From ‘gut feelings’ to first impressions: Phase dependent cardio-visual signals bias the perceived trustworthiness of faces

Ruben T. Azevedo[1], **Mariana von Mohr** [2], **& Manos Tsakiris**[2,3]

[1] School of Psychology, University of Kent, Canterbury, UK

[2] Department of Psychology, Royal Holloway, University of London, London, UK

[3] Centre for the Politics of Feelings, School of Advanced Study, University of London, London, UK

*Corresponding author name(s) here.

Ruben T. Azevedo

Email: r.a.texeira-azevedo@kent.ac.uk

Mariana von Mohr

Email: mariana.vonmohr@rhul.ac.uk

Word count

Abstract : 149

Introduction & Discussion : 1,954

Methods & Results : 2,153

Abstract

When we see new people we rapidly form first impressions. While past research has mostly focused on the role of morphological or emotional cues, we here ask whether the visceral states of the perceiver bias first impressions. Across 3 studies we investigated how "gut feelings", driven by the interoceptive impact of cardiac signals, may influence the perceived trustworthiness of faces. Faces presented in synchrony with the participants' cardiac systole were chosen less often as more trustworthy than those presented out-of-synchrony. Faces presented in synchrony cardiac systole were also explicitly judged as less trustworthy. Finally, the presentation of faces in synchrony with the participants' cardiac diastole did not modulate perceived trustworthiness, suggesting that the systolic phase is necessary for such 'gut feelings'. These findings highlight the role of phasic interoceptive information in the processing of social information and provide a mechanistic account of the role of visceroception for social perception.

Introduction

The formation of first impressions when we see new faces shape our social interactions as we appraise others based on their facial appearance. These face-based inferences occur spontaneously (Klapper, Dotsch, van Rooij, & Wigboldus, 2016) and as fast as 33ms (Todorov, Pakrashi, & Oosterhof, 2009). An important aspect of such appraisals relate to perceived trustworthiness (Winston, Strange, O'Doherty, & Dolan, 2002), which is tightly linked to threat evaluation (Adolphs, Tranel, & Damasio, 1998; Engell, Haxby, & Todorov, 2007; Todorov, Baron, & Oosterhof, 2008; Winston et al., 2002), and influence a wide range of behaviours, from approach and avoidance (Fenske, Raymond, Kessler, Westoby, & Tipper, 2005) to investment decisions in trust games (van 't Wout & Sanfey, 2008). While past research has mainly focused on morphological or emotional cues of facial appearance, we here turn our attention to how 'gut feelings', in other words how visceral states that are interoceptively perceived, can bias our first impressions.

There has been a long-standing interest in the role of interoception in emotional and social processing motivated by the hypothesis that the physiological condition of the body acts as the basic substrate for feeling states and emotions (Craig, 2002; James & Lange, 1922). Afferent information from bodily organs influences various psychological functions, from consciousness (Craig, 2009; Damasio, 2003), emotional experience (Barrett, Quigley, Bliss-Moreau, & Aronson, 2004; von Mohr, Finotti, Villani, & Tsakiris, 2021), and empathy (Grynberg & Pollatos, 2015), to intuitive decision making (Werner, Jung, Duschek, & Schandry, 2009) and information sampling (Galvez-Pol, McConnell, & Kilner, 2020). While several studies have examined the role of interoception in various facets of social cognition (Grynberg & Pollatos, 2015; Heydrich et al., 2021; von Mohr et al., 2021; Shah, Catmur, & Bird, 2017), little is known about the role of interoception in the processing of social information and appraisal of others. We here focus on if and how cardiac afferent signals can influence the first impressions of trustworthiness with the aim of providing a mechanistic account of the role of visceroception for face and social perception.

