ANOVAs) with repeated measures to compare actual heart rates, counted heart rates, differences between actual and counted heart rates, and tracking scores among pacing conditions (Huynh–Feldt epsilon corrections are reported for these comparisons). All analyses included sex as a between-subjects variable. Pearson correlation coefficients were used to determine retest reliability of the tracking scores and to examine the influence of age and body mass index (kg/m^2) on tracking scores. An α-error probability of .05 was adopted for all statistical tests.

Results

Comparison of Patient and Control Participants

The ANCOVA (with actual heart rate as covariate) did not show any significant difference between tracking scores of patients in the medium pacing rate condition and tracking scores of control participants, $F(1,65) = .04$, n.s., no significant effect for sex, $F(1,65) = .003$, n.s., and no significant Sex × Group interaction, $F(1,65) = 0.77$; see Table 1).

Tracking Performance in the Three Pacing Rate Conditions

The ANOVA of patients' actual heart rates showed a highly significant effect of the repeated measures factor, condition, $F(2,94) = 585.26$, $p < .0001$, $\epsilon = 0.74$, but no significant effect of sex and no significant Sex × Condition interaction. Post hoc tests indicated that actual heart rates in the low pacing rate condition were significantly lower than in the medium condition, $F(1,48) = 105.144$, $p < .001$, and actual heart rates in the medium pacing rate condition were significantly higher than in the high pacing rate condition, $F(1,48) = 1176.85$, $p < .0001$.

Counted heart rates differed significantly between conditions, $F(2,94) = 6.66$, $p < .005$, $\epsilon = 0.83$. There was also a significant interaction of Sex × Condition, $F(2,94) = 3.30$, $p = .041$, but no significant main effect of sex. Post hoc tests indicated that female patients did not count differentially in the three pacing rate conditions, $F(2,50) = 1.179$. In male patients, counted heart rates were enhanced in the high pacing rate condition compared with the other two conditions, $F(2,44) = 6.19$, $p < .03$, whereas the low and the medium conditions did not differ significantly, $F(1,22) = 1.91$.

Table 1. *Heartbeat Tracking Performance of Patients With Cardiac Pacemakers and Healthy Control Participants*

Condition/group	Actual heart rates (H_i)	Counted heart rates (H_c)	Difference ($H_i - H_c$)	Tracking score	Overestimations* ($H_i < H_c$)
Low pacing rate	61.14 (12.10)	51.59 (17.75)	9.55 (22.93)	.72 (.24)	18 (36%)
Female	62.19 (13.29)	50.31 (20.59)	11.88 (27.09)	.65 (.26)	7 (27%)
Male	59.96 (10.78)	53.04 (14.19)	6.91 (17.32)	.80 (.19)	11 (48%)
Medium pacing rate	76.02 (5.30)	54.14 (17.01)	21.88 (17.77)	.70 (.20)	5 (10%)
Female	76.88 (4.77)	53.00 (19.28)	23.88 (19.79)	.67 (.22)	3 (11%)
Male	75.04 (5.81)	55.43 (14.34)	19.61 (15.29)	.74 (.18)	2 (9%)
High pacing rate	108.94 (3.48)	59.02 (23.26)	49.92 (23.26)	.54 (.20)	2 (4%)
Female	108.00 (4.62)	53.31 (17.74)	54.69 (18.34)	.49 (.17)	0 (0%)
Male	110.00 (0.0)	65.48 (27.23)	44.52 (27.23)	.58 (.23)	2 (9%)
Control group	82.24 (11.86)	53.19 (18.03)	29.05 (22.96)	.66 (.25)	0 (0%)

*Overestimations refers to the number (proportion) of subjects who overestimated their heart rates.

Differences between actual heart rates and counted heart rates showed a highly significant effect for condition, $F(2,94) = 114.59$, $p < .0001$, $\epsilon = 0.89$. Post hoc analyses showed that the difference in the medium pacing rate condition was significantly higher than the difference in the low pacing rate condition, $F(1,48) = 30.00$, $p < .001$, and the difference in the high pacing rate condition was significantly higher than the difference in the medium pacing rate condition, $F(1,48) = 119.30$, $p < .0001$; see Table 1. The sex effect, $F(1,47) = 1.51$, and the Sex $\times$ Condition interaction, $F(2,94) = .70$ were not significant.

Tracking scores differed significantly for the three conditions, $F(2,94) = 19.96$, $p < .001$, $\epsilon = 0.82$. Post hoc analyses indicated that tracking scores in the high pacing rate condition were on average lower than in the medium, $F(1,48) = 47.80$, $p < .001$, and in the low condition, $F(1,48) = 22.53$, $p < .001$, but that there was no significant difference between the medium and the low conditions, $F(1,48) = 0.38$; see Table 1. The analysis also revealed a significant effect for sex, $F(1,47) = 4.81$, $p < .04$, indicating that male patients had higher tracking scores than female patients (see Table 1). The Sex $\times$ Condition interaction effect was not significant.

