The Heart-Brake of Social Rejection:

Heart Rate Deceleration to Unexpected Peer Rejection

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Abstract

Given the importance of social encounters in human life, social rejection has been conceptualized as a potent social cue resulting in feelings of hurt. The present study investigated the psychophysiological manifestation of feelings of hurt, by examining the beat-by-beat heart rate response associated with the processing of social rejection. Participants were presented with a series of unfamiliar faces and were asked to predict whether (s)he would be liked by the other person. Each judgment was followed by feedback indicating acceptance or rejection. Feedback was associated with a transient heart rate slowing and a return to baseline that was considerably delayed for unexpected social rejection. Results reveal that the processing of unexpected social rejection is associated with a sizeable response of the parasympathetic nervous system. Findings are interpreted in terms of a cardiovagal manifestation of a neural mechanism implicated in the central control of autonomic function vis-à-vis cognitive processes and affective regulation.

Keywords: Social rejection, Heart rate, Feedback, Affective regulation, Central Autonomic Network

Introduction

An important hallmark of the human species is the significance of social interactions and relationships. Given the strong motive of humans to gain acceptance, people typically are highly sensitive to interpersonal rejection. Indeed, social rejection has been conceptualized as a significant threat (e.g., Baumeister & Leary, 1995). In addition, rejection has been implicated in the development of a wide range of psychological disorders (Deater-Deckard, 2001; Nolan, Flynn, & Garber, 2003). Laboratory studies on the phenomenological experience of social rejection predominantly investigated the emotional consequences of short-term rejection by strangers. Rejection has been shown to elicit higher levels of negative emotions and distress (Buckley, Winkel, & Leary, 2004; Leary, Koch, & Hechenbleikner, 2001). Similar to studies reporting elevated cortisol secretion in response to distressing events, social rejection has been found to elicit higher levels of cortisol (Blackhart, Eckel, & Tice, 2007). Finally, studies highlighted the strong impact of social rejection by showing that exclusion is distressing even when it results in financial gain (Van Beest & Williams, 2006) or when a computer rejects the participant (Zadro, Williams, & Richardson, 2004).

Studies exploring the underlying mechanisms of social rejection sensitivity often emphasize the benefits of avoiding rejection from an evolutionary perspective. Humans are likely to have evolved a highly sensitive system for quickly detecting signs of exclusion. More specifically, it has been proposed that the brain is equipped with an efficient alarm system by signalling rejection as painful (Eisenberger & Lieberman, 2004; MacDonald & Leary, 2005). Eisenberger, Lieberman and Williams (2003) examined the notion of an overlap between brain mechanisms implicated in social and physical pain. They scanned participants while playing a virtual ball-tossing game in which they were ultimately excluded. Their results showed that the dorsal anterior cingulate cortex (dACC), anterior insula and right ventral prefrontal cortex (r-VPFC) were more active during exclusion than during inclusion. More specifically, it was shown that while dACC changes correlated positively with self-reported distress, the r-VPFC-distress correlation was in the opposite direction. This pattern of findings was interpreted to suggest that the r-VPFC regulates the distress of social exclusion by disrupting dACC activity (see also Eisenberger & Lieberman, 2004). These findings are consistent with earlier animal studies on attachment showing that separation distress recruits the brain's 'social pain' system that consists of a widely distributed network, including the ACC (Panksepp, 2003).