One way to study the impact of visceral signals on cognition is to synchronize the presentation of stimuli with the participants' physiological rhythms (Aspell et al., 2013; Monti, Porciello, Tieri, & Aglioti, 2020), by presenting visual stimuli in synchrony with the participants' heartbeats (i.e. cardio-visual synchrony). We here use this approach as a way of modelling gut feelings and their influence on face perception. Cardio-visual synchrony facilitates the integration of external body cues into the neural representation of our own bodies (Aspell et al., 2013; Heydrich et al., 2018; Sel, Azevedo, & Tsakiris, 2017; Suzuki, Garfinkel, Critchley, & Seth, 2013), even if participants are typically unaware of the contingency between interoceptive and exteroceptive information (Sel et al., 2017; Suzuki et al., 2013). Cardio-visual synchrony effects can even modulate access to conscious awareness (Salomon et al., 2016) and the subjective appraisal of affectively neutral visual stimuli (Azevedo, Ainley, & Tsakiris, 2015). From a mechanistic perspective, the temporal congruency between interoceptive and exteroceptive information promotes their integration (e.g., Suzuki et al., 2013). However, there is still uncertainty regarding how precisely interoceptive signals contribute to these effects. Specifically, it is not clear whether the cardio-visual synchrony depends only on the frequency or on the cardiac phase of coupling (Salomon et al., 2016), or whether it is determined by the specific phase of the cardiac cycle the visual stimulus is synchronized to (Azevedo, Ainley, & Tsakiris, 2016; Sel et al., 2017; Suzuki et al., 2013). The latter proposal is based on a related experimental technique capitalizing on the phasic discharge of aortic baroreceptors – i.e. pressure and stretch sensors in the aortic arch that signal variations in blood pressure to the brain at each heartbeat. By time-locking the presentation of a brief single stimulus to the systolic period (i.e. ~200-400ms after the ECG's R-peak when the baroreceptors are maximally represented in brain), or to the diastole (i.e. the remaining of the cardiac cycle which corresponds to a period of baroreceptor quiescence), recent studies have documented the influence of these cardiac afferent signals, i.e., at systole vs diastole, in several sensory and cognitive domains (Ambrosini, Finotti, Azevedo, Tsakiris, & Ferri, 2019; Azzalini, Rebollo, & Tallon-Baudry, 2019; Critchley & Garfinkel, 2015). Most notably, afferent cardiac signals contribute to an up-regulation of motivationally salient stimuli, such as fearful faces, which are more easily detected (Garfinkel et al., 2014; but see Leganes-Fonteneau et al., 2020), engage more attentional resources (Azevedo et al., 2018) and are judged as more intense (Garfinkel et al., 2014; Leganes-Fonteneau et al., 2020) when perceived during systole versus diastole. It is argued that such enhancement in the processing of threat signals reflects a selective influence of physiology on motivational systems to direct resources towards relevant impending information (Critchley & Garfinkel, 2015). In other words, these interoceptive signals of bodily arousal help prioritising salient and motivationally relevant information.Even though a recent study found that, in conditions of high attentional load, people tend to judge faces presented during systole as less trustworthy than those presented at diastole (Li, Chiu, Swallow, De Rosa, & Anderson, 2020), it remains unclear to what extent the modulation of social judgements is dependent on cardio-visual synchrony or phasic signals of bodily arousal.

Here we implemented a cardio-visual stimulation paradigm to trigger "gut feelings" like states and study their influence on the perceived trustworthiness of new faces across three studies. In Studies 1-2 participants judged the perceived trustworthiness of faces flashing either in frequency- and phase-synchrony (i.e. at systole) with their own heartbeats (Systole-Self condition) or following someone else's previously recorded heart rhythms (Other conditions). Study 3 followed the same paradigm but with a constant phase shift in the cardio-visual synchrony to coincide with cardiac diastole (Diastole-Self condition), rather than systole to test whether the cardiac influence is dependent on the phase of the cardiac cycle. Following the known increased sensitivity to motivationally salient stimuli (Azevedo et al., 2017; Azevedo et al., 2018; Garfinkel et al., 2014; Li et al., 2020), we predicted reduced trustworthiness during *synchronous* cardio-visual stimulation. Moreover, we predicted this effect to be *cardiac-phase specific (i.e. synchronous with systole)*, rather than simply frequency-dependent (i.e. synchronous with either systole or diastole).

Study 1

Methods

Participants

A total of thirty-five volunteers (Mean age= 22.6, SD= 3.4; 27 females) took part in the study. This sample size was determined based on power calculations using GPower 3.1 based on a previous study on cardiac gating on emotional valence (Garfinkel et al., 2014) with an effect size (f2) 0.40 to achieve power of 85% with alpha = 0.05 and is consistent with other studies in the field (Azevedo et al., 2018; Li et al., 2020). The study was approved by Royal Holloway University of London Department of Psychology ethics committee and written informed consent was obtained from all participants.

Stimuli

Stimuli consisted on images (400 x 477 pixels) of computer generated Caucasian male faces with neutral facial expressions against a black background (Oosterhof & Todorov, 2008). The faces were created using FaceGen 3.1 (http://facegen.com) by the Social Perception Lab at Princeton University (http://tlab.princeton.edu/databases/) to vary along the dimension of trustworthiness. The selected stimuli set comprised a total of 150 different images composed by 24 different face identities, each of them with 6 versions that varied on trustworthiness levels by increments of 1 SD. To create the face masks the shape of the faces were maintained but the faces replaced with pixel size black and white random noise (see Figure1).

