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Review

The time–emotion paradox

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The present manuscript discusses the time–emotion paradox in time psychology: although humans are able to accurately estimate time as if they possess a specific mechanism that allows them to measure time (i.e. an internal clock), their representations of time are easily distorted by the context. Indeed, our sense of time depends on intrinsic context, such as the emotional state, and on extrinsic context, such as the rhythm of others' activity. Existing studies on the relationships between emotion and time suggest that these contextual variations in subjective time do not result from the incorrect functioning of the internal clock but rather from the excellent ability of the internal clock to adapt to events in one's environment. Finally, the fact that we live and move in time and that everything, every act, takes more or less time has often been neglected. Thus, there is no unique, homogeneous time but instead multiple experiences of time. Our subjective temporal distortions directly reflect the way our brain and body adapt to these multiple time scales.

Keywords: emotion; time perception; timing

1. INTRODUCTION

> The heart has it reasons of which reason knows nothing.
> (Pascal, *Les pensées*)

> The organism has certain reasons, that reason must always take into account.
> (Damasio 1994, *Descartes' error*)

One of the greatest paradoxes in the field of time psychology is the time–emotion paradox. Over the last few decades, an increasing volume of data has been identified demonstrating the accuracy with which humans are able to estimate time. Confronted with this amazing ability, psychologists have supposed that humans, as other animals, possess a specific mechanism that allows them to measure time. Gibbon (1977) defined this mechanism as an internal clock. Since then, most psychologists have concentrated their efforts on collecting empirical data with a view to validating the internal clock models, while neuroscientists have focused more on identifying the neural substrates of this clock system. However, under the influence of emotions, humans can be extremely inaccurate in their time judgements (Droit-Volet & Meck 2007). For example, the passage of time seems to vary depending on whether the subject is in an unpleasant or pleasant context. It drags when being criticized by the boss but flies by when discussing with our friends. That is the time–emotion paradox: why, given that we possess a sophisticated time measurement mechanism, are we so inaccurate in our temporal judgements when experiencing emotions?

Researchers into emotions are engaged in a debate concerning the relationship between reason and emotion based on the idea that reason alone confers order on behaviour. Emotions have thus been conceived as disrupting and disorganizing behaviours, in our case our fundamental ability to estimate time. However, as discussed by Damasio (1994), in complex real-world situations, there is no proper reasoning without emotion. Emotions guide reasoning during decision making. Within this theoretical framework we want to defend, in the present manuscript, the idea that temporal illusions such as that time is being shorter or longer, which it really is, are not the result of any additional emotional feeling that disturbs the functioning of the internal clock. On the contrary, these temporal illusions reveal that the internal clock is a highly adaptive system that enables organisms to adapt efficiently to events in their environment. Studying the temporal illusions may thus be a means of gaining a better understanding of the function of emotions and the mechanism underlying their influence on behaviours. Conversely, studying the effect of emotion on time judgements may also help us to arrive at a better understanding of the mechanisms underlying time perception, and perhaps to call the internal clock models into question. In this manuscript, we first present the internal clock models and then examine the results of the few studies that have investigated how emotions affect our perception of time. Each type of emotional stimulus will be considered separately because each source of emotion has a specific function (Frijda 2007), and consequently a specific effect on time perception and motor timing.

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One contribution of 14 to a Theme Issue 'The experience of time: neural mechanisms and the interplay of emotion, cognition and embodiment'.

2. THE INTERNAL CLOCK MODELS AND THE EXPLANATORY MECHANISMS OF TEMPORAL ILLUSIONS

> [humans] 'have a special sense for pure time. […] to what element in the brain process may this sensibility be due?'
>
> (James, *The Principles of psychology*)

The scalar timing theory (scalar expectancy theory, SET) has been the most popular theory of timing. It was originally developed by Gibbon (1977; Gibbon *et al.* 1984) for animals and then successfully applied to human adults (Wearden & McShane 1988; Allan & Gibbon 1991) and children (Droit-Volet & Wearden 2001; Droit-Volet *et al.* 2001). According to the SET, time representation has two fundamental properties: (i) the mean accuracy, i.e. the requirement that the internal estimates of a stimulus duration are on average accurate, and (ii) the scalar property, i.e. the requirement that the standard deviation of temporal judgement grows as a linear function of the mean. According to the SET, the mean accuracy of time estimates originates in a pacemaker–accumulator system that provides the raw material for time representation (Gibbon *et al.* 1984; figure 1). During the stimulus that is to be timed, the pulses emitted by a pacemaker are stored in an accumulator in such a way that the greater the number of accumulated pulses is, the longer the duration is judged to be. However, in order to explain temporal judgements and their variability, two stages of a higher cognitive level have been added to this clock system: a memory and a decisional stage. At the memory stage, the content of the accumulator is stored in working memory, while significant durations experienced previously (e.g. time previously reinforced, standard duration) are stored in long-term memory. At the decision stage, the temporal judgement results from the comparison of the current subjective time with the representation of durations in long-term memory. More recently, an attention-based system has been added to this conception of time processing in the form of a switch that closes and opens at the onset and the offset, respectively, of the stimulus to be timed (Zakay & Block 1996).

