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Physiological evidence for a dual process model of the social effects of emotion in computers ☆

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ABSTRACT

There has been recent interest on the impact of emotional expressions of computers on people's decision making. However, despite a growing body of empirical work, the mechanism underlying such effects is still not clearly understood. To address this issue the paper explores two kinds of processes studied by emotion theorists in human–human interaction: inferential processes, whereby people retrieve information from emotion expressions about other's beliefs, desires, and intentions; affective processes, whereby emotion expressions evoke emotions in others, which then influence their decisions. To tease apart these two processes as they occur in human–computer interaction, we looked at physiological measures (electrodermal activity and heart rate deceleration). We present two experiments where participants engaged in social dilemmas with embodied agents that expressed emotion. Our results show, first, that people's decisions were influenced by affective and cognitive processes and, according to the prevailing process, people behaved differently and formed contrasting subjective ratings of the agents; second we show that an individual trait known as electrodermal lability, which measures people's physiological sensitivity, predicted the extent to which affective or inferential processes dominated the interaction. We discuss implications for the design of embodied agents and decision making systems that use emotion expression to enhance interaction between humans and computers.

1. Introduction

There has been growing interest in the development of embodied social agents that show emotion facial expressions (Bartneck and Reichenbach, 2005; Beale and Creed, 2009; Cassell et al., 1994; Gratch et al., 2002; Niewiadomski and Pelachaud, 2010). Part of this interest stems from findings that emotional facial expressions affect people's decisions in human–agent interactions (de Melo et al., 2014; Gong, 2007; Kiesler et al., 1996; Yuasa and Mukawa, 2007). These results are tantalizing because they reinforce more general findings that people can treat computers as social actors (Nass et al., 1994; Reeves and Nass, 1996) and be socially influenced by them (Blascovich and McCall, 2013; Blascovich et al., 2002). However, what is less clear is the mechanism by which emotional displays achieve these effects. In this paper we aim to shed light on this issue by teasing apart alternative theories of how computer emotion might impact human–computer interaction, thereby providing insight into the design of such systems.

1.1. Mechanisms for the social effects of emotion expressions

Emotion researchers have proposed two basic theories on how emotion expressions influence decision making in human–human interaction (Parkinson and Simons, 2009; Van Kleef et al., 2010). One theory argues for *inferential* processes whereby people retrieve from emotional facial expressions information about the other party's beliefs, desires and intentions (Frijda and Mesquita, 1994; Keltner and Kring, 1998; Morris and Keltner, 2000), and people rationally use this information to reach social decisions (de Melo et al., 2014; Sinaceur and Tiedens, 2006; Van Kleef et al., 2004, 2006). For instance, Van Kleef et al. (2004) showed that people negotiating with angry counterparts inferred the others to have high aspirations and, so as to avoid costly impasse, strategically conceded more. In contrast, when people engaged with guilty counterparts, people inferred others to be in debt and strategically conceded less (Van Kleef et al., 2006). In the prisoner's dilemma,

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de Melo et al. (2014) showed that people could also make, from emotional expressions, appropriate inferences about the others' mental states and retrieve information about the counterparts' likelihood of cooperation.

The other theory argues for *affective* processes whereby emotion begets emotion, that is, emotional expressions by one party evoke emotions in the other, and these evoked emotions influence decision making. The prototypical example of an affective process is emotional contagion or mimicry (Hatfield et al., 1994; Niedenthal et al., 2010) which is said to occur due to people's natural tendency to automatically mimic and synchronize with others' facial expressions, vocalizations and postures; afferent feedback from mimicked behavior, then, leads to the experience of similar emotions. After catching others' emotions, people's decisions might be influenced, for instance, by (mis)attributing the current affective state to the current context (i.e., the affect-as-information heuristic; Schwarz and Clore, 1983). As an example, Parkinson and Simons (2009) showed that people's decisions in daily life were influenced by others' emotional expressions; moreover, these decisions were mediated, on the one hand, by information retrieved from emotion expressions (i.e., an inferential process) and, on the other hand, by own emotions (i.e., an affective process).

We draw on these two theories for our investigation of human–computer interaction. Our earlier work has presented evidence that supports the existence of inferential processes (de Melo et al., 2014); however, this work did not focus on the role of affective processes and did not present any physiological evidence. In this paper, we try to differentiate these two alternative mechanisms and we consider two related questions: Do people engage affectively or cognitively with expressive animated agents? And, according to the prevailing mechanism, how are decisions influenced? To accomplish this, we examine people's physiological and behavioral responses to agent expressions in the context of social decision making.

1.2. *Psychophysiology of emotion*

There is still much debate about whether it is possible to distinguish discrete emotions (e.g., anger, joy) based on patterns of automatic physiological responses (Larsen et al., 2008; Cacioppo et al., 2000). In contrast, other researchers have looked at dimensional theories of emotion (e.g., Mehrabian, 1996; Russell, 1980) and tried to find the physiological correlates for dimensions underlying discrete emotions, such as arousal and valence. We followed the latter approach in this work and looked at two physiological measures that, in decision making contexts, have shown promising correlation with arousal and valence, namely electrodermal activity (EDA) and heart rate (HR) deceleration.

Electrodermal activity, or skin conductance, measures electrical conductance of the skin, as sweating occurs (Dawson et al., 2007). In particular, sweat glands on the palmar or plantar surfaces have been shown to be more responsive to psychologically significant stimuli than thermal stimuli. This response system has also been linked with emotion and arousal. Lang et al. (1998) have developed a set of widely used pictures (the International Affective Picture System, or IAPS) that have been rated for arousal and valence. EDA elicited by these pictures have reliably been shown to relate to the arousal dimension, with response magnitude correlating with arousal ratings (both for negatively and positively rated pictures). In a series of studies with embodied social agents that showed empathy, Prendinger and colleagues demonstrated the usefulness of measuring EDA to infer the user's arousal and frustration level when engaging in a quiz (Mori et al., 2003) or cards game (Prendinger and Ishizuka, 2007; Prendinger et al., 2006). In a decision making context, van't Wout et al. (2006) showed that EDA increased just before unfair offers were rejected in the ultimatum game, which they interpreted to support the contention that people experience anger when faced with unfairness (Pillutla and Murnighan, 1996; Sanfey et al., 2003). However, Osumi and Ohira (2009) complemented this work by showing that EDA also increases when fair offers are made, which they took to reflect positive emotions related to an upcoming reward. Thus, the key determinant for EDA seems to be the arousal associated with an emotion, rather than valence.