Trustworthiness judgment task

Each trial began with the presentation of two shapes of faces (masks) flashing side-by-side on a 1280 x 1024 computer screen (distance between the centre of the two pictures was 700 pixels). After a variable period of time, 8500-9000ms, the masks were replaced with two different pictures of male faces that continued flashing with the same rhythms for 3000-3500ms (see figure 1A). Once the faces disappeared from the screen, participants were asked to answer, with a key press, to the question “Which of the faces seemed more trustworthy to you?”. Importantly, each mask/face of the pair flashed (for 100ms) with different rhythms: synchronized with the participants heart (Systole-Self), following another heart rhythm either 8% faster (Other-Fast) or 8% slower (Other-Slow) than the participant’s heart. Faces were always paired with another face with equivalent trustworthiness level and each face, and thus face-pair, was presented three times, once in each rhythm combination: Systole-Self vs Other-Slow, Systole-Self vs Other-Fast, Other-Slow vs Other-Fast. The task comprised a total of 90 trials, 30 per condition combination, randomly presented. The inter-trial interval was 1200ms or 2200ms plus a variable time to detect an R-peak in trials with the Systole-Self condition and a variable delay (from 1ms to the average interbeat interval) in the Other conditions. Cases with scores 2 SD above / below the mean were set to be excluded from main analyses. No participants met these criteria and thus there were no exclusions on this basis.