The informational component of this internal clock model has been criticized for its lack of neurobiological plausibility (e.g. Lewis & Miall 2006; Karmarkar & Buonomano 2007). Alternative models suggest the existence of neural oscillators distributed in the brain which serve as the basis for the clock, rather than a simple pacemaker (e.g. Matell & Meck 2004). However, the internal clock model remains the dominant theoretical model of time because it permits an excellent description of a wide range of experimental results across many paradigms (Buhusi & Meck 2005; Droit-Volet *et al.* 2007). Furthermore, it admits that many factors might modulate the perception of time and predicts specific patterns of behavioural data for each type of involved mechanism (i.e. arousal, attention, memory or decision). This makes it possible for psychologists studying behaviour to try to identify the main sources of temporal illusions. Within this framework, there is now ample evidence that when the level

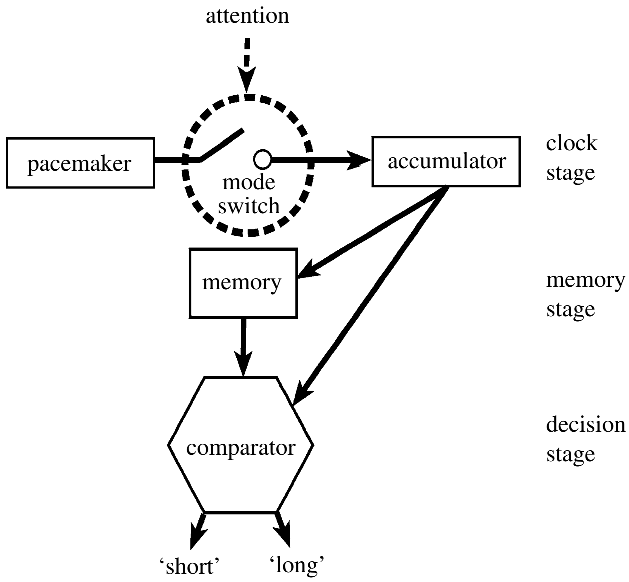

Figure 1. The temporal information processing model (Gibbon *et al.* 1984).

of physiological activation increases, a specific clock effect occurs. The internal clock speeds up, thus causing more pulses to accumulate for the same physical unit of time. This arousal-induced temporal overestimation has been documented in numerous studies that have manipulated the level of arousal by using click or flicker trains (Treisman *et al.* 1990; Penton-Voak *et al.* 1996; Droit-Volet & Wearden 2002; Ortega & Lopez 2008), by changing body temperature (Wearden & Penton-Voak 1995), or by administrating drugs that modulate arousal by altering the effective level of dopamine in the brain. For example, following the administration of dopanimergic agonists (methamphetamine or cocaine), participants either overestimate the elapsed interval or respond earlier, a phenomenon that is characteristic of an increase in the clock rate (Maricq *et al.* 1981; Cheng *et al.* 2007). By contrast, dopaminergic antagonists, such as haloperidol, produce a temporal underestimation as if the clock were running more slowly (Rammsayer 1989, 1999; Drew *et al.* 2003).

When attentional resources are diverted away from the processing of time, an attention-related effect occurs, causing the subjective experience of time to be shorter than it really is. This is explained by the fact that the on-line accumulation of temporal 'pulses' during the stimulus to be timed is compromised when we pay less attention to time. More precisely, the distraction of attention would delay the latency of a switch closure, or/and would open the switch temporarily (Lejeune 1998). In each case, some pulses are lost and the stimulus duration is judged shorter. This attention-mediated shortening effect has been extensively demonstrated in studies using the dual-task paradigm (Macar 2002; Coull *et al.* 2004). However, a temporal underestimation of time could also reflect a slowing down of the clock speed. Nevertheless, thanks to the internal clock model, these two types of temporal underestimation can be dissociated when multiple duration values are used. Indeed, the slowing down of the clock would be evidenced by an effect that changes with the stimulus duration values (i.e. multiplicative effect), being relatively greater with longer durations than with shorter durations, whereas the attention-related process would be reflected by a constant effect, irrespective of the duration values (i.e. additive effect) (Maricq *et al.* 1981; Burle & Casini 2001). As far as memory storage is concerned, the effect would appear to depend on the cholinergic activity in the frontal cortex, which is affected by cholinergic drugs (acetylcholine) (Meck 1983, 1996). Moreover, the memory-related effect emerges progressively and remains relatively permanent, unlike the clock effect that disappears after repeated feedback, which enables participants to recalibrate their timers. The latter effect is associated with decisional processes and is without doubt the least well investigated of the effects (Wittman & Paulus 2007). However, the mathematical modelling of the data in temporal studies that have manipulated the type of feedback suggests that the participants' more or less conservative attitude does not affect their general temporal performance, but only their responses on ambiguous cases in which the duration values are insufficiently differentiated (Wearden & Grindrod 2003; Droit-Volet & Izaute 2007). To summarize, the value of the SET and its derived temporal information processing model lies in its ability to provide explanations in terms of mechanisms (arousal-induced or attention-related mechanism), resulting in the distortion of perceived time compared with physical time.