Heart rate is a psychophysiological measure related to autonomous nervous system activity and it has been used before to study emotion in human–computer interaction (Peter and Herbon, 2006). In particular, heart rate deceleration has recently been shown to provide insight on the valence of the emotional experience. Heart rate deceleration is a classic physiological index of the orienting response (Graham, 1979). The argument is that cardiac deceleration helps the organism focus on novel or significant stimuli. After this period of sensory intake and processing, the heart rate may accelerate so as to prepare the organism for a defensive response (e.g., flight at the sight of a predator). Researchers are beginning to find that HR deceleration also has affective significance. Several studies have found large HR deceleration in response to negative emotional stimuli (Anttonen and Surakka, 2005; Bradley and Lang, 2000; Bradley et al., 1996, 2001; Codispoti et al., 2001; Lang et al., 1997, 1993; Peter and Herbon, 2006; Sánchez-Navarro et al., 2006). In contrast, HR deceleration is less pronounced with positive emotional stimuli (Bradley et al., 2001; Codispoti et al., 2001; Sánchez-Navarro et al., 2006) or nonexistent (Azevedo et al., 2005; Bernat et al., 2006; Ritz et al., 2002). These findings are in line with a meta-review of physiological correlates of emotion (Cacioppo et al., 2000) that suggests changes associated with negative stimuli tend to be larger than with positive stimuli, a discrepancy that has been referred to as the "negativity bias" (Cacioppo and Berntson, 1994). HR deceleration has also been shown to occur with unfair, but not with fair, offers in the ultimatum game (Osumi and Ohira, 2009). Even though research on the emotional significance of HR deceleration is still in its infancy, here we look at HR deceleration to gather further insight on the participants' emotional experience, in particular, regarding emotional valence.

1.3. *Individual differences in physiological sensitivity*

To understand whether people's decisions will be predominantly influenced by affective or inferential processes, we look at a personality trait known as *electrodermal lability* (Crider, 1993; Dawson et al., 2007; Lacey and Lacey, 1958; Mundy-Castle and McKiever, 1953), and divide participants into 'highly sensitive' (HS) and 'less sensitive' (LS) groups. This individual trait is characterized by the rate of habituation of EDA responses and the rate of EDA associated with the absence of identifiable eliciting stimuli. Electrodermal "labiles", or highly sensitive people, are participants that show high occurrence of non-stimuli EDA and slow EDA habituation; on the other hand, electrodermal "stabiles", or less sensitive people, show low occurrence of non-stimuli EDA and fast EDA habituation. This trait has been shown to be relatively stable over time, and labiles differ from stabiles with respect to important psychophysiological variables (Katkin, 1975; Kelsey, 1991; Schell et al., 1988). Electrodermal lability has been shown to enhance attention and performance in tasks which require sustained vigilance (Crider and Augenbraun, 1975; Davies and Parasuraman, 1982; Hastrup, 1979; Munro et al., 1987; Vossel and Rossman, 1984) and facilitate continuous information processing of novel and significant stimuli (Lacey and Lacey, 1958; Katkin, 1975; Schell et al., 1988). We, thus, expect HS individuals to experience more physiological reactivity, including affective experiences, than LS individuals;

consequently, we expect HS individuals' decision making to be predominantly influenced by affective processes and LS individuals' decisions to be predominantly influenced by inferential processes.

1.4. Overview and general hypotheses

The literature in human–human interaction suggests that the effects of emotion expressions can be achieved through inferential and affective processes (Parkinson and Simons, 2009; Van Kleef et al., 2010). In our approach, we look at participants' physiological reactions and behavior to determine which processes are at play in a human–computer interaction setting. Building on previous work that has looked at physiological reactions to make inferences about participants' emotions (Bradley et al., 2001; Lang et al., 1998; Mori et al., 2003; Osumi and Ohira, 2009; Peter and Herbon, 2006; Prendinger and Ishizuka, 2007; Prendinger et al., 2006; van't Wout et al., 2006), we look at EDA and HR to determine whether affective processes are involved. We then integrate physiological with behavioral data to further tease apart whether participants' decisions were being driven by inferential or affective processes. Finally, we establish that an individual trait – electrodermal lability – can predict which of these processes is likely to dominate.

We use social dilemmas as an experimental framework to study the effects of emotion expressions on people's decision making. Social dilemmas are situations where one must decide between behaving selfishly or cooperating and trusting that others will do so as well (Kollock, 1998). Social dilemmas are characterized by a deficient equilibrium, i.e., everybody has a rational – i.e., utility maximizing (von Neumann and Morgenstern, 1944) – incentive to defect but, if everybody did so, then everybody would be worse off. Researchers have argued that, in such dilemmas, people look for social cues that others are likely to cooperate and facial displays of emotion are one such cue (Frank, 1988, 2004; Nesse, 1990; Trivers, 1971). Accordingly, in a human–computer interaction setting, de Melo et al. (2014) showed that people were more likely to cooperate in the prisoner's dilemma when facing a computer that showed cooperative displays (e.g., joy after mutual cooperation) than competitive displays (e.g., joy after exploiting the participant). This earlier work, however, did not measure participants' physiology and did not try to tease apart the roles of affective and inferential processes.

Our general hypotheses in the present work were that (H1) affective and inferential processes can lead to different effects of computers' emotion on people's decisions, (H2) affective and inferential processes can lead to different subjective ratings of computers that express emotions and, finally, (H3) highly sensitive individuals are predominantly influenced by affective processes, whereas less sensitive individuals are predominantly influenced by inferential processes.

To test these hypotheses, we present two novel experiments where participants engaged in social dilemmas with embodied agents that showed facial expressions of emotion. In each case we measured participants' physiological reactions – as measured by EDA and HR deceleration – and whether people's behavior and subjective ratings of the agents were influenced by emotion displays. In a pilot experiment, people engaged in the assurance game, in a repeated measures design, with a cooperative (e.g., shows joy after mutual cooperation), competitive (e.g., shows joy after exploiting the participant), and control agents. This experiment demonstrated that both affective and inferential processes were at play in this type of interaction. In the main experiment, we teased apart these two processes by having people interact in the prisoner's dilemma, in a repeated measures design, with three carefully designed agents: a strong agent that punished non-cooperation from the participant, through corresponding emotion displays (e.g., anger after being exploited by the participant); a soft agent that reinforced cooperation (e.g., regret after exploiting the participant); and, a cooperative agent that both reinforced cooperation and punished non-cooperation. The results showed that people whose decision making was predominantly driven by affective processes displayed different cooperation behavior and formed different subjective ratings than those whose decisions were driven by inferential processes.

2. Pilot experiment

In a pilot experiment, participants engaged in the assurance game with emotional embodied agents that, despite following the same strategies to choose their strategies, expressed cooperative, competitive or no emotion displays. Following previous findings that suggest people are sensitive to the goal orientation of emotion expressions (de Melo et al., 2014), we expected people to cooperate more with the cooperative than the competitive agents, and that people's subjective ratings would also favor the cooperative agents. Previous research had already shown that emotion expressions can influence people's decisions in a social dilemma through inferential processes (de Melo et al., 2014); we wanted to clarify whether affective processes also play a role.

2.1. Method

2.1.1. Task

Participants engaged in the assurance game (Kollock, 1998), which is a two-player game where players have to make a simultaneous decision to either cooperate or defect. According to their choices, different payoffs ensue. We used a standard payoff matrix for the assurance game (Table 1). The game is characterized by two equilibria: mutual cooperation, which is payoff dominant since it maximizes the collective payoffs; and mutual defection, which is risk dominant since it provides the greatest individual payoff if there is uncertainty about the other player's action (Harsanyi and Selten, 1988). Thus, the game is

Table 1
Payoff matrix for the assurance game (pilot experiment).

		Agent			
		Cooperation		Defection	
Participant	Cooperation	Agent	10 pts	Agent	5 pts
		Participant	10 pts	Participant	0 pts
	Defection	Agent	0 pts	Agent	5 pts
		Participant	5 pts	Participant	5 pts

Table 2
The emotion displays for the cooperative, competitive and control agents (pilot experiment).