Despite the wealth of research suggesting that social rejection produces 'feelings of hurt', it is not yet known how these feelings of hurt are represented in bodily responses. The goal of the current study is to examine the impact of social rejection on autonomic nervous system function, by examining changes in heart-beat timing. Beat-by-beat heart rate changes are under the joint control of the sympathetic and the parasympathetic nervous system. While the sympathetic system takes several seconds to increase the beating of the heart, the parasympathetic system affects the heart very quickly by slowing heart rate (e.g., Demaree et al., 2006). There is a substantial body of evidence establishing how brain responses act in the regulation of the autonomic nervous system (for a recent review see Cechetto & Shoemaker, 2009). More specifically, several neuroimaging studies obtained evidence showing that regions of the ACC, an area previously implicated in negative feelings of social rejection, are involved in cardiovagal control (e.g., Ahs, Sollers, Furmark, Fredrikson & Thayer, 2009; Lane et al., 2009; Wong, Massé, Kimmerly, Menon, &, Shoemaker, 2007), suggesting an overlap between brain regions involved in social rejection processing and the central regulation of heart beat timing. Interestingly, Porro, Cettolo, Franscescato, and Baraldi (2003) observed systematic relations between activation of various ACC regions and heart rate changes during the anticipation of pain. In addition, more recent studies showed that ACC activity mediated heart rate changes associated with negative affect (e.g., Urry, Van Reekum, Johnstone, & Davidson, 2009). This combined evidence suggests that the dACC, and other ACC areas to which it is connected, play a key role in the regulation of a cortical-autonomic network implicated in the processing of negative affect (Vogt, 2005). The hypothesis assessed in the current study assumes that social rejection results in feelings of hurt affecting the parasympathetic system, and therefore would be accompanied by a transient slowing of heart rate.

To assess the cardiac concomitants of social rejection processing, we used a modified version of a paradigm previously used by Somerville, Heatherton and Kelley (2006). Several weeks before testing, participants were required to send a photograph of their portrait to the researcher and were led to believe that others would be forming impressions of them. During the experiment, the participant viewed faces and was asked to predict whether the other person would like them. The participant then received acceptance or rejection feedback from this person that, unbeknown to the participant, was generated by the computer. Somerville et al. (2006) observed that the ventral part of the ACC was differentially activated by social acceptance versus rejection while the dACC was implicated in expectancy violations. Given the strong negative impact of social rejection we predicted that feedback communicating social rejection will be associated with cardiac slowing. A second goal of this study was to test whether the impact of social rejection differs depending on expectations relating to acceptance and rejection. Such a context-dependency of feedback effects would be consistent with studies showing that prior knowledge and person-related schemas are important in guiding social and emotional behavior (e.g., Nummenmaa, Peets, & Salmivalli, 2008). More specifically, we hypothesized cardiac slowing to be most pronounced for rejection feedback following the expectation to be liked. Social rejection following a negative expectation of social evaluation was predicted to have weaker impact, since the feedback is aligned with the individual's own expectations of social evaluation.

A non-social task was added to the Somerville et al. paradigm to determine whether the processing of social rejection adds to the cardiac response over and above the impact of negative cognitive performance feedback *per se*. The non-social task was identical to the social task with the exception of the question asked to the participant. The participant was now asked to judge whether the person on the picture was 21 or older, followed by feedback indicating correctness concerning their judgment about age. We predicted that negative feedback, or feedback that is not aligned with the expectations of the participant, is associated with a transient heart rate slowing. But the magnitude of this cardiac response should be considerably less compared to the social-judgment task, assuming that the impact of social rejection is stronger than the effect of negative performance feedback. Findings could possibly provide valuable insights regarding the neural mechanisms of cognitive and affective responses to social rejection.

Methods

Participants

Twenty-seven 18-25-year-old undergraduate students participated in the study (18 female, 9 male; mean age = 19.9, *SD* = 2.22 years). Subjects received course credit or a fixed payment for participation. All participants reported to be healthy, had no history of neurological or psychiatric disorders and had normal or corrected-to normal vision. Five additional participants (4 female, 1 male; mean age = 19.8, *SD* = 1.72 years) were excluded due to uncorrectable artefacts in ECG recordings, a lack of sufficient observations in task conditions or because they expressed doubts about the cover story.

Stimulus Material and Task Description

Approximately two weeks prior to the experiment participants were contacted by telephone and were told that this was a study about first impressions. For this reason, participants were instructed to send a photograph of their portrait to the researcher. They were told that their photograph would be sent to another university participating in the study where it would be rated by a panel of undergraduates. During the experiment, participants performed two tasks in which neutral faces of age-matched peers were presented. Faces (5.9 cm by 7.4 cm) were presented in color against a black background on the center of a 17-inch computer screen (see Figure 1). 120 pictures of different faces were used with an equal distribution of male and female faces. In each task, all facial stimuli were displayed once. Facial stimuli were obtained by taking photographs of 18-25-year-old students at the campus of another University (mean age = 22.1, *SD* = 2.17 years) after written approval.