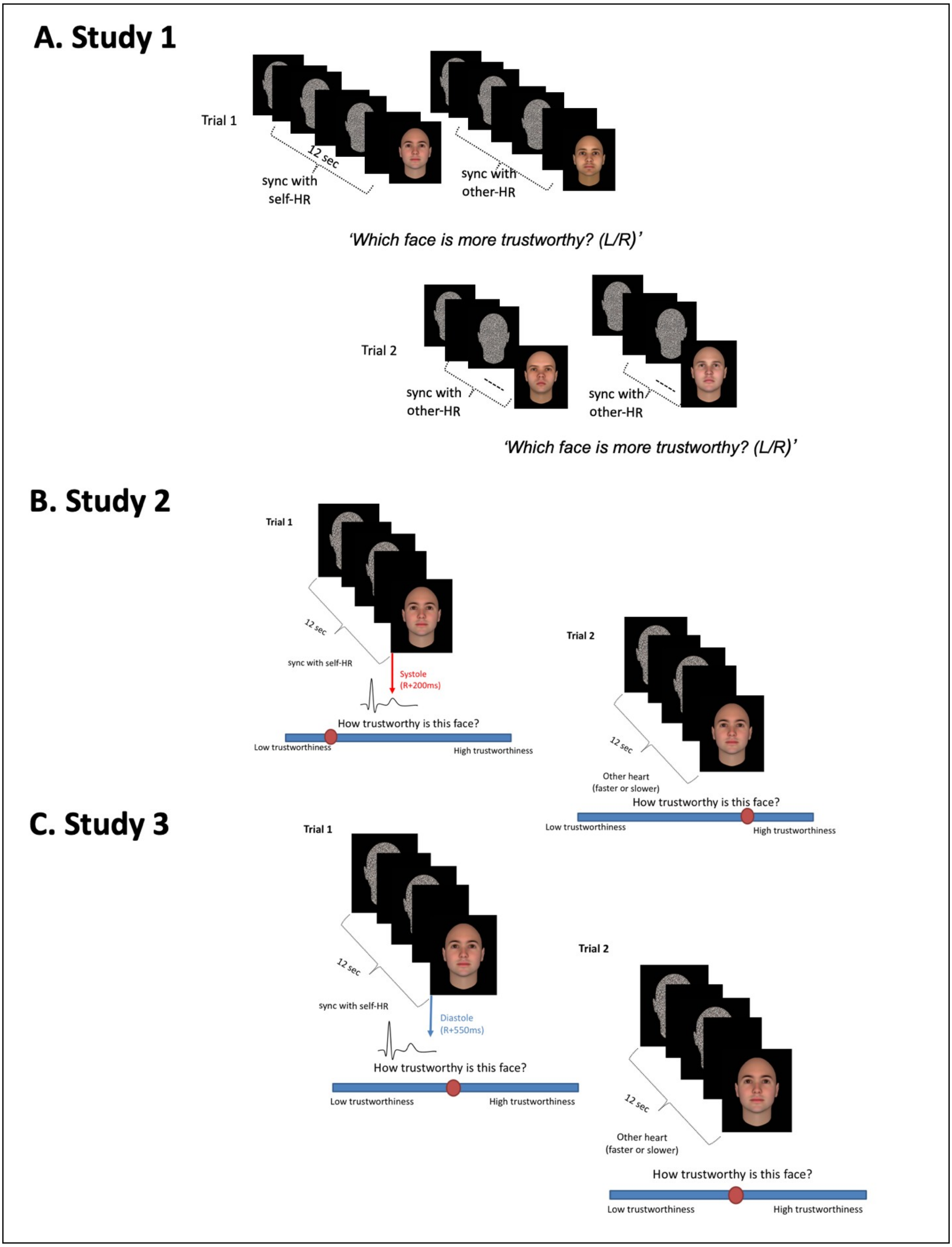

Figure 1. *Schematic overview of an example trial. (A) Study 1: Each trial began with the presentation of two shapes of faces (masks) flashing side-by-side and were then replaced with two different pictures of male faces that continued flashing with the same rhythms, e.g. synch with one's own heart rhythm at systole (left) vs. someone else's previously recorded slightly faster (right) (there were three possible combinations for rhythm pairings, see text for details). Once the faces disappeared from the screen, participants were asked to answer, with a key press, to the question "Which of the faces seemed more trustworthy to you?". (B) Study 2: Only one face was presented*

at a time (at three possible rhythm types: Self-Systole; Other-Slow; Other-Fast) followed by the instruction to judge the perceived trustworthiness of each face using a visual analogue scale ranging from 1: "Not trustworthy at all" to 100 "Extremely trustworthy". (C) Study 3 followed precisely the same design of Study 2 with the unique difference consisting of a phase shift in the synchronization for the stimuli in the Self condition to be presented during cardiac diastole (in between heartbeats; Self-Diastole) instead of cardiac systole as in Studies1-2.

Synchronization procedure

Three disposable ECG electrodes were placed in a modified lead I chest configuration: two electrodes were positioned underneath the left and right collarbone and another on the participant's lower back on the left side. The ECG signal was recorded at 1000HZ (band pass filter between 0.3 and 1000Hz) with a Powerlab 8/35 (Powerlab, ADInstruments, http://www.adinstruments.com/) using LAbchart 8 Pro software. Heartbeat online detection was achieved with a hardware based function (fast output response; www.adinstruments.com/), which identifies the ECG's R-wave, when the amplitude exceeds an individually defined threshold, with a delay smaller than 1ms. In the Systole-Self condition, pictures were presented at R+200ms (Azevedo et al., 2015; Sel et al.2017) to coincide with the cardiac systole and the period of maximal representation of arterial baroreceptors in the brain . Other heart rhythms consisted in pre-recorded interbeat intervals, of previous participants performing a similar task (Azevedo et al., 2015), adjusted in each trial to be 8% faster or slower than the participant's heart, as estimated during the precedent trial. In Other-Slow vs Other-Fast trials, the average heart rhythms were 4% slower and faster, respectively, than the participants' own heart to maintain the 8% relative difference between the two rhythms. The Other-hearts database contained several different heartbeat samples from distinct participants and each trial presented a random portion of one of these samples. Thus, no Other-heart trials had exactly the same heart-rate-variability.

Heartbeat detection task

To measure participants' ability to detect their heartbeats, i.e. their interoceptive accuracy (IAcc; Garfinkel, Seth, Barrett, Suzuki, & Critchley, 2015), we asked them to perform the Heartbeat Detection Task (Whitehead, 1971) at the end of the trustworthiness judgements protocol. In this task, participants were presented with sequences of 10 auditory tones that could be either synchronous with their heartbeats (R+200ms) or in between heartbeats (R+500ms) and asked to judge whether each sequence was synchronous (i.e. "onbeat") or asynchronous (i.e. "offbeat") with their own hearts. There were 20 trials for each condition presented in random order. The percentage of correct answers was taken as an index of participants' IAcc.