		Agent	
		Cooperation	Defection
(a) Cooperative			
Participant	Cooperation	Joy	Anger
	Defection	Neutral	Neutral
(b) Competitive			
Participant	Cooperation	Anger	Joy
	Defection	Neutral	Neutral
(c) Control			
Participant	Cooperation	Neutral	Neutral
	Defection	Neutral	Neutral

Fig. 1. The embodied agents' facial displays used in our experiments.

a dilemma because cooperation is only a dominant strategy if each player is assured the other won't defect. Participants engaged in this task for 25 rounds with each agent. There was no time constraint on each round of the game. Participants were told there would be no communication between the players before choosing an action and, that the other player would make his or her decision without knowledge of the participant's choice. After the round was over, the action each chose was made available to both players and the outcome of the round, i.e., the number of points each player got, was shown. Participants were instructed that their goal was to maximize their points over all rounds. Finally, similarly to Kiesler et al. (1996), we recast the game as an investment game, thus avoiding labels such as "cooperation" or "defection".

2.1.2. Conditions

Participants engaged in a repeated measures design with three kinds of agents that showed different patterns of emotion displays. Following de Melo et al. (2014)'s previous findings, the *cooperative* agent (Table 2a) expressed joy after mutual cooperation, anger after exploiting the participant, and nothing otherwise; the *competitive* agent (Table 2b) expressed anger after mutual cooperation, joy after exploiting the participant, and nothing otherwise; finally, the *control* agent (Table 2c) expressed no emotion. These patterns of emotion expressions reflect the importance of context for the interpretation of emotion displays (Aviezer et al., 2008; Hareli and Hess, 2010; Lanzetta and Englis, 1989; Van Kleef et al., 2010): joy, which reflects progress toward the realization of one's goals (Lazarus, 1991), suggests a cooperative goal orientation if displayed after mutual cooperation, but a competitive orientation if displayed after exploiting the participant; anger, which reflects strong dissatisfaction with the current state-of-affairs (Averill, 1982), was found to increase expectations of cooperation after the outcome where the participant is exploited and decrease expectations of cooperation after mutual cooperation (de Melo et al., 2014). All emotional expressions were generated based on a pseudo-muscular model of the face that supports wrinkles and blushing (de Melo and Gratch, 2009). Different faces were assigned to each condition, in a counterbalanced fashion. We used the same emotion facial displays that were validated and used in de Melo et al. (2014)'s experiments. Fig. 1 shows the expressions for one of the faces we used and Fig. 2 shows a screenshot of the game.

Independently of the emotion displays, agents always followed the same strategy to choose their actions: tit-for-tat, starting with a defection. The rationale for starting with a defection comes from previous research that shows that initial toughness followed by cooperation is more effective at eliciting cooperation than cooperation from the start (Bixenstine and Wilson, 1963; Hilty and Carnevale, 1993).

2.1.3. Procedure

The experiments took about one and a half hours and proceeded as follows. Upon arrival, the participants received an overview of the study, at which time they could ask any questions about the purpose of the study, the experimental procedures, and what was expected of them. They read and, if they agreed to participate, gave informed consent. Participants then filled out a pre-questionnaire inquiring about their background and demographic information.

Participants in all conditions were seated in front of a 60-in. computer monitor connected to a main computer as shown in Figs. 2 and 3. The experiment was conducted in a room with constant lighting and temperature. The physiological sensors were attached to the subjects' fingertips. Physiological data were acquired using a BIOPAC MP150 (BIOPAC Systems, Inc., Goleta, CA, USA), which included a PhotoPlethysmoGraph (PPG) for HR and an EDA reader for changes in sweat gland activity. The sensors were placed on the fingertips of the non-dominant hand; the index and ring fingers (EDA) and thumb (PPG). The other hand was left unencumbered to allow the user to make decisions in the game using a mouse.

Before running the game, participants watched a set of pictures from the International Affective Picture System (Lang et al., 1998), or IAPS. We selected 36 pictures from IAPS: 12 pictures labeled 'pleasant', 12 'neutral', and 12 'unpleasant'. The pictures were shown in random order. Each picture was shown for 6 s, followed by a black screen for 6 s. We used pleasant pictures, characterized by a valence rating of 7.658, arousal rating of 6.099, and dominance rating of 5.838 on the basis of a self-report scale of 1 to 10; the neutral pictures had ratings of 4.844 for valence, 2.332 for arousal, and 6.142 for dominance; finally, the negative pictures had ratings of 1.798 for valence, 6.883 for arousal, and 2.885 for dominance. These pictures were used to evoke positive, neutral, and negative emotions. We used participants' reactions to images in IAPS as a manipulation check that compared our measures of EDA and HR deceleration for positive and negative pictures with those reported in the literature (Bradley et al., 2001). More importantly, physiological reactivity in IAPS was used to classify participants as HS or LS. We used *k*-means clustering on EDA values to accomplish this. The rationale for classifying participants using the IAPS data, rather than physiological data obtained during the game, is two-fold: (a) IAPS is a standard dataset of pictures that has been used many times to elicit physiological reactions in participants (Lang et al., 1998); (b) using an independent dataset to classify participants avoids circular reasoning if we later want to argue that HS and LS participants are influenced differently by inferential and affective processes in the game.[1]

After a waiting period, participants played a tutorial for the game, followed by the actual game with the cooperative, competitive and control agents, in a counterbalanced order. Upon

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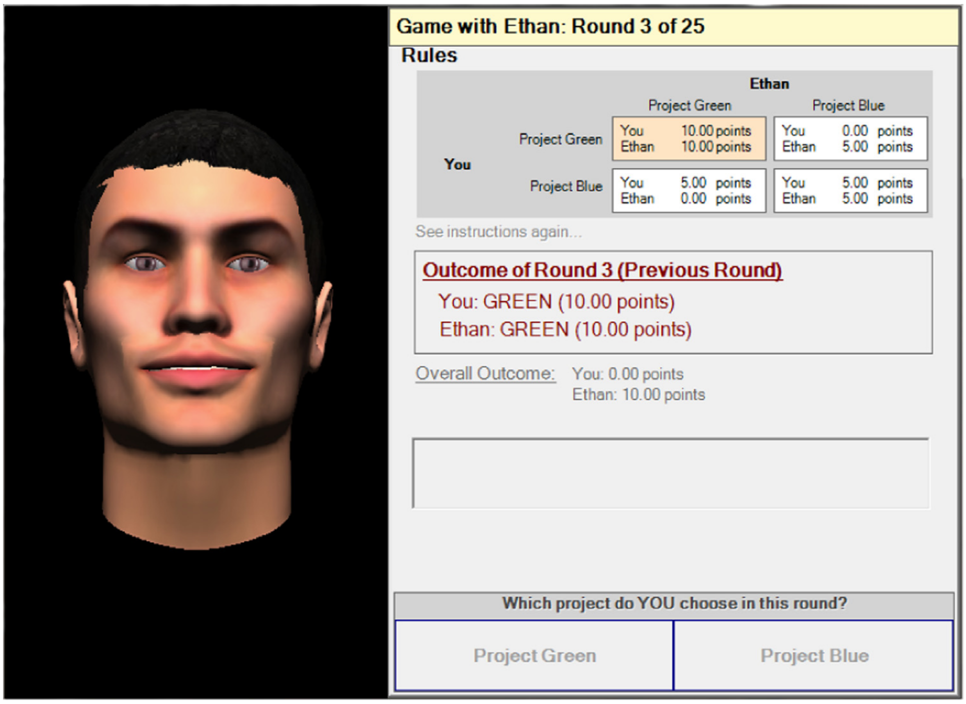
[1] This is particularly relevant in the main experiment where we show that participants with different electrodermal profiles reach different decisions because they are influenced by different emotion processes.



