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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;