3. THE STANDARDIZED EMOTIONAL PICTURES OR SOUNDS AND THEIR EFFECT ON TIME PERCEPTION

> At the beginning was the emotion, but at the beginning of the emotion was the action.
>
> (Damasio 2003, *Looking for Spinoza*)

Interest in the subjective experience of time and its variability in response to emotion is most certainly not a recent phenomenon. As long ago as 1890, James noted that 'a certain emotional feeling accompanies the intervals of time […]' and 'that our feeling of time harmonizes with different mental moods'. However, studies of this topic are infrequent and most of them have used the retrospective temporal judgement paradigm (e.g. Gorn *et al.* 2004; Danckert & Allman 2005; Anderson *et al.* 2007; Campbell & Bryant 2007). In the retrospective paradigm, participants are unaware that they will be asked to judge the duration of a stimulus event. In this condition, the duration is rarely encoded because their attention is not focused on temporal information but on the non-temporal proprieties of events which are particularly salient in the experienced present. The retrospective temporal judgement is then re-constructed on the basis of the non-temporal information retrieved from memory (Zakay & Block 1996). Consequently, although the studies of retrospective time are particularly interesting for our understanding of the autobiographical memory of duration of emotional events, such as traumatic experiences, they tell us nothing about the effect of emotions on the processing of time *per se*. A further problem lies in the fact that these studies have often used long intervals of more than 10 s or 1 min. Angrilli *et al.* (1997), as well as Noulhiane *et al.* (2007), found that the effect of emotions on temporal judgements disappeared with intervals of more than 4 s. When long durations are involved, it is methodologically difficult to control the temporal dynamic of emotion. Nevertheless, a small number of pioneering studies, all focusing on stressful situations, have used the prospective paradigm and consistently found that stressful situations lengthen subjective time (Langer *et al.* 1961; Thayer & Schiff 1975; Meck 1983; Watts & Sharrock 1984). In a temporal bisection task, Meck (1983) showed that rats overestimated a signal duration when exposed to continuous footshock stress. In human adults, Langer *et al.* (1961) observed that a 5-s duration was overestimated when the participants were approaching a dangerous precipice compared with when they were moving away from it. As these authors explained, the stressful conditions increased the arousal level, which in turn accelerated the clock speed, thus producing an overestimation of the duration.

More conclusive results have recently been provided by studies that have employed the standardized emotional stimuli currently used in studies of emotions. Noulhiane *et al.* (2007) used emotional sounds from the international affective digitals sounds (IADS) (Bradley & Lang 1999). They found that the emotional sounds were judged longer than the neutral sound. Moreover, the negative sounds were judged longer than the positive sounds. They thus concluded that the physiological activation induced by an emotional stimulus is 'the predominant aspect of the influence of emotions on time perception' (p. 702). Using pictures from the international affective pictures system (IAPS; Lang *et al.* 2005) and measurements of physiological changes induced by emotion (heart rate and skin conductance response), Angrilli *et al.* (1997) observed the essential role of arousal on time judgements but also identified the influence of the motivational systems involved in emotions. Indeed, the pictures that induced a strong arousal level in association with bodily changes (increase in skin conductance) had different effects on the participants' time judgements as a function of their affective valence. In high-arousal conditions, unpleasant pictures (mutilated bodies) were overestimated, whereas pleasant pictures (erotic scenes) were underestimated. Inversely, in low-arousal conditions, unpleasant pictures were underestimated and pleasant pictures overestimated. This opposite direction of the valence effect as a function of arousal suggests that two different mechanisms are triggered by arousal levels: an attention-driven mechanism for low arousal, and an emotion-driven mechanism for high arousal (Angrilli *et al.* 1997). High-arousal pictures should lead to the activation of the entire body (e.g. heart rate, blood pressure, contracted muscles) in order to prepare the organism for action. However, the urgency of this readiness for action is greater in the case of defensive (attack or escape) than appetitive motivations (procreation) (Bradley *et al.* 2001). As Darwin (1872/1998) himself explains within his evolutionist perspective, readiness to react (to flee or to attack) to a dangerous event as quickly as possible is an automatic reaction that contributes to survival. Consequently, when a subject is confronted with a threatening event, the internal clock runs faster under the influence of dopamine, and the preparation for action is quicker. By modifying the perception of time, the internal clock ensures the survival of the organism in urgent situations. Consequently, the magnitude of the temporal overestimation in high-arousal conditions should be an accurate index of the basic function of certain emotions.