Game with Ethan: Round 3 of 25

Rules

		Ethan	
		Project Green	Project Blue
You	Project Green	You 10.00 points Ethan 10.00 points	You 0.00 points Ethan 5.00 points
	Project Blue	You 5.00 points Ethan 0.00 points	You 5.00 points Ethan 5.00 points

See instructions again...

Outcome of Round 3 (Previous Round)

You: GREEN (10.00 points)

Ethan: GREEN (10.00 points)

Overall Outcome: You: 0.00 points

Ethan: 10.00 points

Which project do YOU choose in this round?

Fig. 2. Screenshot of the game in the pilot experiment.

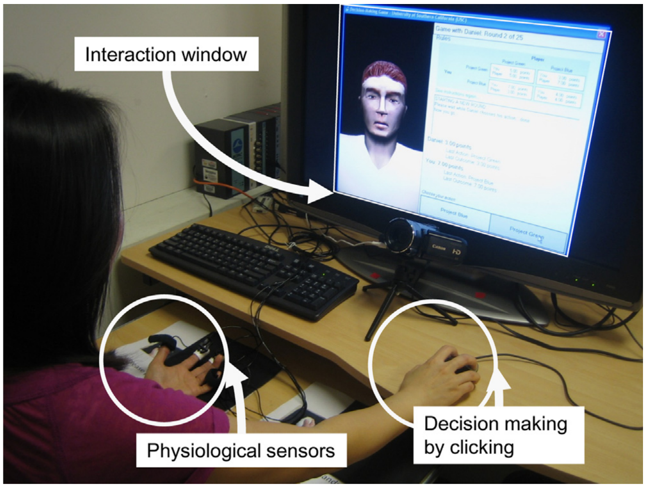


Fig. 3. Experimental setup for our experiments.

finishing the game, participants were asked to answer a post-questionnaire.

2.1.4. Measures

Our physiological measures were EDA and HR deceleration. Regarding EDA, intensity was used. We transformed EDA intensity with a log transformation; $\log(\mu S+1)$ (Dawson et al., 1990). Finally, following Bradley et al. (2001)'s analysis protocol, we averaged each of the first 6-s window across each round. We checked for the presence of outliers with a normality test assuming that all physiological signal distributions followed a Gaussian distribution and removed outliers. Then, we estimated the current physiological distribution that maximized the probability by assuming a Gaussian mixture model. Regarding HR deceleration, we looked at the trend from 0 to 6 s. Regarding behavioral measures, we looked at cooperation rate, i.e., the number of times participants cooperated over all rounds. Regarding subjective measures, we included the person perception scale (Bente et al., 1994), which consists of pairs of words that measure people's impressions of the agents – for example, likable-dislikable, kind-cruel, and friendly-unfriendly.

2.1.5. Data analysis

To analyze the data we followed a four-step strategy: first, we split participants according to their electrodermal lability using data from IAPS; second, to understand whether inferential and affective processes were involved, we looked at the physiological reactions of HS and LS participants in the game; third, to understand the behavioral effects, we ran an Electrodermal Lability × Emotion Expressions mixed ANOVA on cooperation rate; and, finally, to understand the effects on subjective impressions, we compared HS and LS participants' ratings on the person perception scale.

2.1.6. Participants

We recruited 80 volunteers from a public website (http://losangeles.craigslist.org/) during a period of about 2 months. A total of 49 men and 31 women participated in the study. Their average age was 33.25 years old. One participant did not finish the study and, thus, was excluded from analysis. Participants were paid $35.00 as compensation for their time.

2.2. Results

The results for physiological measures regarding participants' reactions when watching positive, negative and neutral pictures in IAPS are shown in Fig. 4. We observed a similar pattern for EDA as the one previously reported in the literature (Bradley et al., 2001): there was significantly increased EDA intensity for positive and negative pictures when compared with neutral pictures, $F(2, 1855)=75.885$, $p<0.001$. We then used participants' EDA reactions in IAPS to measure the electrodermal lability trait and classify them as either HS or LS. Analysis of heart rate also confirmed that HS individuals where experiencing higher deceleration with negative than positive pictures

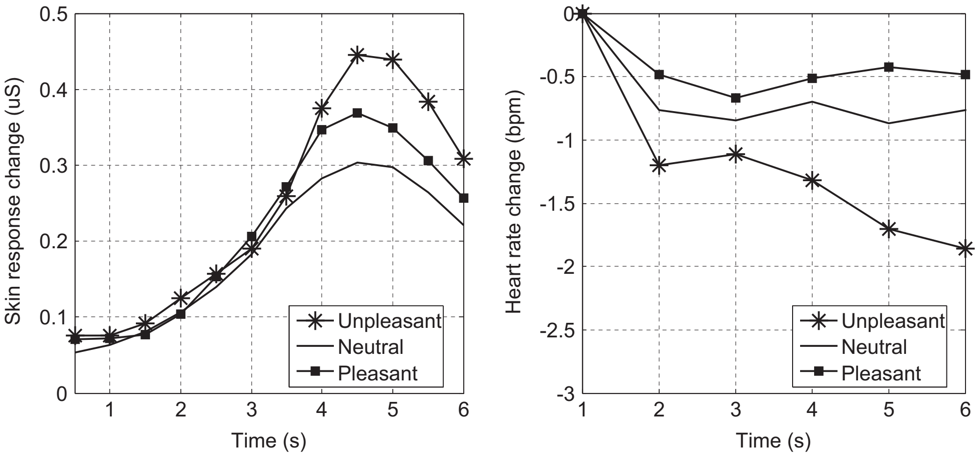


Fig. 4. Physiological reactions to positive, negative and neutral pictures in IAPS (pilot experiment). Curves show average across all participants. Electrodermal activity is shown on the left, and the 6-s window for heart rate change on the right.

($p < 0.05$), which is in line with previous results in the literature (Bradley et al., 2001); in contrast, LS individuals did not show distinct HR deceleration with negative and positive pictures ($p > 0.05$).

We proceeded to look at the physiological reactions to facial expressions in the game. Specifically, we analyzed EDA and HR deceleration for every combination of emotion display and outcome because the arousal and valence patterns of these features were well matched with previous findings. Fig. 5 shows the comparison with the neutral expression for the cases of joy in mutual cooperation (CC-Joy), joy when the participant was exploited (C_PD_A-Joy), anger in mutual cooperation (CC-Anger), and anger when the participant was exploited (C_PD_A-Anger). As expected, the results confirmed that HS individuals experienced more arousal, as measured by EDA, than LS individuals (Fig. 5, on the left). In general, this happened independently of whether emotion was expressed (e.g., CC-Joy) but, at times, emotion expression further increased EDA when compared to the neutral expression (e.g., C_PD_A-Joy). HS individuals also displayed higher HR deceleration than LS individuals (e.g., C_PC_A-Anger) but, these reactions were more subtle.