Data Availability

Data-set (Study 1) is available at the Open Science Framework: https://osf.io/m74tj/

Results

Each condition (Systole-Self; Other-Slow; Other-Fast) and condition pair (Systole-Self vs Other-slow, Systole-Self vs Other-Fast, Other-Slow vs Other-Fast) had the same number or trials, therefore our dependent variable was the number of times each participant chose as more trustworthy a face flashing with each rhythm. We submitted these values to a repeated measures ANOVA with Rhythm (Systole-Self; Other-Slow; Other-Fast) as within-subject factor and performed post-hoc comparisons (two-tailed t-tests) between each Rhythm. As presented in Figure 2A, results revealed an influence of flashing rhythm in participants' judgments ($F(2,68)=3.50$, $p=0.036$, partial $\eta^2=0.093$) as they chose less often, as more trustworthy, faces synchronized with their own heart ($M=28.26$, $SD=3.66$, CI 95%[27.00,29.51]) than faces following Other-Slow ($M=30.66$, $SD=3.72$, CI 95%[29.38,31.93], $t(34)=-2.40$, $p=0.022$, Cohen's $d=0.40$) and Other-Fast ($M=31.08$, $SD=4.39$, CI 95%[29.58,32.60], $t(34)=-2.33$, $p=0.026$, Cohen's $d=0.39$) rhythms (see Figure 2A). No difference between Other-Fast and Other-Slow was observed (t(34)=-0.35, p=0.73, Cohen's D=0.059). To understand if the observed effects were related to participants' ability to detect their own heartbeats, we correlated IAcc scores (M=57.6; SD=10.7) with the difference between the number of times participants chose the face in the Self condition vs the average of Other conditions. No significant relation between the two measures was found (r=-0.22, p=0.20). Thus, faces synchronized with the participant's heart rhythm were chosen less often as more trustworthy than those flashing according to someone else's pre-recorded heart rhythms suggesting an influence of ongoing interoceptive information when making social inferences from others' faces. However, because the two faces were presented almost simultaneously, it is also possible that stimuli presented in synchrony with the participants' hearts are given less attention and therefore chosen less often. To rule out this hypothesis we carried out a separate study.

