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# Effects of heartbeat feedback on beliefs about heart rate and heartbeat counting: A cautionary tale about interoceptive awareness

Christopher Ring[a,*], Jasper Brener[b], Kelley Knapp[c], Jennifer Mailloux[d]

[a] School of Sport, Exercise & Rehabilitation Sciences, University of Birmingham, UK
[b] Department of Psychology, S.U.N.Y. at Stony Brook, USA
[c] Department of Psychology, Florida State University, USA
[d] Department of Psychology, University of Mary Washington, USA

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ABSTRACT

Heartbeat counting improves after exposure to heartbeat feedback either because feedback trains individuals to detect heartbeats or updates their knowledge/beliefs about heart rate. These possibilities were examined by assessing heartbeat counting, in different postures and following exercise, before and after exposure to immediate and delayed heartbeat feedback. Immediate and delayed feedback provided accurate information about heart rate and, therefore, either could update beliefs about heart rate. However, only immediate feedback marked each ventricular contraction and, thereby, could train participants to detect the beating of the heart by focusing attention on relevant internal sensations. Exposure to immediate and delayed feedback resulted in similar, significant increases in the accuracy of heartbeat counting, indicating that the feedback effect was mediated by non-sensory processes rather than by training participants to detect heartbeat sensations. The current findings demonstrate that the heartbeat counting task is not a valid method to assess cardioception.



In the heartbeat counting task (Dale & Anderson, 1978; Schandry, 1981), a brief and simple method designed to measure sensitivity to heartbeat sensations, participants are required to count heartbeats for short periods. This method is increasingly being used in the neuroscientific literature to study the moderating role of conscious visceroception on the regulation of cortical and behavioral responses by visceral afferent feedback, a research endeavor underpinned by Damasio's (1994) somatic marker hypothesis (e.g., Ainley, Brass, & Tsakiris, 2014; Dunn et al., 2010; Park & Tallon-Baudry, 2014). It is also being used to study the role of cardioception in patient groups, based on the premise that awareness of bodily symptoms could impact on psychopathology (e.g., Dunn, Dalgleish, Ogilvie, & Lawrence, 2007; Terhaar, Viola, Bär, & Debener, 2012). In the heartbeat counting task, sensitivity to heartbeat sensations is indexed by a perception score based on the difference between the number of actual heartbeats and the number of counted heartbeats. It is assumed that the number of heartbeats counted is based on the detection of actual cardiac activity. In this case, a small difference between actual and counted heartbeats arises if participants accurately detect concurrent heartbeat sensations.

However, the number of heartbeats counted may be based on the rate at which participants believe their hearts to be beating, rather than on the real-time processing of heartbeat sensations. This may arise either because it takes less effort to count at that rate when heartbeat sensations are weak or because participants cannot feel the beating of their heart at all. Sources of beliefs or knowledge about heart rate (cf., Pennebaker & Epstein, 1983) include both formal and informal education as well as occasional or situational experiences of cardiac activity (Ring & Brener, 1996). Beliefs about heart rate may also include knowledge about the effects of various challenges, such as orthostatic, exercise and mental stress, on heart rate.

Pennebaker and Epstein (1983) found that the less individuals use physiological information to report a physical symptom, the more they rely on belief information. It follows that if individuals are unable to gather physiological information, which may arise when heartbeats are weak or undetectable, then the only information that they can rely on is belief information. In such cases, if the participant's beliefs about heart rate are accurate then a small difference between actual and counted heartbeats will also arise and give the false impression of accurate heartbeat detection. Thus,

* Corresponding author at: School of Sport, Exercise & Rehabilitation Sciences, University of Birmingham, Edgbaston, Birmingham B15 2TT, UK.
Tel.: +44 121 414 4115; fax: +44 121 414 4121.
*E-mail address:* c.m.ring@bham.ac.uk (C. Ring).

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in the heartbeat counting task, beliefs about heart rate (i.e., non-sensory processes) may generate spurious evidence of the ability to detect heartbeat sensations (i.e., a sensory process). This concern was highlighted by an ingenious study by Windmann, Schonecke, Frohlig, and Maldener (1999) which showed that remotely controlled increases and decreases in heart rate among individuals fitted with cardiac pacemakers were not associated with corresponding increases and decreases in the number of counted heartbeats reported. Paced heart rates averaging 61, 76 and 109 beats per minute were associated with counted heart rates of 52, 54 and 59 beats per minute, respectively. Therefore, evidence that beliefs about heart rate may determine accurate heartbeat counting performance challenges the validity of the heartbeat counting task as a measure of sensitivity to heartbeat sensations.

Indeed, evidence suggesting that beliefs about heart rate confound tests of sensitivity to heartbeat sensations that require participants to track their heartbeats has fueled the argument that such tests do not yield interpretable indices of sensitivity to heartbeat sensations (Flynn & Clemens, 1988; Katkin & Reed, 1988; Knoll & Hodapp, 1992; Pennebaker & Hoover, 1984; Pennebaker, 1981). Heartbeat tracking tests that are influenced by beliefs include those that require participants to tap on each heartbeat (e.g., Hamano, 1980; Kleinman, 1970; McFarland, 1975), to adjust the frequency of a metronome to match their heart rate (e.g., Carroll & Whellock, 1980; Gannon, 1980), and to count heartbeats (Phillips, Jones, Rieger, & Snell, 1999; Ring & Brener, 1996; Windmann et al., 1999). If heartbeat tracking performance (i.e., tapping, adjustment, or counting) is based on beliefs about heart rate (Pennebaker & Epstein, 1983; Pennebaker & Hoover, 1984), then manipulations that alter these beliefs would be expected to influence heart rate estimates acquired by tapping, adjustment, or counting. This possibility has been explored in the laboratory by examining the effects of providing information about heart rate, in the form of feedback, on heartbeat tracking performance.