Table 3 shows cooperation rates for HS and LS participants. We ran an Electrodermal Lability × Emotion Expressions mixed ANOVA. The results showed a marginal main effect of Emotion Expressions, $F(2, 154)=2.533$, $p=0.083$, partial $\eta^2=0.032$. Post-hoc Bonferroni tests revealed that people were cooperating, as expected, more with cooperative than competitive agents ($p=0.064$); the differences with respect to the control agent were not significant. The results showed no main effect of Electrodermal Lability, $F(2, 154)=0.440$, $p=0.645$, and no significant Electrodermal Lability × Emotion Expressions interaction, $F(2, 154)=0.040$, $p=0.842$. Thus, the results suggest that HS and LS individuals displayed similar cooperation behavior in this experiment.

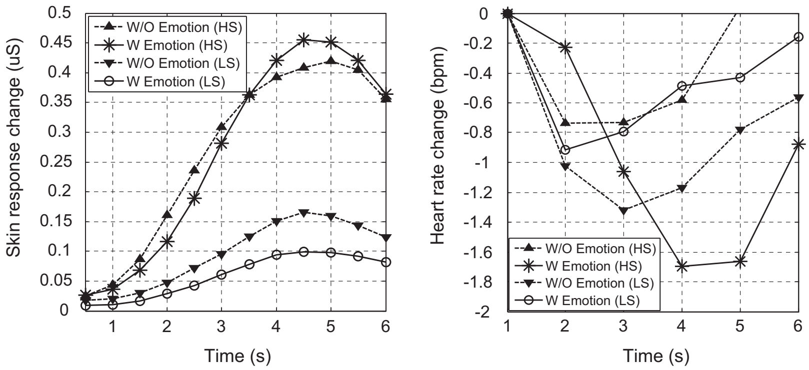
Finally, the person perception subjective ratings are shown in Table 4. The results indicated that HS participants had a positive perception of the cooperative agents but a negative perception of the competitive agents. On the other hand, LS participants did not show significant differences between the agents.

2.3. Discussion

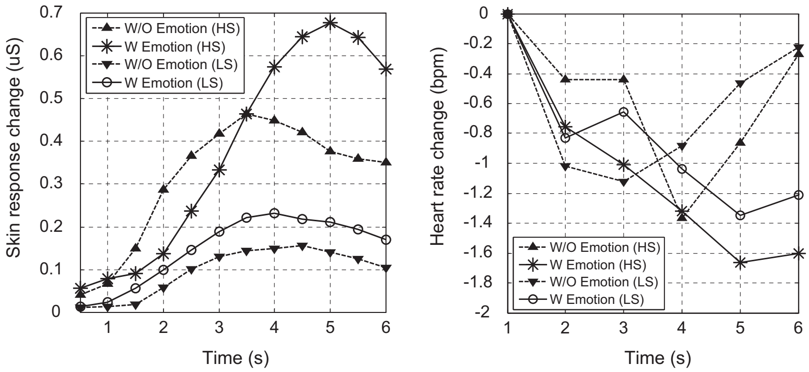
The results looked at participants' electrodermal signatures on a standard task (IAPS) and confirmed the existence of two kinds of people (Crider, 1993; Dawson et al., 2007; Lacey and Lacey, 1958; Mundy-Castle and McKiever, 1953): HS and LS. Our results show that HS individuals also displayed higher physiological reactivity when they subsequently engaged in the assurance game with emotional embodied agents. Following previous findings (e.g., Bradley et al., 2001; Osumi and Ohira, 2009), we looked at patterns of EDA and HR deceleration to gather insight on arousal and valence. Since arousal and valence can be interpreted as dimensions of emotion (Mehrabian, 1996; Russell, 1980), the results suggest that HS individuals experienced more emotion than LS individuals. This, in turn, provides support that affective and inferential processes were involved (Hypothesis 3).

The results for cooperation rate revealed a (marginal) main effect of emotion displays with people cooperating more with cooperative than competitive agents. This result is in line with de Melo et al. (2014) previous findings. Whereas it seems clear that LS individuals reach this behavior through inferential processes (i.e., treat emotion expressions as information about the others' intentions; de Melo et al., 2014), it is less clear whether HS individuals are reaching this behavior through affective processes. One possibility is that, despite experiencing emotion, they ignore it and still reach decisions through inferential processes (e.g., Van Kleef et al., 2004). An alternative possibility is that they are being influenced by affective processes, but this leads to the same prediction as inferential processes. We suspect the latter is occurring. The reason affective processes predict more cooperation with the cooperative than the competitive agent could be explained by looking at the structural characteristics of the assurance game. In this game, mutual cooperation and mutual defection are behaviorally reinforcing (Kollock, 1998) and, as expected, occurred more frequently than either the outcome where the participant was exploited or the outcome where the participant exploits. This means that participants experienced, in practice, more joy with the cooperative agent and, in turn, more anger with the competitive agent. Thus, according to affective processes, joy leads to joy and, thus, motivates more cooperation; and, anger leads to anger and, thus, less cooperation. The ratings for subjective impressions seem to further support our contention.

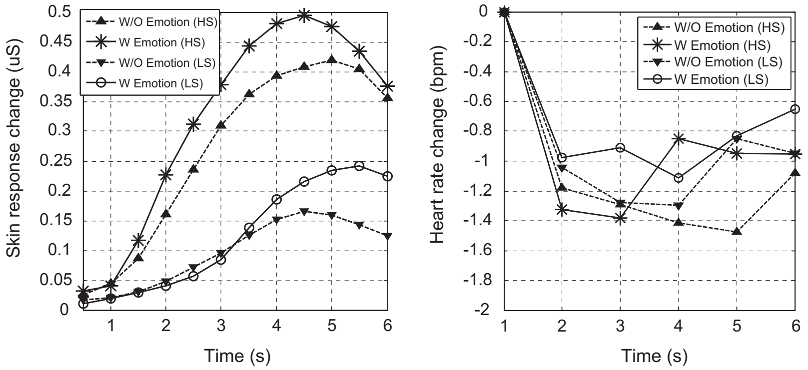
The results for the person-perception scale showed that HS individuals made distinct subjective impressions of cooperative agents, when compared to competitive agents. This is in line with earlier research that shows that felt emotion can impact perceptions of others (Kenny, 2004). In contrast, LS individuals did not distinguish cooperative and competitive agents with respect to subjective impressions. The result, thus, suggests that different emotion processes can have a different impact on subjective impressions of others (Hypothesis 2).



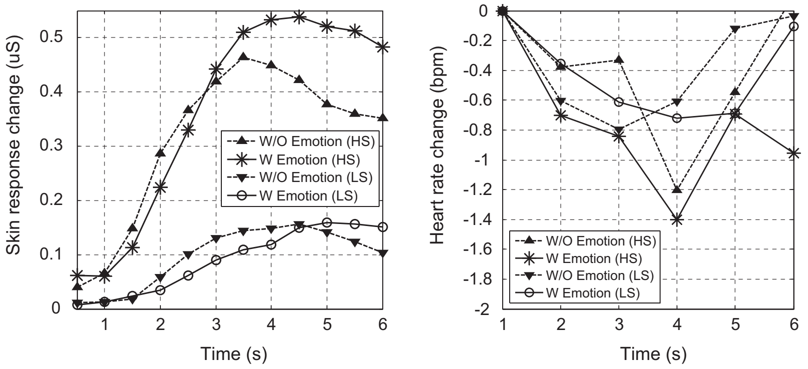
CC-Joy vs CC-Neutral



C_PD_A -Joy vs C_PD_A -Neutral



CC-Anger vs CC-Neutral



C_PD_A-Anger vs C_PD_A -Neutral

Fig. 5. Physiological reactions to the emotion displays in the game for highly sensitive and less sensitive people (pilot experiment). Electrodermal activity is shown on the left, and the 6-s window for heart rate change on the right.