Both the direction and the magnitude of the temporal distortions seem to depend on the emotions and their functions. In their studies, Noulhiane *et al.* (2007), as well as Angrilli *et al.* (1997), adopted a dimensional approach that organizes the emotional space along two major dimensions: pleasant–unpleasant and low–high arousal. Although this broad classification is useful, it is not able to take account of the complexity of emotions and the function of each discrete emotion. For instance, do anger and disgust, which are both categorized as negative and highly arousing, produce the same effect on time judgements? In the discrete emotional approach (Izard & Ackerman 2000; Mikels *et al.* 2005), the characteristics and the functions of each emotion are delimited, as is their relation with cognition and action. The idea is that emotions organize and motivate significant aspects of behaviour as a function of their meaning in a specific context (Izard 1991). Future studies will therefore be necessary in order to determine how each discrete emotion affects the perception of time. Within this perspective, we have decided to begin an examination of the influence of emotional facial expressions on time perception since these play an essential role in social communication.

4. THE FACIAL EXPRESSION OF EMOTIONS

> Before you speak, one must be able to read on your face what you will say.
>
> (Aurèle 1992, *Pensées pour moi-même*)

The effectiveness of social interaction depends primarily on the capacity of the interlocutors to share time, to synchronize their rate of speech, to anticipate other people's reactions, to answer their requests as and when it is appropriate. Social interaction thus forms part of a temporal dynamic which requires that each participating individual continuously processes temporal information. To ensure that social interaction is conducted efficiently, we are also specialized in the rapid detection and recognition of certain signs of emotion on our interlocutors' faces (Russel & Fernandez-Dols 1997). The early emergence and cross-cultural consistencies of this capacity suggest that it is based on innate programs (Ekman 1982). In our laboratory research, we have systematically investigated the perception of the presentation duration of pictures of faces expressing emotions by using the temporal bisection task (Droit-Volet *et al.* 2004; Droit-Volet & Meck 2007; Gil *et al.* 2007; Gil & Droit-Volet submitted). In this task, participants are initially presented with two anchor durations, namely a short one (400 ms) and a long one (1600 ms), presented in the form of a pink oval. Next, in a testing phase, they are presented with a series of seven comparison durations, i.e. one for each anchor duration, and five for the intermediate durations which differ from each other by 200 ms (600, 800, 1000, 1200 and 1400 ms). In the testing phase, the stimuli consist of faces expressing a basic emotion (anger, fear, happiness, sadness or disgust) or a neutral emotion. The participants' task is to judge whether the presentation duration of the face corresponds to the short or the long anchor duration (short versus long response). The results show that the facial expressions of anger and fear shift the bisection function towards the left compared with the neutral faces, thus significantly lowering the point of subjective equality (bisection point) (stimulus that gives rise to 50% of long responses), and do so to a greater extent than any of the other emotions. This indicates that participants respond 'long' more often for the angry and fearful faces than for the neutral faces. The Weber ratio (i.e. coefficient of variation), which is an index of time sensitivity, does not vary with the facial type. The perception of emotional facial expressions thus dilates time without modifying sensitivity to time. Figure 2 illustrates these results. Figure 2 presents a difference score (d) between the proportion of long responses for the emotional faces and for the neutral ones. A d-value significantly greater than zero indicates an overestimation of time for the emotional expression compared with the neutral expression, while a d smaller than zero indicates an underestimation. As figure 2 shows, the d-value is significantly greater than zero and consequently indicates an overestimation of the presentation duration of angry and fearful faces compared with neutral faces. These results for angry faces have been replicated in adults by Tipples (2008), and have also been observed in children as young as 3 years of age (Gil *et al.* 2007). Statistical analyses, based on the internal clock model, suggest that this temporal overestimation is due to an increase in the clock rate. When the clock runs faster, more pulses are accumulated and the duration is judged longer. This is consistent with studies showing that anger and fear are arousing emotions (Phelps & Ledoux 2005). Both the range of durations used (shorter than 2 s) and the early emergence of the emotional effect lead us to suppose that this effect of anger and fear on the perception of time results from an automatic process linked to the dopamine activity which allows humans to anticipate an event by preparing them to act quickly. The more rapidly time passes, the sooner humans are ready to act.