Exposure to cardiac-contingent feedback has been shown to increase the accuracy of both heartbeat tapping rates (Weisz, Balazs, & Adam, 1988) and heartbeat counting rates (Ring & Brener, 1996) but not heart rate adjustment frequencies (Carroll & Whellock, 1980). That the accuracy of individuals' subjective heart rate estimates (e.g., counted heartbeats) improved after exposure to cardiac-contingent feedback indicates that the feedback either trained subjects to identify the internal sensations associated with the beating heart or modified their beliefs about heart rate. However, information about heart rate in the form of cardiac-noncontingent feedback (Valins, 1966,1967) has also been shown to increase the accuracy of heartbeat tapping rates (Ludwick-Rosenthal & Neufeld, 1985) and heartbeat counting (Phillips et al., 1999). Because cardiac-noncontingent feedback also improved the accuracy of heartbeat tracking, these results suggest that in this case feedback operated by updating participants' beliefs about heart rate. Since none of these experiments compared the effects of cardiac-contingent and cardiac-noncontingent feedback, the question remains as to whether feedback improves heartbeat counting accuracy by training individuals to detect heartbeat sensations or by modifying their beliefs about heart rate.

Cardiac-contingent feedback supplies accurate information about heart rate which could be used to update beliefs about heart rate. Furthermore, under conditions of cardiac-contingent feedback, the occurrence of each feedback stimulus is time-locked to a heartbeat. This feature could train participants to identify heartbeats by focusing their attention on physiological sensations at an appropriate time in the cardiac cycle. Cardiac-noncontingent feedback, on the other hand, may only supply accurate information about heart rate. In the present experiment, the cardiac-noncontingent feedback stimuli presented to each participant occurred at the same rate as that participant's heart rate but the feedback stimuli were delayed by approximately six heartbeats. Since the occurrence of cardiac-noncontingent feedback stimuli is not time-locked to concurrent cardiac activity, it cannot train participants to detect individual heartbeats. It can only be used to update beliefs about heart rate.

The present experiment sought to determine whether cardiac-contingent feedback has an effect on heartbeat counting performance that is distinguishable from the effect of cardiac-noncontingent feedback. It was reasoned that if cardiac-contingent feedback resulted in greater improvements in heartbeat counting accuracy than cardiac-noncontingent feedback then this differential effect could be attributed to improvements in the detection of actual cardiac activity produced by the cardiac-contingent feedback. However, if the cardiac-contingent and cardiac-noncontingent feedback conditions did not generate differential improvements in heartbeat counting, this would suggest that the effects of feedback were due to influences on beliefs or knowledge about heart rate.

Since previous experiments did not include a no-feedback control group (cf., Pennebaker, 1981), it is unclear whether the improvements in heartbeat counting accuracy attributed to feedback were actually the result of repeated performance of the heartbeat counting task; in other words, a practice effect. To test this possibility in the present experiment, a group of participants was submitted to a procedure that did not involve exposure to heartbeat feedback.

Participants in all groups were required to count their heartbeats while supine, sitting, standing, and during recovery from exercise. This series of heartbeat counting conditions was completed both prior to and following a heartbeat feedback manipulation in which participants were assigned to one of three groups. Participants in an Immediate Feedback group were presented with tones that were contingent on the R-wave of the electrocardiogram (ECG). Participants in a Delayed Feedback group heard tones that were not contingent on concurrent cardiac activity but were triggered by their prerecorded R-waves. A No Feedback (Control) group was instructed to count backwards between the first and second presentations of the heartbeat counting task and received no heartbeat feedback.

An effect of feedback on heartbeat counting accuracy would be demonstrated if either the Immediate or Delayed Feedback group, or both groups, exhibited post-feedback improvements in heartbeat counting accuracy but participants in the No Feedback group did not. The hypothesis that feedback trains participants to detect heartbeat sensations would receive support if the Immediate Feedback group exhibited greater post-feedback improvements in heartbeat counting than the Delayed Feedback and No Feedback groups. However, if the Immediate Feedback and Delayed Feedback groups exhibited similar post-feedback improvements in heartbeat counting and these were not exhibited by the No Feedback group, it could be concluded that feedback does not train participants to detect heartbeat sensations but rather that feedback influences the accuracy of heartbeat counting through some non-sensory route (e.g., beliefs about heart rate).

## 1. Method

### 1.1. Participants

Seventy-seven undergraduates (29 men, 48 women) with a mean age of 21 ($SD$ = 3.3) years, a mean weight of 64 ($SD$ = 14.6) kg, and a mean height of 1.68 (SD = 0.115) m received course credit for participating[1].

[1] Participants in the Immediate Feedback group had a mean age of 21 years, a mean weight of 66 kg, and a mean height of 1.69 m. Participants in the Delayed Feedback group had a mean age of 21 years, a mean weight of 65 kg, and a mean