3. Main experiment

The pilot experiment showed that inferential and affective processes are at play when people engage with computers in decision making settings and suggested that these processes can lead to distinct subjective impressions. Nevertheless, the experiment had a few limitations which we sought to address in the main experiment. First, we improved the emotional patterns we used in our agents, as some of the earlier ones did not have a clear interpretation (e.g., anger following mutual cooperation). Second, because of the structural issues in the assurance game mentioned in the previous discussion, we used the prisoner's dilemma in the main experiment. Finally, the pilot experiment failed to show an effect on people's behavior. One of the main objectives of the main experiment was to show that inferential and affective processes can lead to distinct behavior.

To accomplish this, following de Melo et al. (2014) previous findings, participants engaged with three new types of agents (Table 6): the *strong* agent (Table 6a), which only showed emotions that punished non-cooperation – anger after the participant exploited the agent and sadness in mutual defection; the *soft* agent (Table 6b), which only showed emotions that reinforced cooperation – joy after mutual cooperation and regret after exploiting the participant; and, the *cooperative* agent (Table 6c), which combines the emotions shown by the previous two.

Our expectation was that these emotion patterns would impact people's decisions differently according to affective or inferential processes. Specifically, through affective processes people were expected to catch the agent's emotion (Hatfield et al., 1994) and thus: (1) cooperate the most with soft agents, since they only experience reinforcing positive emotion with them; (2) cooperate the least with strong agents, since they only experience negative emotion with them; and, (3) cooperate at an intermediary level with cooperative agents. In contrast, through inferential processes, we expected people to behave more strategically (Van Kleef et al., 2004, 2006, 2010): with soft agents, despite seeing joy in mutual cooperation, the display of regret following the case where they exploit the participant would be more predominant and lead people to exploit them (Van Kleef et al., 2006); with strong agents, since they show negative emotion when the participant defects, people would infer them to have high aspirations and, thus, concede by cooperating; finally, cooperative agents would provide the clearest information about their intentions – through displays that both reinforce cooperation and punish non-cooperation – and, thus, people would cooperate the most with them.

3.1. Method

People engaged in the iterated prisoner's dilemma (Poundstone, 1993). This is a two-player task where the payoffs of each player depend on the simultaneous choice of both players. A standard payoff matrix for this task was used and is shown in Table 5. The task represents a dilemma because the rational (i.e., utility-maximizing) choice for both players is to defect, which results in an outcome (mutual defection) that is worse than mutual cooperation. Thus, one would only cooperate when there was evidence that others intend to cooperate (Frank, 2004). Following the approach by Kiesler et al. (1996), the prisoner's dilemma was recast as an investment game. Each participant played this game for 25 rounds. A tutorial was also presented to the participants before actually starting the game.

Participants engaged in a repeated measures design with the strong, soft and cooperative agents (Table 6). The emotional expressions were, once again, generated using a pseudo-muscular model of the face (de Melo and Gratch, 2009), and the expressions were validated elsewhere (de Melo et al., 2014). All agents followed a tit-for-tat strategy, starting with defection.

The experiment followed the same procedure as in the pilot experiment with participants engaging in sequence in the pre-questionnaire, IAPS, tutorial, game and post-questionnaire.

Table 3
Cooperation rates in the pilot experiment.

Electrodermal lability	*n*	Cooperative		Control		Competitive	
		M	*SD*	*M*	*SD*	*M*	*SD*
Highly sensitive	40	0.411	0.288	0.351	0.311	0.334	0.306
Low sensitive	39	0.397	0.291	0.391	0.320	0.345	0.318

Table 5
Payoff matrix for the prisoner's dilemma (main experiment).

		Agent			
		Cooperation		Defection	
Participant	Cooperation	Agent	5 pts	Agent	7 pts
		Participant	5 pts	Participant	3 pts
	Defection	Agent	3 pts	Agent	4 pts
		Participant	7 pts	Participant	4 pts

Table 4
Person perception subjective ratings in the pilot experiment.

	Highly sensitive				Less sensitive			
	Coop.	Control	Comp.	Sig.	Coop.	Control	Comp.	Sig.
Friendly	0.950	0.400	−0.750	0.040*	1.000	0.615	0.667	0.567
Warm	0.800	0.125	−0.150	0.052	0.923	0.179	0.578	0.150
Reliable	1.300	1.075	0.325	0.034*	1.641	1.932	1.617	0.916
Involved	1.475	0.100	1.375	0.000*	1.153	0.564	1.410	0.090
Sensitive	0.800	0.250	−0.175	0.056	0.410	−0.230	0.410	0.148
Humble	0.250	0.500	−0.725	0.007*	0.589	0.153	−0.153	0.131
Sympathetic	0.675	0.225	−0.500	0.021*	0.076	0.025	0.307	0.672
Tender	0.400	0.150	−0.550	0.025*	0.205	−0.051	0.051	0.731
Arrogant	0.000	−0.150	0.775	0.053	0.333	0.359	0.487	0.905
Conceited	0.025	−0.475	0.500	0.056	0.102	0.282	0.461	0.617
Quiet	0.150	1.400	0.025	0.000*	0.589	1.076	0.435	0.190
Calm	0.875	1.525	0.575	0.004*	0.812	1.128	0.692	0.313

Note. Scale: −3, mostly negative attributes; +3, mostly positive attributes.

* $p < 0.05$.

Table 6
The emotion displays for the cooperative, strong and soft agents (main experiment).

		Agent	
		Cooperation	Defection
(a) Strong			
Participant	Cooperation	Neutral	Neutral
	Defection	Anger	Sadness
(b) Soft			
Participant	Cooperation	Joy	Regret
	Defection	Neutral	Neutral
(c) Cooperative			
Participant	Cooperation	Joy	Regret
	Defection	Anger	Sadness

We collected the same physiological, behavioral and subjective measures.

Fifty volunteers were recruited from Craigslist over a 2-month period; each was paid \$20.00 as compensation for their time. A total of 35 men and 15 women participated in the study (average age was 33.4 years). Some data was removed because of errors in their physiological responses.

3.2. Results

As in the pilot experiment, we determined participants' electrodermal lability according to EDA measurements when watching pictures in IAPS. We then looked at HS and LS participants' physiological reactions to the agents' facial expressions (Fig. 6). Our results showed, once again, that HS individuals had higher physiological reactivity than LS individuals, with respect to arousal (EDA) and valence (HR deceleration). For instance, when the participant exploited the agent, HS individuals experienced higher arousal and higher HR deceleration (i.e., negative valence) when anger was shown by the agent than when nothing was shown, $F(2, 1128)=5.438$, $p=0.004<0.05$; this suggests these participants were experiencing a negative affective reaction to the strong agent's display of anger. In contrast, for the same case, LS individuals showed much less physiological reaction.