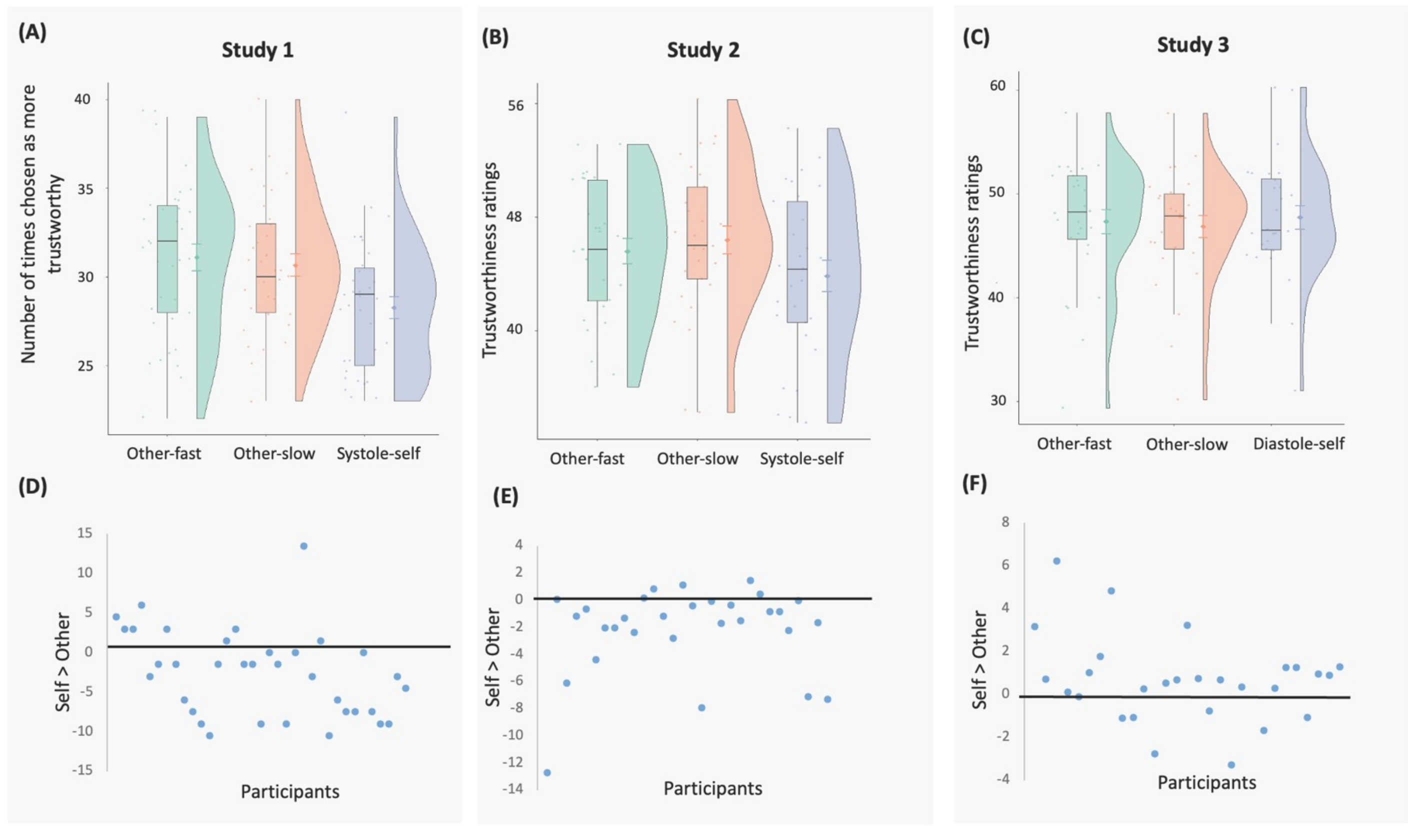

Figure 2. *Trustworthiness judgments for Study 1 (A), Study 2 (B) and Study 3 (C) for each cardiac rhythm condition. The raincloud plots provide data distribution, the central tendency by boxplots and the jittered presentation of our raw data. Error bars denote SEM for each condition. (D) Magnitude of Other vs Self bias for each participant in Study 1. The bias was calculated as follows: Systole-Self – (Other-Slow + Other-Fast)/2. Values below zero reflect lower number of times faces synchronized with the participants' hearts were chosen as more trustworthy compared to those following someone else's heart. (E) Magnitude of Other vs Self bias for each participant in Study 2. This was calculated by subtracting the average ratings across Other-Fast and Other-Slow from those to -Self. Values below zero indicate reduced trustworthiness ratings in the Systole-Self condition compared to the Other conditions. (F) Magnitude of Other vs Self bias for each participant in Study 3. This was calculated by subtracting the average ratings across Other-Fast and Other-Slow from Diastole-Self. Values below zero indicates reduced trustworthiness ratings in the Diastole-Self condition. Note that no effect of Heart Rhythm was found in Study 3.*

Study 2

Methods

In Study 2, we presented only one face at a time and asked participants to judge the perceived trustworthiness of each face (see Figure 1B). Lower ratings to faces synchronized with the participants' heartbeats would provide a conceptual replication of Study 1 and rule out the possibility that the previously observed effects are driven by attention competition between the two faces.

Participants

Given that Study 1 revealed an effect size of partial $\eta 2=0.093$ suggesting that at least 27 participants are needed to obtain a power of 95% using GPower 3.1, a similar sample was selected for this experiment. Specifically, thirty-one volunteers (Mean age=24.17, SD=4.90; 21 females) were recruited from Royal Holloway University of London. Data from one participant was excluded due to technical problems during the session. The study was approved by Royal Holloway University of London Department of Psychology ethics committee and written informed consent was obtained from all participants.

Trustworthiness judgment task

The stimuli, task and procedures were identical to those of Study 1 with the exception that in this study only one face was presented at a time in the centre of the screen (see Figure 1B). The trial ended with participant's answer to the question "How trustworthy is this face?" in a visual analogue scale (VAS) (1-100) anchored with the labels "Not trustworthy at all" and "Extremely trustworthy". Each face was presented three times, once with each rhythm type: Self-Systole; Other-Slow; Other-Fast. As in Study 1, in the Self condition pictures were presented during cardiac systole (R+200ms). Cases with scores 2 SD above / below the mean were excluded from main analyses. One participant was excluded on this basis (note that we obtain the exact same pattern of results when including this participant in the main analyses).

Data Availability

Data-set (Study 2) is available at the Open Science Framework: https://osf.io/m74tj/