However, in a recent study (Droit-Volet & Meck 2007; Gil & Droit-Volet submitted), we have observed that the emotional facial expression of disgust did not cause any time distortion, although disgust, similar to anger and fear, is categorized as a high-arousal and unpleasant emotion. As previously suggested, the influence of emotions on time discrimination depends on each discrete emotion. Neuroimaging studies have shown that the processing of angry and fearful faces activates cortical and subcortical structures centred on the amygdala, whereas that of disgusted faces activates the insula (Adolphs 2002). In patients with bilateral amygdala damage, the ability to recognize facial expressions was impaired in the case of fear and,

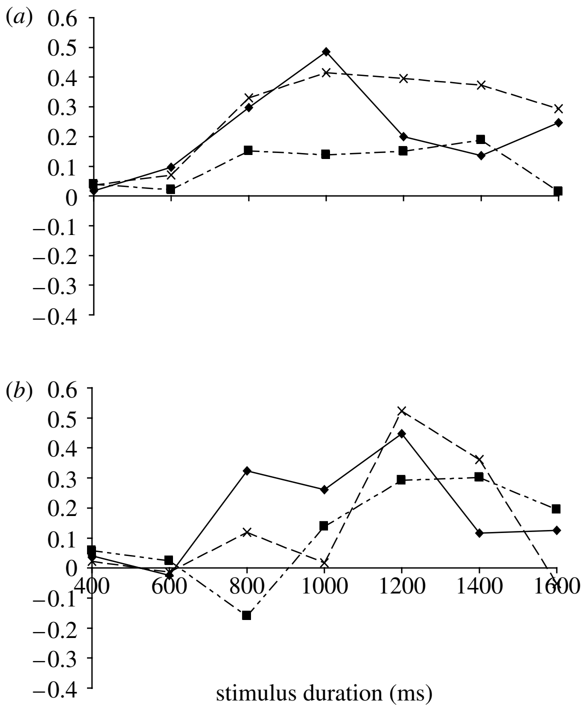

Figure 2. Difference scores (*p*(*long*) *emotion*–*p*(*long*) *neutral*) plotted against stimulus durations, as a function of age groups, for the facial expressions of (*a*) anger and (*b*) fear. Diamonds, adults; squares, eight years; crosses, 5 years.

in some cases, anger, but not in the case of disgust, happiness and sadness (Calder *et al.* 1996; Adolphs *et al.* 1998). Conversely, patients with damage to the insula experience difficulties in recognizing the facial expression of disgust, but not that of fear or anger (Calder *et al.* 2000). There is growing evidence that the amygdala plays a critical role in the high-priority processing of unusual or potentially dangerous events. The rapid detection of a threatening stimulus in the environment in order to prepare the organism to act is a specific function of the emotions of anger and fear (Ledoux 2000; Eastwood *et al.* 2001; Öhman *et al.* 2001). The overestimation of time in the presence of angry faces (signals of potential aggression) and fearful faces (signals of the presence of a danger in the environment) would therefore seem to be related to the activation of the autonomic system that switches the mind and the body to action readiness.

The basic function of disgust is not to avoid imminent danger but to reject something bad for health (Rozin & Fallon 1987). The term disgust, in its simplest sense, means something offensive to the taste. As noted by Darwin (1872/1998, p. 255), 'it is curious how readily this feeling is excited by anything unusual in the appearance or nature of our food'. Consequently, the effect of disgust on time perception might differ as a function of the source of the emotion: disgusted faces, a mutilated body as in the IAPS or disgusting food. In a non-ecological laboratory situation, observing a disgusted face would not be a significant enough stimulus in terms of motor timing or attention to alter the functioning of the internal clock. By contrast, in response to more relevant disgust stimuli such as pictures of disgusting food, we have observed a temporal effect. Indeed, in a bisection task, the presentation durations were judged shorter for disgusting than for liked food (Gil *et al.* in press). This higher level of temporal underestimation in the case of disliked food pictures is consistent with the original function of the emotion of disgust, namely to avoid the consumption of something potentially dangerous for health. It is therefore not surprising that, disliked foods capture more attentional resources than liked foods, as individuals must consider disgusting foods more attentively, thus causing relative time underestimation. As Rozin & Fallon (1987) have argued, the emotion of disgust is generated by cognitive appraisals, allowing us to decide to accept or reject substances.

As far as the facial expression of happiness and, to a lesser extent, that of sadness are concerned, the results of the bisection task show that these emotions also produce a significant overestimation of time, although of a lesser magnitude than in the case of anger and fear (Droit-Volet *et al.* 2004; Effron *et al.* 2006). Another person's smile, if meant sincerely (i.e. Duchenne smile) (Ekman *et al.* 1990), implies affiliation behaviours (Mehu *et al.* 2007). It is similar to an invitation to approach more closely: 'you can come, I am ready to give you a warm welcome'. Here again, the time distortions are intrinsically linked to motor timing, i.e. the readiness to move. In the presence of a happy face, you are ready to act, to cooperate with somebody. As far as sadness is concerned, this emotion is generally recognized as being less arousing and thought to induce a general slowing down of the individual (Schwartz *et al.* 1981; Gil & Droit-Volet 2009). However, experiencing sadness in the same way that a depressed person would is different from the perception of a sad expression in a person's face. A sad expression informs the perceiver that the other needs help (Russel & Fernandez-Dols 1997). In this case, the perception of a sad face should increase the level of arousal in order to prepare the perceiver to give assistance. However, in our studies, there was a great inter-individual variability in the sad face-related effect on time perception (Droit-Volet *et al.* 2004).