Table 7 shows the cooperation rates for HS and LS participants. We ran an Electrodermal Lability × Emotion Expressions mixed ANOVA. The results showed a significant main effect of Emotion Expressions, $F(2, 96)=12.868$, $p<0.001$, partial $\eta^2=0.211$, and also a main effect of Electrodermal Lability, $F(1, 48)=25.042$, $p<0.001$, partial $\eta^2=0.343$—LS individuals cooperated more than HS individuals. As hypothesized, there was a significant Electrodermal Lability × Emotion Expressions interaction, $F(2, 96)=26.734$, $p<0.001$, $\eta^2=0.358$. To get further insight into this interaction we ran one-way ANOVAs for each level of Electrodermal Lability: for HS individuals, $F(2, 47)=13.183$, $p<0.001$; for LS individuals, $F(2, 47)=24.272$, $p<0.001$. Post-hoc analysis results showed that HS individuals cooperated significantly more with the cooperative than the strong agent ($p=0.012$), and more with the soft than the strong agent ($p<0.001$). In contrast, LS individuals cooperated more with the cooperative than the strong ($p<0.001$) and soft ($p=0.001$) agents; additionally, they cooperated more with the strong than the soft agent ($p=0.004$).

Finally, the person perception subjective ratings are shown in Table 8. The results showed that HS individuals' ratings favored the soft agent the most, and the strong agent the least. In contrast, LS individuals' ratings did not present a clear pattern of preference between the agents.

3.3. Discussion

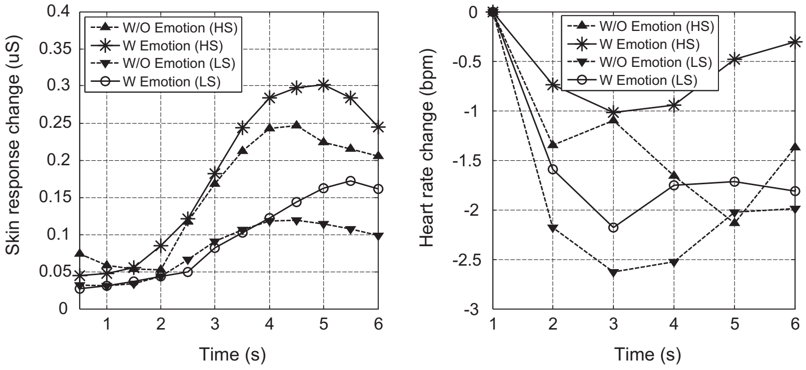
The results replicated the pilot experiment's finding that HS individuals are more physiologically reactive during the game, thus suggesting they experience more emotion than LS individuals. Once again, this suggests that both inferential and affective processes are at play (Hypothesis 3). The experiment also replicated the finding that HS individuals make more distinctions in their subjective ratings than LS individuals (Hypothesis 2). The novel result in this experiment was that, as predicted by Hypothesis 1, HS individuals showed qualitatively different cooperation behavior when compared to LS individuals. Indeed, the results showed that, for HS individuals, cooperation rate was highest with agents that showed positive emotion, and lowest with the agent that only showed negative emotion. This suggests, thus, that these participants were catching the agents' expressions (e.g., negative emotions from strong agents) and reacting accordingly, as predicted by affective processes. In contrast, the results suggest LS individuals were being more strategic in their interactions (Van Kleef et al., 2004, 2010), as predicted by inferential processes. Since soft agents showed regret after exploiting, these participants exploited them back (Van Kleef et al., 2006); in contrast, since cooperative agents provided the clearest information about their intentions – through displays that reinforced cooperation and punished non-cooperation – these participants cooperated with them the most.

4. General discussion

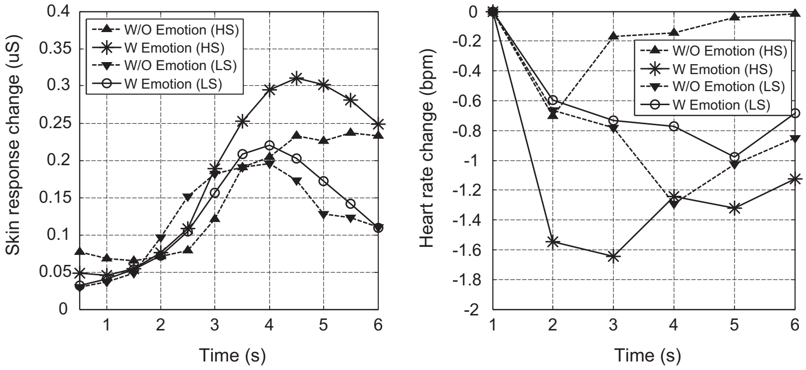
This paper argues that emotional expressions in computers achieve their effects on people's decision making via two processes: inferential processes, whereby emotion expressions provide information about other's mental states; and affective processes, whereby emotion expressions elicit emotion in the receiver which, in turn, impacts his or her decisions. In support of this view, the results showed that, when engaging in decision making with computers that express emotion, some participants experienced more emotion than others, as measured by electrodermal activity and heart rate deceleration. On the one hand, those that experienced more emotion behaved in a manner compatible with affective processes: they cooperated more with, and formed more positive subjective impressions of, computers that showed positive emotion. On the other hand, those that experienced less emotion tended to be more strategic as predicted by inferential processes – for instance, they exploited computers that showed regret; moreover, reflecting a colder more cognitive attitude, these participants did not form distinct subjective impressions. The results, thus, confirmed that affective and inferential processes can lead to different behavior (Hypothesis 1) and subjective impressions (Hypothesis 2). Finally, Hypothesis 3 predicted that electrodermal lability, an individual trait which reflects how physiologically reactive a person is, can predict which individuals will be influenced by affective or inferential processes. Our results confirmed that, when splitting participants according to their electrodermal lability in an independent task, those that showed more physiological sensitivity were more likely to be influenced by affective processes in the game; and, those that were less sensitive were more likely to be influenced by inferential processes.

4.1. Implications and contributions

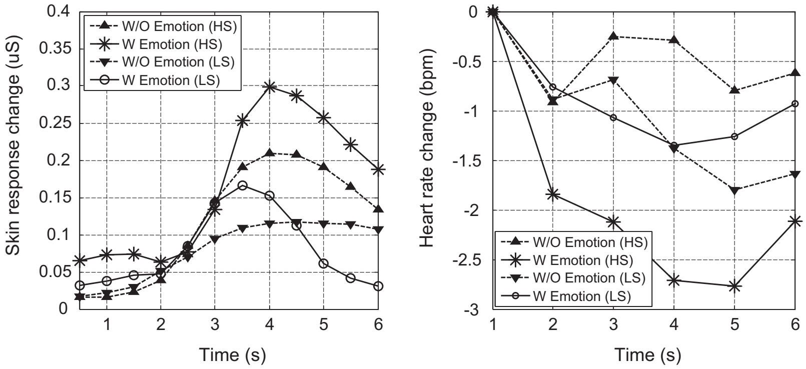
This work has implications for the design of social agents. In line with previous findings (de Melo et al., 2014; Gong, 2007; Kiesler et al., 1996; Yuasa and Mukawa, 2007), the results present further evidence that people's decisions can be influenced by