Results

Average trustworthiness ratings were submitted to a repeated-measures ANOVA with Rhythm (Systole-Self; Other-Slow; Other-Fast) as within-subjects factor. In line with results from Study 1, we found a significant effect of Rhythm ($F(2,56)=8.57$, $p= 0.001$, partial $\eta 2=0.23$) that could be explained by lower trustworthiness ratings for faces in the Systole-Self condition (M=43.85 , SD=5.88, CI 95%[41.62.00, 46.09]) compared to those in the Other-Slow (M= 46.40 , SD=5 .30, CI 95%[44.38, 48.41] ; $t(28)=-3.78$, $p= 0.001$, Cohen's d=0.7 0) and Other-Fast (M=45 .59 , SD=4 .84 , CI 95%[43.75, 47.43] ; $t(28)=-2.69$, $p=0.012$, Cohen's d=0.5 0) conditions (see Figure 2B). There was no difference in the ratings given to the Other-Slow and Other-Fast faces ($t(28)=1.44$, $p=0.16$, Cohen's d=0.27). No correlation was found between participants' IAcc (M=55.23, SD=9.03) and the difference in trustworthiness ratings in the Self and the average of Other conditions ($r=0.16$, $p=0.42$). This pattern provides a conceptual replication of Study 1 by showing that faces presented in synchrony with the participants' hearts are judged as less trustworthy, consistent with the cardiac cycle literature showing increased sensitivity to threat-related stimuli (Azevedo et al. 2018; Garfinkel et al., 2020, 2014; Garfinkel, & Critchley, 2016; Leganes-Fonteneau et al., 2020;) and diminished trustworthiness ratings (Li et al, 2020) when faces were presented during cardiac systole. However, both Studies 1 and 2 implemented the cardio-visual synchrony manipulation only during systolic periods. To establish whether the observed effects are indeed associated with transient neuromodulatory states induced by phasic cardiac signals we need to test if cardio-visual synchrony delivered during diastole leads to similar effects.

Study 3

Methods

In Study 3, we made a single but important modification to the design of Study 2. Here, self-heart synchrony was defined by presenting faces during cardiac diastole, when the representation of cardiac signals in the brain is minimal (see Figure 1C). An absence of modulation in participants' ratings across the different conditions will confirm our hypothesis that cardiac afferent signals are essential for the lower trustworthiness judgements.

Participants

To maximize comparability between studies our target sample size was equivalent to that of Study 2. Specifically, a new group of 29 volunteers (Mean age= 25.03, SD=5.27; 20 females) were recruited to take part in the study. The study was approved by Royal Holloway University of London Department of Psychology ethics committee and written informed consent was obtained from all participants.

Trustworthiness judgment task

The stimuli, task and procedures were identical to those of Study 2 with the exception that in this study stimuli in the synchronous condition were presented during cardiac diastole (R+500ms; Diastole-Self condition). This procedure preserves the frequency and heart-dynamics of the previous cardio-visual stimulation procedure but introduces a phase-shift (i.e. consistent delay) of the visual presentation in relation to the cardiac cycle (cf Salomon et al., 2016). In other words, the exteroceptive and interoceptive information are still coupled but synchrony is now achieved by presenting stimuli during the quiescent phase of the cardiac cycle. Cases with scores 2 SD above / below the mean were excluded from main analyses. One participant was excluded on this basis (note that we obtain the exact same pattern of results when including this participant in the main analyses).

Data Availability

Data-set (Study 3) is available at the Open Science Framework: https://osf.io/m74tj/

Results

A repeated-measures ANOVA with Rhythm (Diastole-Self; Other-Slow; Other-Fast) as within-subjects factor was used to test for differences in average trustworthiness ratings in each condition. Contrary to Study 2, there was no significant effect of Rhythm ($F(2,54)=0.93$, $p=0.40$, partial $\eta^2=0.033$) (see Figure 2C). The contrast with Study 2 was further qualified by additional analysis merging the two datasets in a single ANOVA with Study (Study 2; Study 3) as between-subjects factor. While we found a significant Rhythm x Study interaction ($F(2,110)=7.32$, $p=0.001$, partial $\eta^2=0.117$), neither the main effect of Rhythm ($F(2,110)=1.86$, $p=0.16$, partial $\eta^2=0.033$) nor the main effect of Study ($F(1,55)=2.10$, $p=0.15$, partial $\eta^2=0.037$) were significant. As in the previous studies, we found no correlation between IAcc (M=50.80; SD=8.4) and the difference in trustworthiness ratings in the Self and the average of Other conditions ($r=-0.25$, $p=0.20$). Thus, contrary to Studies 1-2, Study 3 did not show a modulation in participants' judgments as a function of the presentation rhythm, suggesting that the phase (i.e systole) of the cardiac cycle in which synchronization occurs is crucial for the effects to take place.

General discussion

We investigated the role of cardio-visual stimulation on trustworthiness judgments. Faces presented in synchrony with the participant's heart rhythm (at systole) were chosen less often as more trustworthy (Study 1) and were explicitly judged as less trustworthy (Study 2) than those presented asynchronously. These patterns suggest an influence of ongoing interoceptive information when making social inferences from others' faces. Importantly, presenting faces synchronized with the participant's heart rhythm at diastole (Study 3) did not modulate participants' judgments, suggesting that the cardiac cycle phase is critical. Thus, the mere integration between the visual and cardiac modalities that may take place due to the temporal congruency between the two is not sufficient to modulate the processing of external social information, such as perceived trustworthiness. These results suggest a crucial role for the phasic cardiac afferent signals conveyed to the brain during systole in the modulation of social judgments. Together these results advance our understanding of the mechanisms underlying the integration of interoceptive and exteroceptive information via cardio-visual stimulation by highlighting the importance of phasic interoceptive information in the modulation of social judgments.