Both tasks required participants to make judgments about the presented faces. The tasks differed with regard to the type of judgment they were instructed to make. In the social-judgment task (adopted from Somerville et al., 2006), participants were instructed to predict whether the person on the picture would accept or reject them. On each trial, the participant was required to answer the question 'Do you think this person liked you?'. The age-judgment task involved making judgments about the age of the other person. In this task participants were instructed to decide whether the person on the picture was 21 years or older. Judgments in both tasks were followed by feedback indicating acceptance or rejection by the other person (social-judgment task) or correctness concerning the age of the other person (age-judgment task). In reality, the persons whose faces were presented in the task did not rate the faces of the participant, but the feedback was generated by the computer. The age-judgment task served as a control task to examine cardiac responses to feedback outcomes that did not have a social component.

The trial sequence (see Figure 1) started with a fixation cross having a variable duration between 450 and 1,550 ms (1,000 msec average), which served as an intertrial interval. The fixation cross is followed by a 3,000 ms cue displaying a neutral face, which remained on the screen until the end of the trial. During the cue display participants were instructed to respond ‘yes’ or ‘no’, depending on the instruction of the task. Responses could be made using the index and middle finger of the dominant hand, by pressing the ‘b’ or ‘m’ key of a computer keyboard. Participants were required to respond within a 3,000 ms time frame. Responses that were not made within this time period elicited the feedback ‘Too Slow’, signalling the end of the trial. This occurred on 0.62 % of the trials in the social-judgment task and 0.74% of the trials in the age-judgment task, and did not differ between tasks ($p > .05$). For choices that were made in time, the choice of the participant appeared on the left side of the face (‘Yes’/’No’), during a fixed delay of 1,000 ms. The 2,000 ms feedback display contained the ‘Yes’ or ‘No’ feedback presented at the right side of the face.

--Insert Figure 1 about here---

Experimental design

The order of the tasks was counterbalanced across participants. In both tasks, facial stimuli and feedback type were presented in a random order. Participants received ‘Yes’ feedback on half of the trials and ‘No’ feedback on the other half. Both tasks included four conditions: Yes-Yes, Yes-No, No-Yes, and No-No. It should be noted that the tasks differed in communicating negative feedback. In the social-judgment task, the participant received negative feedback in the Yes-No and No-No conditions—‘No’ communicating social rejection. In the age-judgment task, however, the participant received negative feedback in the Yes-No and No-Yes conditions. In the former condition, the participant was wrong in deciding that the person on the picture was 21 or older and in the latter condition the participant was wrong in deciding that the person was younger. Hence, the critical comparisons are between the Yes-No condition of the social-judgment task with (1) the other conditions of the social-judgment task and (2) the Yes-No and No-Yes conditions of the age-judgment task. The first comparison should establish that the cardiac response to unexpected social rejection (Yes-No) differs from the other social feedback conditions. The second comparisons should reveal that the cardiac response to negative *social* feedback is more pronounced than the cardiac response to negative *cognitive* feedback.

Procedure

All participants were tested individually in a quiet laboratory with dimmed light. Participants sat in a comfortable chair at a distance of approximately 75 cm from the computer monitor. Each session began with a rehearsal of the cover story. Both tasks consisted of 120 trials, separated in 3 blocks of 40 trials with short breaks in between. To familiarize participants with the tasks, they received one block of 10 practice trials in advance. At the end of the experiment, participants were debriefed about the cover story. Participants who expressed doubts about the cover story were excluded from analyses.

Data Recording and Analysis

During both tasks, the electrocardiogram (ECG) was recorded continuously using the Biopac System at a sample frequency of 400 Hz. ECG was recorded with three matching Ag-AgCL electrodes, attached via the modified lead-2 placement. Recorded interbeat intervals (IBIs) were screened and corrected for artefacts by specific parameters in the program that extracted the IBIs. Seven IBIs were selected around the feedback, the IBI concurrent with the feedback (IBI 0), two IBIs preceding the feedback (IBI-2, IBI-1) and four IBIs following the feedback (IBI 1 to IBI 4). In order to obtain a sensitive index of phasic heart rate change, IBI difference scores were referenced to the second IBI preceding the feedback (IBI-2) on each trial. Preliminary analyses on IBI-2 values did not result in any differences across tasks and feedback conditions (all *p*'s > .10), showing that baseline values were not sensitive to any experimental manipulation before feedback presentation. In addition, analyses on the IBI-1 difference scores failed to reveal significant differences (all *p*'s > .10). Given the focus of the present study on feedback processing, IBI-1 difference scores were excluded from statistical analyses. Heart rate responses were evaluated statistically using repeated-measures analysis of variance (ANOVA) with sequential IBI differences scores (IBI 0 to IBI 4). Huyn-Feldt corrections for violations of the assumptions of sphericity were used when necessary (Vasey & Thayer, 1987). All analyses were considered significant when the p-value was equal or less than .05.