Perhaps, the most interesting observation associated with the facial expression of sadness is that of a developmental change in time judgement (Droit-Volet & Meck 2007; Gil & Droit-Volet submitted). As figure 3 shows, the magnitude of the temporal overestimation for sad faces compared with the neutral faces was greater in the 5-year-old children than in the older participants. We made two assumptions concerning the precise nature of this 'overreaction'. Firstly, according to (Izard 1991, p. 5), 'the infant depends upon the mother for sustenance, nurturing, warmth, hygiene, and protection from danger. […He] is also dependent on parental affection for health and psychological well-being'. Distress expressed by a woman would thus be highly arousing for such young children. Secondly, this effect may arise from the acquisition of social rules. Indeed, sadness is considered to be a prejudicial emotion that has to be hidden in society (Saarni & Von Salisch 1993). If this is the case, older children and adults would under-react to sad faces compared with young children because

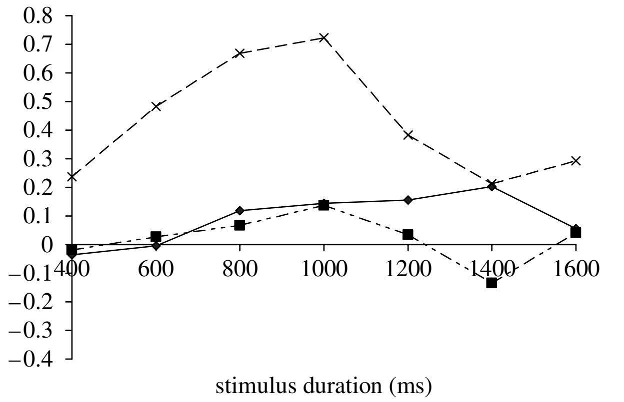

Figure 3. Difference scores (*p*(*long*) *emotion*–*p*(*long*) *neutral*) plotted against stimulus durations, as a function of age groups, for facial expressions of sadness. Diamonds, adults; squares, 8 years; crosses, 5 years.

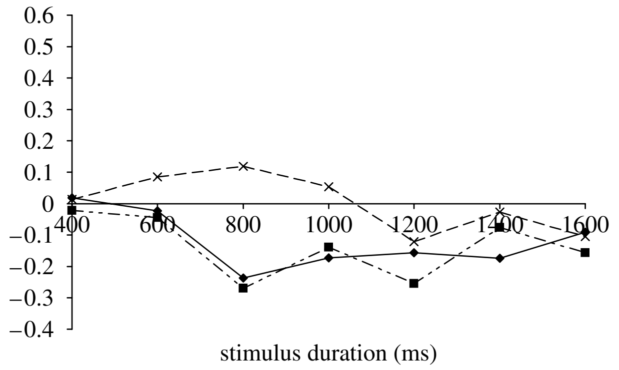

Figure 4. Difference scores (*p*(*long*) *emotion*–*p*(*long*) *neutral*) plotted against stimulus durations, as a function of age groups, for facial expressions of shame. Diamonds, adults; squares, 8 years; crosses, 5 years.

they inhibit this emotion. In the case of the other basic emotions (happiness, fear, anger), no age-related difference was observed (Gil *et al.* 2007), except in Gil & Droit-Volet (submitted) in the case of anger perceived by 8-year-old children. Indeed, in this study, the magnitude of the temporal overestimation appeared to be smaller in the 8-year-olds than in the younger or older participants. This could also be explained in terms of the acquisition of cultural rules concerning emotional expressiveness due to the negative consequence of displaying anger in front of adults (Saarni 1979). However it remains to be determined if this reduction in temporal distortions results from the inhibition of the automatic acceleration of the internal clock or from an attentional filter related to the appraisal of the emotional context. Whatever the case, this series of results supports the idea that, although genetically determined, some aspects of basic emotions can be modified through experience and social development (Izard 1991).

The development of emotions and their role in time perception appear clearly when one examines cognitive-dependent emotions such as shame. Shame is not a basic emotion, but a more complex emotion that has been called a socio-moral or self-conscious emotion (Haidt 2003). It therefore emerges later in the process of ontogenesis when the sense of self is developed and moral norms are internalized (Lagattuta & Thompson 2007). For this reason, we did not observe any time distortion in a bisection task in 5-year-old children who did not recognize the facial expression of shame (figure 4; Droit-Volet & Meck 2007; Gil & Droit-Volet submitted). By contrast, in older children and adults, the facial expression of shame caused not an overestimation but an underestimation of durations. According to the internal clock models, this type of temporal underestimation is due to attention-based processes. As Lewis (1971) has suggested, the perception of faces expressing shame may capture the subject's attentional resources by means of a reflective activity relating to self-evaluation or the attribution of causality in shame.