Indeed, heightened arousal has been associated with reduced perceived trustworthiness of others. For example, when judging trustworthiness of faces, participants tend to give lower trustworthiness ratings following a negative arousal induction procedure (Abbott, Middlemiss, Bruce, Smailes, & Dudley, 2018). Hooker et al (2011) also suggested that individuals in a heightened state of arousal perceive unfamiliar individuals as less trustworthy. The link between arousal and trustworthiness was further qualified in a study by Aguado and colleagues (2011) showing that untrustworthy faces were judged more negatively and as more arousing than trustworthy faces even after both types were conditioned to elicit positive associations. Our findings provide a mechanistic illustration of these patterns. Given that at systole one's own cardiac physiological information is accentuated, when faces are presented in a state of heightened physiological arousal are more likely to be perceived as less trustworthy.

In line with this, Li and colleagues showed that people tend to judge faces presented during systole (vs diastole) as less trustworthy in conditions of high attentional load (Li et al., 2020). We extend these findings by showing that biases in judgments can occur across constant attentional conditions, and that the critical process underlying cardiac modulation on trustworthiness judgments seem to be driven specifically by systole-related neurovisceral states rather than those occurring during diastole. In fact, standard cardiac cycle paradigms, such as that employed by Li and colleagues (2020), compare responses to stimuli presented at systole relative to those at diastole, making it difficult to ascertain which condition is driving the observed effects, e.g. whether "diastolic states" are associated with increased trust or "systolic states" with decreased trust. The dissociation observed between our Studies 2 and 3 disambiguates this pattern: these effects are indeed driven by phasic activity taking place during systole alone.

The specific cardio-visual effects observed on perceived trustworthiness reported here go beyond the multisensory integration process that seems to explain some of the past studies using cardio-visual stimulation (Aspell et al., 2013; Heydrich et al., 2018; Ronchi et al., 2015; Salomon et al., 2016). A key difference between these studies and the present one is the lack of social salience or relevance of the stimuli in the former studies. Judging trustworthiness is an important spontaneous inference made from facial appearance tightly related to threat evaluation and amygdala integrity and functioning (Adolphs et al., 1998). Such differential effects according to stimuli type are well known in the cardiac cycle literature (Azzalini et al., 2019; Garfinkel , 2016). Specifically, context-relevant salient stimuli, such as those likely to promote orienting responses, are more easily detected, engage additional attentional resources and are judged as more intense when perceived during systole (Azevedo et al., 2017; Garfinkel et al., 2020, 2014). Conversely, the processing of weak sensory stimuli (e.g. Motyka et al, 2019; Al et al, 2020) or those promoting withdrawal responses (e.g. Edwards, Ring, McIntyre, & Carroll, 2001;

Gray et al., 2009), are inhibited during systole. This is in line with known neuromodulatory systems tightly linked to arousal and autonomic feedback, such as the noradrenergic system, that selectively increase neural gain to the processing of contextually relevant stimuli and facilitate orienting responses (Aston-Jones & Cohen, 2005; Sara, 2009). Thus, the observed selective cardio-visual effect on trustworthiness judgments at systole is likely to go beyond simple interoceptive-exteroceptive integration and may reflect a neuromodulation of saliency and orienting systems driven by the cardiac cycle.

Despite these insights, our findings should be considered in light of the study's limitations and directions for future research. Firstly, our studies examined the role of cardio-visual stimulation on trustworthiness judgements, yet its impact on the processing of other types of social inferences from faces remains unknown. Future studies should investigate if ongoing afferent interoceptive signals also modulate the appraisal of other, non-threat related, social information from others' faces such as, for example, physical attractiveness. Furthermore, it remains unknown if other interoceptive dimensions, such as interoceptive sensibility or awareness (Garfinkel et al., 2015), may play a role on perceived trustworthiness or if they interact with the phase of cardio-visual synchrony.

In sum, across three experiments we demonstrate and substantiate an effect of cardiac-visual stimulation on the social evaluation of faces, and more specifically on trustworthy judgments. Moreover, we show that these effects only occur when cardio-visual coupling occurs during cardiac systole highlighting the importance of phasic interoceptive signals in the modulation of social judgments.

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