Results

Behavior

Participants made on average 56.8% 'yes' judgments and 42.8% 'no' judgments in the social-judgment task. One sample t-tests confirmed that on average participants made significantly more 'yes' judgments relative to a 50% baseline and significantly fewer 'no' judgments (both *p*'s < .05). These findings indicate that participants more often predict to be liked than disliked.

In the age-judgment task, participants made on average 53.5% ‘yes’ judgments and 45.8% ‘no’ judgments. Again, one sample t-tests confirmed that on average participants made significantly more ‘yes’ judgments relative to a 50% baseline and significantly fewer ‘no’ judgments (both *p*’s $< .05$). The mean numbers of trials per feedback condition are presented in Table 1 for both tasks separately. To examine whether there were differences in the number of trials per condition across tasks, a 2 (Task) x 4 (Feedback condition) ANOVA was performed. This analysis resulted in a main effect of Feedback condition, $F(3,78) = 16.54$, $p < .001$, but there was no significant difference between tasks ($p > .15$).

--Insert Table 1 about here---

Heart Rate

Figure 2 shows heart rate responses associated with feedback processing for the social-judgment task and the age-judgment task. The cardiac response is plotted around the presentation of the feedback (IBI 0) and following feedback presentation (IBIs 1-4). All IBIs were referenced to IBI-2. An increase in IBI difference scores indicates a slowing of heart rate. As can be seen in the figure, heart rate slowed in anticipation of the feedback and showed an additional slowing following the presentation of the feedback (IBI 0). This slowing was then followed by an acceleratory recovery to baseline.

--Insert Figure 2 about here---

First, we predicted that unexpected negative social feedback would be associated with a delay in heart beat timing. Indeed, in panel A of Figure 2, it can be seen that the IBI response to the Yes-No condition stands out from the cardiac response associated with the other conditions of the social-judgment task. This visual impression was statistically verified by performing a 2 (Congruency) x 2 (Feedback type) x 5 (IBI 0-IBI 4) repeated measures ANOVA on sequential IBIs that were referenced to IBI-2. The analysis resulted in a main effect of IBI, $F(1.82, 47.24) = 6.76$, $p < .005$, and the predicted Congruency x Feedback x IBI interaction, $F(2.35, 61.24) = 3.09$, $p < .05$. No main effects for Congruency and Feedback type were found (both *p*'s > .3). To further test our predictions concerning cardiac slowing for unexpected rejection trials (Yes-No condition), paired sample t-tests were conducted on the IBIs following the presentation of the feedback. These comparisons showed that the IBI differences scores were significantly larger for the Yes-No condition compared to all other feedback conditions at IBI 3 (No-No: $t(26) = 2.68$, $p < .05$; No-Yes: $t(26) = 2.35$, $p < .05$ and Yes-Yes: $t(26) = -3.4$, $p < .005$) and IBI 4 (No-No: $t(26) = 3.08$, $p < .01$; No-Yes: $t(26) = 2.28$, $p < .05$ and Yes-Yes: $t(26) = -2.52$, $p < .05$).

Secondly, we predicted that the cardiac slowing to negative *social* feedback would be more pronounced compared to the cardiac response elicited to negative *cognitive* feedback. This prediction was tested by comparing the IBI response in the Yes-No condition of the social-judgment task to the IBI response associated with the Yes-No and No-Yes conditions of the age-judgment task. In line with our prediction, the IBI response to unexpected negative social feedback was larger compared to the response obtained for the Yes-No and No-Yes conditions of the age-judgment task; respectively $F(2.97, 77.3) = 6.14$, $p = .001$ and $F(2.85, 74.01) = 11.41$, $p < .001$. Thus, as anticipated, the additional transient cardiac slowing at IBI 3 and IBI 4 was specific for unexpected social rejection.