Overall, our results relating to the facial expressions of emotions have revealed that their effect on the perception of time depends on the fundamental function of each discrete emotion and its underlying mechanism (e.g. attention, arousal). Although further investigations are now required, our studies indicate that the subjective experience of time is highly sensitive to emotional contexts. This may ultimately provide a basis for the construction of a tool for the behavioural measurement of the functioning of emotions and their disorders. It is possible that people who do not feel guilt or shame might not produce any temporal underestimation when confronted with facial expressions of shame or scenes involving a feeling of shame. Similarly, people lacking the ability to empathize with others might produce no temporal overestimation when perceiving angry people or people in pain.

5. THE EMBODIMENT OF THE OTHER PERSON'S TIME

> External perception and perception of the body vary together because they are the two faces of the same act.
> (Merleau-Ponty 1976, *Phénoménologie de la perception*)

As we have indicated above, the effectiveness of social interaction is determined by our capacity to synchronize our activity with that of the individual with whom we are dealing. In social interaction, babies learn to synchronize their vocalizations with those of their mothers. At the same time, mothers spontaneously adjust their speech speed to their children's information processing speed (Pouthas *et al.* 1993). In other words, individuals adopt other people's rhythms and incorporate other people's time. This was demonstrated in one of our recent studies in which people's subjective experience of time required the embodiment of the motor movement speed of elderly persons (Chambon *et al.* 2005, 2008). In this study, men and women were presented with pictures of faces of elderly and younger males and females (figure 5) as part of a temporal bisection task similar to the one described above. When the participants viewed the elderly faces, their bisection functions shifted significantly towards the right compared with the young faces, thus indicating that the presentation duration of elderly faces was underestimated (figure 6). A further analysis of the data indicated a slope effect (multiplicative effect), suggesting that this underestimation is owing to a slowing down of the internal clock. This is entirely consistent with the results of a seminal study

Figure 5. Examples of (*a*) elderly and (*b*) young women's faces with a neutral expression.

conducted by Bargh *et al.* (1996) in the field of social psychology. In this study, the subjects had to form sentences from a list of words. In the control group, the words were neutral, while, in the experimental group, a subset of the words related to elderly traits, e.g. grey, bingo, were used. When they left the laboratory to reach the elevator, the students primed with the elderly category walked more slowly than the non-primed students. According to the theories of embodied cognition, these findings are explained by the embodied simulation of elderly people, who tend to move slowly (Barsalou *et al.* 2003; Niedenthal 2007). We experience the slow movements of elderly people and construct sensori-motor knowledge associated with their old age. Perceiving or remembering elderly people thus induces a reenactment, also called a simulation, of their bodily states, i.e. their slow movement. By means of this embodiment, our internal clock adapts to the speed of movement of elderly people and makes the elapsed stimulus duration feel shorter. To summarize, our feeling of time varies with our experiences, in this case the other's bodily state.

It might seem surprising that the simple perception of another person's face expressing a behavioural state (being old) or an emotion (being fearful) can cause the internal clock to slow down or speed up. However, a functional imaging study conducted by Wicker *et al.* (2003) shows that the same areas of the brain are activated during the experience of an emotion and the observation of the facial expression of this emotion. Even if to a lesser extent, another person's anger creates anger in the perceiver and fear creates fear. In the case of fear, this phenomenon acts as a quick and easy way of becoming alerted to environmental danger without having to face the danger oneself (Chakrabarti & Baron-Cohen 2006). The fact that emotion perceived in others produces the same emotion in the perceiver arises from a brain circuit that is specialized for mimicry. There is evidence that people involuntarily mimic perceived facial expressions (Hatfield *et al.* 1992; Dimberg *et al.* 2000). Furthermore, Rizollatti and colleagues have identified a mirror neuron circuit that produces motor mimicry in response to perceived actions (Gallese *et al.* 2004). As a part of our laboratory research, the effect of embodied emotion on time perception and the role of imitation have been shown in Effron *et al.*'s (2006) study. In the bisection study conducted by these authors, the participants had to judge the presentation duration of neutral, happy and

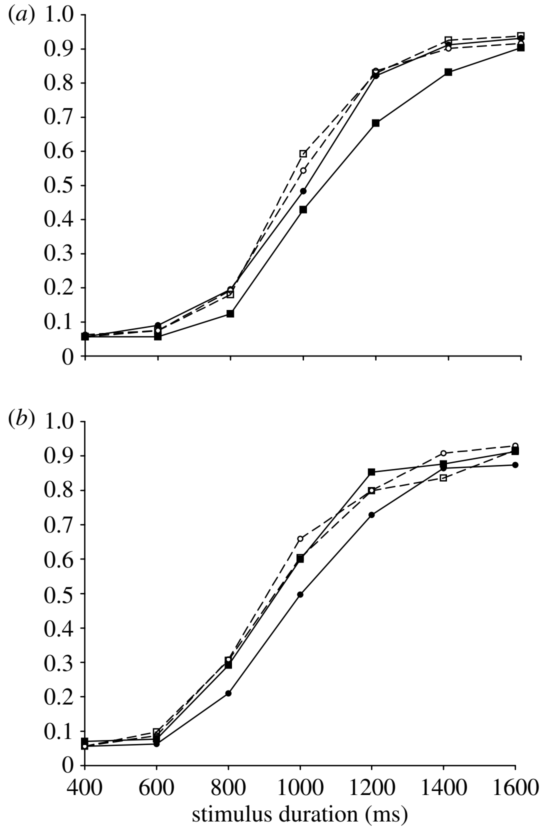

Figure 6. Proportion of long responses plotted against the stimulus duration value for (*a*) men and (*b*) women and the faces of a young man and woman and an elderly man and woman. Filled circles, elderly woman; open circles, young woman; filled squares, elderly man; open squares, young man.