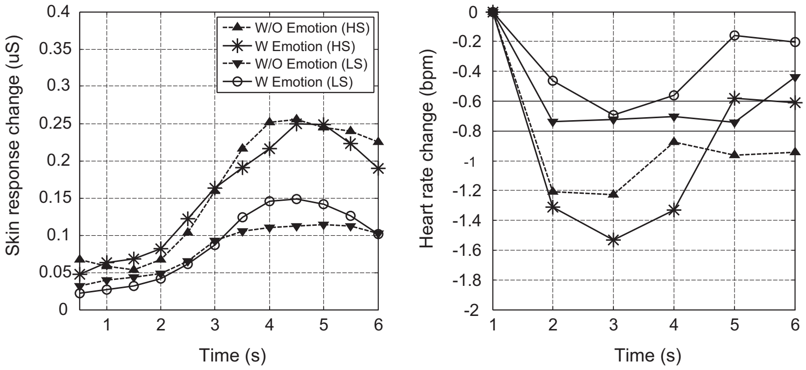
CC-Joy vs CC-Neutral



D_PC_A -Anger vs D_PC_A -Neutral



C_PD_A-Regret vs C_PD_A -Neutral



DD-Sadness vs DD-Neutral

Fig. 6. Physiological reactions to the emotion displays in the game for highly sensitive and less sensitive people (main experiment). Electrodermal activity is shown on the left, and the 6-s window for heart rate change on the right.

emotions displayed by a computer. Pragmatically, the patterns of emotion expressions described in the paper could be used to strategically manipulate users' subjective ratings and cooperation behavior. The paper further shows that, just like in human–human interaction (Parkinson and Simons, 2009; Van Kleef et al., 2010), emotion displays can achieve their effects in human–computer interaction through affective and inferential processes. Since affective processes rely on emotional contagion and mimicry (Hatfield et al., 1994; Niedenthal et al., 2010), the implication is that designers need to be able to express emotions as they are seen in nature. This speaks to the importance of having embodied computer interfaces, with virtual faces (Bartneck and Reichenbach, 2005; Beale and Creed, 2009; Cassell et al., 1994; Gratch et al., 2002; Niewiadomski and Pelachaud, 2010). On the other hand, if it is not desired or possible to have an embodied interface, then designers can at least explore inferential processes. Effectively, de Melo et al. (2014) showed that it was possible to achieve similar social effects if, instead of facial displays of emotion, textual information about the other's beliefs, desires and intentions was communicated directly.

Our work also shows there are two kinds of users: highly sensitive and less sensitive. HS users are likely to experience more emotion when engaging with computers that show emotion, whereas LS users are likely to be more cognitive in their interaction. To identify the user type, system designers can, as demonstrated in our experiments, look at two relatively unobtrusive physiological measures: electrodermal activity and heart rate deceleration. Having identified the user type, the system could adapt accordingly; for instance, when engaging with HS users, the system could maintain a model of the user's affective state and tune the interaction appropriately; in contrast, when interacting with LS users, the system could focus on communicating information about the system's state and focus less on the users' emotions. Finally, looking in the reverse direction, the work also suggests how to make appropriate inferences about the users' physiological states, from their behavior or subjective ratings.

Table 7
Cooperation rates in the main experiment.

Electrodermal lability	*n*	Strong		Soft		Cooperative	
		M	*SD*	*M*	*SD*	*M*	*SD*
Highly sensitive	15	0.235	0.057	0.382	0.060	0.320	0.038
Less sensitive	21	0.406	0.045	0.309	0.047	0.520	0.058

4.2. Limitations and future work

One limitation in this work is that we did not experimentally activate inferential or affective processes; instead, we relied on an individual trait – namely, electrodermal lability – to separate participants whose decision making was driven by one or the other type of process. Other dispositional factors have been proposed as well, such as the individual's epistemic motivation (Van Kleef et al., 2010), i.e., the motivation to scrutinize and thoroughly process information. The higher the epistemic motivation, the more likely inferential processes are to occur. Whereas it is important to study dispositional factors such as these, it is also important to understand the situational factors that affect which processes are at play. For instance, Van Kleef et al. (2010) argue that the perceived competitiveness of the social setting is an important moderator. In cooperative settings (e.g., teamwork), people are more likely to care about each other and feel more emotion; in contrast, in competitive settings (e.g., distributive negotiation), people are more likely to trust each other less and use the information retrieved from emotion displays strategically. Thus, these authors argue that inferential processes are likely to be more important in competitive settings, whereas affective processes are especially relevant in cooperative settings. Future work, therefore, needs to understand the situational factors that influence whether, in human–computer interaction, inferential or affective processes will dominate.

This work demonstrated the importance of affective and inferential processes in the context of two-person social dilemmas. However, the behavioral sciences have suggested that these processes play a role in diverse social settings (Parkinson and Simons, 2009; Van Kleef et al., 2010). In human–computer interaction, de Melo et al. (2011) have already demonstrated that emotion displayed by computers can impact people's concession making in negotiation. In the future, thus, it is important to confirm that both processes play a role in more diverse human–computer interaction settings such as negotiation or group contexts.

It would also be interesting to look at further physiological measures. On the one hand, we could look at other peripheral physiology measures. For instance, researchers have already shown that facial electromyography – i.e., measurement of activity in facial musculature – can reveal whether the individual is experiencing emotion (Cacioppo et al., 1986; Prendinger and Ishizuka, 2007). On the other hand, we could look at neurophysiological measures. In fact, researchers have already shown some promise in distinguishing the occurrence of cognitive and affective

Table 8
Person perception subjective ratings in the main experiment.

	Highly sensitive				Less sensitive			
	Strong	Coop	Soft	Sig.	Strong	Coop	Soft	Sig.
Friendly	0.000	0.267	1.000	0.042*	1.336	0.620	1.240	0.422
Warm	−0.266	0.200	0.800	0.037*	1.002	0.572	1.146	0.559
Reliable	0.067	0.200	0.733	0.226	1.193	0.620	1.145	0.509
Involved	1.400	0.867	0.267	0.035*	1.384	0.382	1.193	0.162
Sensitive	−0.133	0.267	0.667	0.112	0.811	0.239	0.811	0.473
Humble	−0.333	−0.133	1.000	0.003*	0.573	0.334	1.146	0.285
Sympathetic	−0.533	0.067	1.000	0.002*	0.955	0.382	0.716	0.560
Tender	−0.600	−0.267	0.933	0.000*	0.430	0.286	0.764	0.663
Arrogant	0.533	0.000	−1.067	0.004*	0.000	−0.286	−0.239	0.788
Conceited	0.333	−0.200	−1.000	0.022*	−0.095	−0.191	−0.573	0.526
Quiet	−0.133	−0.133	0.400	0.347	1.289	0.239	0.620	0.110
Calm	0.067	0.533	0.200	0.500	0.764	0.764	0.716	0.995

Note. Scale: −3, mostly negative attributes; +3, mostly positive attributes.

* $p < 0.05$.

processes in the brain (Gallagher et al., 2002; Rilling et al., 2002; Sanfey et al., 2003).

Overall, this work presents a first step in understanding how emotion expressions in computers achieve their effects on people's decisions through a dual process model based on affective and inferential processes; however, future work with more decision tasks and with additional psychophysiological measures will help further clarify the nature of decision making in human–computer interaction.

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