Discussion

This study aimed at examining the cardiac concomitants of the processing of social rejection. Participants performed two tasks having the same format—the social-judgment task and the age-judgment task that served as a control. Participants were presented with a series of unfamiliar faces and were asked to predict whether the other person would like them or whether they thought that the other person was 21 or older. Each judgment was followed by feedback indicating acceptance or rejection by the other person or correctness concerning the age of the other person. It was predicted that the processing of feedback communicating social rejection would result in feelings of hurt, and therefore would be accompanied by a transient slowing of heart rate that is most pronounced for rejection following a positive expectation of social evaluation. In addition, this response was hypothesized to be larger than the cardiac response associated with negative cognitive feedback in the age-judgment task. The results from the current study were in support of these predictions.

The proportion of positive vs. negative judgments differed somewhat from 50% in both tasks but, importantly, these proportions did not differ across tasks. Both tasks yielded the typical heart rate pattern associated with feedback processing (e.g., Crone et al., 2003;

Van der Veen, Van der Molen, Crone, & Jennings, 2004). This pattern consists of a transient heart rate slowing to the feedback stimulus. The heart rate slowing reached its maximum during the IBI following feedback onset (IBI 1), which is consistent with the heart rate literature indicating that maximum heart rate slowing occurs during the IBI subsequent to the IBI of feedback occurrence (e.g., Crone et al. 2003). The transient slowing of heart rate to the feedback stimulus is usually interpreted in terms of a vagal response associated with the cognitive elaboration of the information provided by the stimulus (e.g., Van der Molen, Somsen, Jennings, Nieuwboer, & Orlebeke, 1987).

The transient slowing of heart rate associated with feedback processing is followed by an acceleratory recovery to baseline. Previous research established that the recovery is delayed when the feedback stimulus conveys negative information; that is, stimuli providing negative performance feedback (e.g., Hajcak, McDonald, & Simons, 2003), stimuli signalling punishment (e.g., Luman, Oosterlaan, Knol, & Sergeant, 2008), stimuli violating expectations based upon previous task experience (e.g., Somsen, Van der Molen, Jennings, & Van Beek, 2000), or following unpleasant affective stimuli (e.g., Bradley, 2009). The current findings add to this literature by showing a pronounced heart rate slowing to rejection feedback following the participant's prediction that (s)he would be liked by the other person. This finding implicates that social rejection literally results in bodily responses reflecting social 'hurt' (Eisenberger et al., 2003).

The cardiac response to unexpected social rejection was considerable larger than the heart rate changes associated with expected social rejection. Results confirm the hypothesis concerning the context-dependency of social rejection effects. This finding may suggest that negative feelings associated with being socially rejected are reduced substantially when negative peer evaluation was anticipated. It should be noted, however, that self-report ratings of distress were not administered in the current study. In future studies, it will be important to collect self-report ratings to better understand the affective responses elicited by social feedback. Importantly, the cardiac response to unexpected social rejection was larger than the heart rate change observed for the other conditions in which the feedback was not aligned with the expectations of the participant (i.e., No-Yes condition in the social-judgment task and Yes-No or No-Yes conditions in the age-judgment task), indicating that the impact of social rejection is stronger than the effect of expectancy violation *per se.* Together, the pattern of results that emerged from the current study show that cardiac slowing was most pronounced for unexpected social rejection.

Thus, feelings of hurt associated with unexpected social rejection result not only in central brain responses that are implicated in physical pain processing (Eisenberger et al., 2003), but also in autonomic feelings of hurt as reflected in heart rate changes. This pattern of results is consistent with recent findings suggesting a link between negative affect and the parasympathetic nervous system. For example, Heilman et al. (2008) studied the psychophysiological response profile in young children to two different challenges—a physical challenge (i.e., bike pedalling) and a social challenge (i.e., staying in a room with the experimenter while the parent exited the place). Obviously, heart rate increased when pedalling but, interestingly, heart rate decreased to the social challenge. From an evolutionary viewpoint, the current findings support the strong motivational importance of social belonging. That is, humans are likely to have evolved a highly sensitive system for quickly processing signals of social threat. Indeed, the ability of the vagus to assert parasympathetic control is proposed to be indicative of a self-regulatory process that promotes a healthy style of adaptive and flexible behaviour (Thayer & Brosschot, 2005; Thayer & Lane, 2009). More specifically, cardiac deceleration has been associated with enhanced sensory intake and active engagement with the environment (e.g., Bradley, 2009).