Correlation of Tracking Scores With Other Variables

Tracking scores of patients with cardiac pacemakers did not correlate significantly with age or with body mass index. All coefficients were below .15.

Tracking scores in the low pacing rate condition correlated significantly with tracking scores in the medium condition in female patients ($r = .451$, $p < .05$) and in male patients ($r = .554$, $p < .05$), but not with tracking scores in the high pacing rate condition, neither in female ($r = .11$, n.s.) nor in male patients ($r = .33$, n.s.).

Discussion

We manipulated actual heart rates in patients with cardiac pacemakers while they performed a mental heartbeat tracking task, with patients not knowing that their heart rates were being manipulated. Thus, the patients had no chance to infer their actual heart rate changes from any sources of information other than from their cardiac sensations. We investigated whether patients' heartbeat counting would reflect the shifts in their actual heart rates adequately.

Results showed that patients did not change their heartbeat counting to the same extent as their actual heart rates changed. Only male participants showed an increase in heartbeat counting in the high pacing rate condition, and this increase was weak when compared with the drastic variations in *actual* heart rates. Correspondingly, the difference between actual and counted heart rates showed a marked effect of the experimental manipulations without any significant sex effects. As this difference is the most direct measure for the degree of correspondence between actual heart rates and counted heart rates, we conclude that heartbeat counting of both male and female patients did not follow the shifts in actual heart rates adequately. The higher the pacemaker rate was set, the greater was the difference between actual and counted heartbeats.

Tracking scores were affected significantly by this failure of the patients to realize the magnitude of their actual heart rate variations. Tracking scores decreased considerably in the high pacing rate condition, in which actual heart rates and beliefs about heart rates were most extremely dissociated. This effect occurred because heartbeat counting remained relatively constant across conditions, especially in female patients, regardless of the enormous actual heart rate increase in the high pacing rate condition. Thus, it seems that patients followed their beliefs about heart rates rather than their cardiac sensitivity when they performed the task. Whereas this method worked relatively well in the low and the medium pacing rate condition, it failed in the high pacing rate condition. Thus, only the high pacing rate condition revealed that most patients were actually less good at heartbeat perception than tracking scores in the low and the medium condition suggested. Without considering the high pacing rate condition, patients' cardiac awareness would have been highly overestimated.

This interpretation is further supported by the finding that tracking scores in the low pacing rate condition did not correlate significantly with tracking scores in the high condition. As retest reliability is a prerequisite for the validity of a stable trait measure, this finding raises some doubts as to whether the tracking paradigm is appropriate for assessing interindividual differences in cardiac sensitivity. Irrespective of absolute performance level, interindividual differences have to be consistent to be interpretable in terms of a trait construct.

Besides arguments related to the high pacing rate condition, our data provide further evidence supporting the assumption that tracking scores can be misleading. In the low and the medium condition, tracking scores were practically identical (.72 and .70) despite highly significant differences in actual heart rates. Initially, this finding seems to suggest that heartbeat counting performance was perfectly consistent across these two conditions, i.e., counted heartbeats increased from the low to the medium condition the same way as actual heart rates increased. However, the analysis of the *differences* between actual and counted heart rates shows that this is not the case. The medium pacing rate condition had produced many *under*estimations of actual heart rates, as it is usually observed in the mental tracking paradigm (Brener & Knapp, 1995; Ring & Brener, 1996), whereas the low condition (where the pacemaker was set to an unusually low pacing rate) had produced relatively many *over*estimations of actual heart rates. Thus, patients did *not* actually count differently in these two conditions, but counted a relatively constant number of heartbeats despite the significant shifts in their actual heart rates. The fact that tracking scores do not differentiate between excessive and insufficient heartbeat counting (that is, false-positive and false-negative errors; see Reed et al., 1990, p. 275) made heartbeat counting in the low and the medium condition *appear* to be consistently related to the shifts in actual heart rates although in actuality the counting was not.

Finally, our results are unlikely to reflect a specific cardiac insensitivity in patients with cardiac pacemakers, because their tracking performance was comparable to that of young and healthy control participants. Thus, the findings provide consistent evidence in support of the hypothesis that tracking scores reflect accuracy of beliefs about (or estimates of) heart rates rather than accuracy of heartbeat perception (Jones, 1994, p. 67ff; Knoll & Hodapp, 1992; Phillips & Jones, 1997; Ring & Brener, 1996).

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