At a neural level, the dACC has previously been shown to be implicated in both pain distress and discrepancy detection (Eisenberger et al., 2003). As a result, Eisenberger and Lieberman (2004) conceptualized the dorsal ACC as a neural alarm system in which both functions act as two complementary processes. Current findings regarding the context-dependency of social rejection effects could further support this alarm system by showing an interplay between expectancy violations and distress. Possibly, unexpected social rejection easily triggers this alarm system alerting the discrepancy from an expected or desired state of social belonging. Furthermore, findings are consistent with the work by Ploghaus, Becerra, Borras and Borsook (2003) showing a mediating role of expectations on affective consequences of physical pain. Notably, they demonstrated a distinction in the neural pathways involved in physical pain processing, such that expected pain activates the rostral ACC and unexpected pain the dACC (Eisenberger & Lieberman, 2004). Current results extend these findings to the social domain by showing differences in the psychophysiological manifestation of unexpected and expected social rejection.

From a broader perspective current findings are consistent with the concept of a ‘central autonomic network’ that has been recognized by investigators working in diverse areas of research (e.g., Benarroch, 1993; Saper, 2002). This network consists of both prefrontal and midbrain structures and is characterized by reciprocal interconnections. Thus, the output of the network is directly linked to beat-by-beat heart rate changes and, vice versa, sensory information from the heart is fed back to the network to allow for central-autonomic integration. Indeed, studies demonstrated correlations between beat-to-beat heart rate changes and brain activity in areas comprised by this network (e.g., Critchley et al., 2003; Gianaros, Van der Veen, & Jennings, 2004; Napadow et al., 2008). This work and our current findings converge on the hypothesis that cortical and midbrain areas involved in cardiovagal control mediate the relation between cognitive and social-emotional processes, and affective regulation (Thayer & Brosschot, 2005). Within this context, cardiac slowing associated with unexpected social rejection is interpreted as a cardiac manifestation of the central-autonomic network facilitating the processing of relevant social information (Porges, 2003). It would be of considerable interest to examine the cardiovagal response to social rejection in individuals who are hypersensitive to social exclusion.

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Table 1: Mean numbers of trials per feedback condition for the social-judgment task and the age-judgment task (SD in parenthesis).

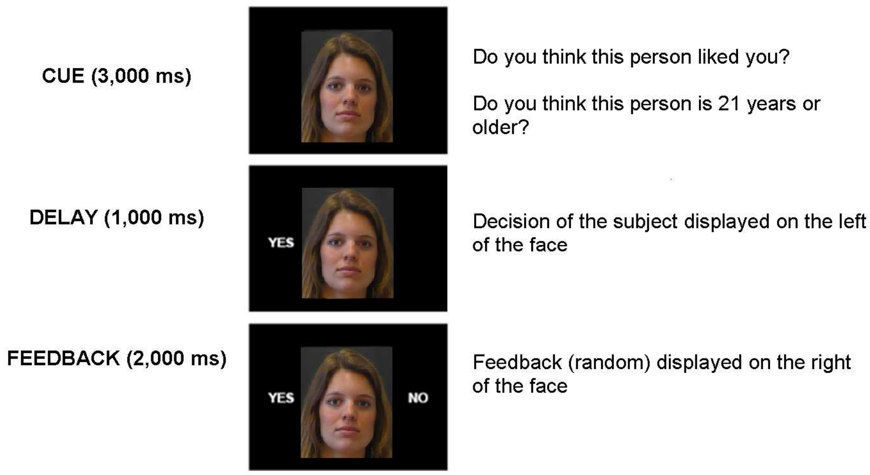
Feedback condition	Social-judgment task	Age-judgment task
Yes-Yes	35.1 (6.61)	32.3 (4.53)
Yes-No	33.1 (6.93)	31.9 (4.42)
No-Yes	24.5 (6.87)	27.3 (4.41)
No-No	26.8 (6.84)	27.7 (4.54)

Figure Captions

Figure 1: Example of a trial sequence (yes-no condition) in the social-judgment task and the age-judgment task. During the cue period participants responded to the question, “Do you think this person liked you?” (social-judgment task) or to the question, “Do you think this person is 21 years or older?” (age-judgment task). During the delay period the choice of the participant appeared on the left side of the face. Following the delay, feedback was presented at the right side of the face. Trials were separated by intertrial intervals (1,000 ms average), where a central fixation cross was shown.

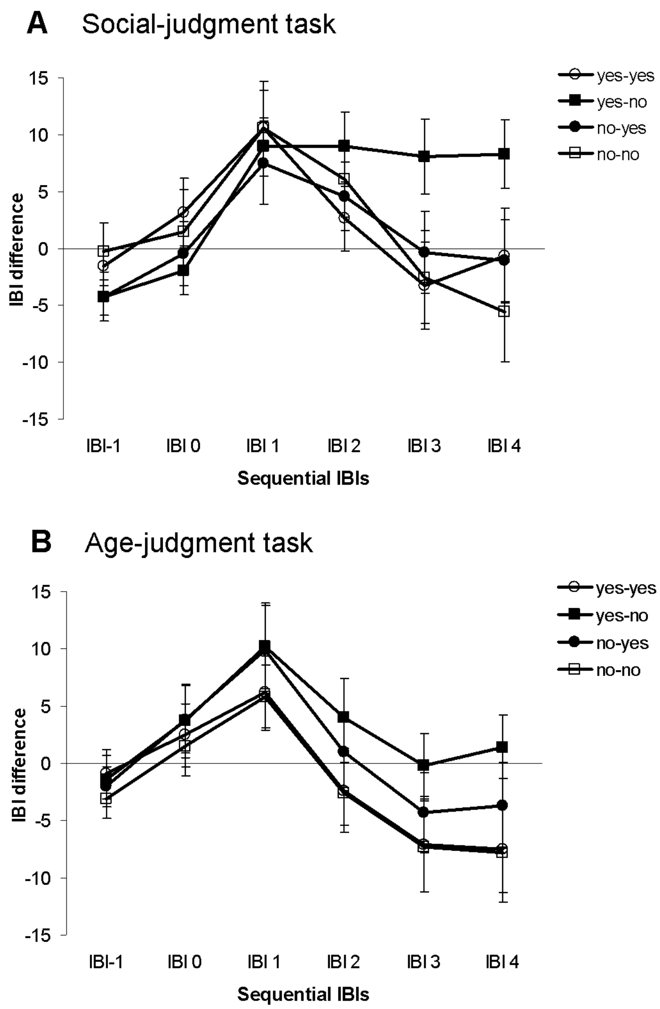
Figure 2: Inter-beat-interval (IBI) response (referenced to IBI-2) associated with feedback processing for the social-judgment task (panel A) and the age-judgment task (panel B). The four lines represent the four feedback conditions. IBI 0 refers to the IBI concurrent with feedback presentation and IBIs 1-4 to the IBIs following feedback presentation. An increase in IBI difference scores indicates heart rate slowing, and a decrease in IBI difference scores indicates heart rate speeding.

Figure 1:



CUE (3,000 ms)
Do you think this person liked you?
Do you think this person is 21 years or older?
DELAY (1,000 ms)
YES
Decision of the subject displayed on the left of the face
FEEDBACK (2,000 ms)
YES
NO
Feedback (random) displayed on the right of the face

Figure 2:


A
Social-judgment task
15
10
5
0
-5
-10
-15
IBI difference
IBI-1
IBI 0
IBI 1
IBI 2
IBI 3
IBI 4
Sequential IBIs
yes-yes
yes-no
no-yes
no-no
B
Age-judgment task
15
10
5
0
-5
-10
-15
IBI difference
IBI-1
IBI 0
IBI 1
IBI 2
IBI 3
IBI 4
Sequential IBIs
yes-yes
yes-no
no-yes
no-no