angry faces. However, in one condition, imitation remained spontaneous, while, in the other, imitation was inhibited by asking the participants to hold a pen between their lips. The results show that, in the spontaneous imitation condition, the presentation duration of angry and happy faces was significantly overestimated and that this overestimation was greater for anger than for happiness. This finding is consistent with Droit-Volet *et al.*'s (2004) results. By contrast, in the inhibited imitation condition, the difference between the emotional and the neutral faces was close to zero, thus indicating that there was no temporal distortion when imitation was inhibited.

Chakrabarti & Baron-Cohen (2006) define emotional contagion as 'the tendency to automatically mimic and synchronize facial expressions, vocalizations, postures and movements with those of another person'. To summarize, our results on the effect of embodied emotion on time perception suggest that individuals match their time with that of others. However, sharing other people's time also implies a desire to empathize with them. Generally speaking, individuals are more likely to imitate the gestures and emotions of people they identify with or wish to associate with (Elfenbein & Ambady 2003; Lakin & Chartrand 2005). In Chambon *et al.*'s (2007) study, the effect induced by pictures of elderly people occurred only when the participants and the individuals on the pictures were of the same sex, i.e. when women saw an

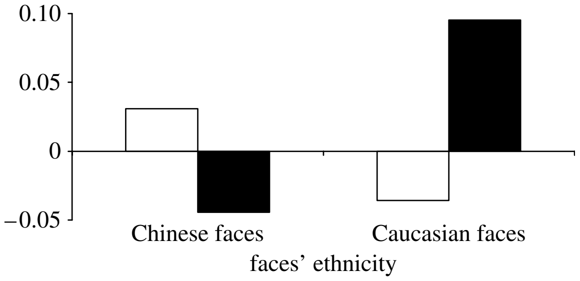

Figure 7. Difference scores (*p*(*long*) *emotion*–*p*(*long*) *neutral*) for the Caucasian participants seeing Chinese versus Caucasian faces, as a function of the participants' empathy level. White bars, low empathics; black bars, high empathics.

elderly woman and the men an elderly man. This motivation to empathize therefore imposes limits on the extent to which the behaviour of others is embodied (Decety & Jackson 2004). We have recently provided a clear demonstration of the important role of the motivation to imitate others in a bisection task in which Caucasian participants were presented with pictures of angry and neutral faces of Caucasian and Chinese people (Mondillon *et al.* 2007). As figure 7 shows, the temporal overestimation relating to the facial expression of anger was significant in the Caucasian participants when they viewed Caucasian faces (in-group effect), but not when they looked at Chinese faces (out-group effect). Empathy makes it possible to understand another person, to connect or resonate with him or her emotionally. Consequently, and in line with social studies on imitation (Hatfield *et al.* 1992), our results suggest that we are not motivated to empathize with everybody. Furthermore, empathy is an ability that does not develop to the same level in all individuals. For example, in the case of certain pathologies, such as autism, this lack of empathy causes difficulties in recognizing other people's emotions and resonating with them. To test the effect of individual differences on empathy, we evaluated the empathy quotient (EQ) in each participant by using the Baron-Cohen EQ (Baron-Cohen & Wheelwright 2004). As figure 7 illustrates, only the participants who were capable of a high-level of empathy produced a clear overestimation of time when confronted with angry faces.

6. CONCLUSION

In conclusion, one of the greatest paradoxes in time psychology is that we imagine that there is a mechanism that enables humans to measure time accurately, whereas, in an emotional context, this mechanism distorts their subjective time when compared with an objective measurement. Further investigations, with different duration ranges or different tasks, are now required to better understand the role of emotion in the perception of time. The entire series of studies that we have reported nevertheless show that the representation of a particular duration is highly context dependent. It depends on both intrinsic context, such as the emotional state at the onset of time processing, and extrinsic context, such as others' activity rhythm. Our studies also suggest that these contextual variations of subjective time do not result from the incorrect functioning of the internal clock but, on the contrary, from the excellent ability of the internal clock to adapt to events in the environment. Finally, the fact that we live and move in time and that everything takes more or less time has often been neglected. There is thus no unique, homogeneous time but instead multiple experiences of time. Our temporal distortions directly reflect the way our brain and body adapt to these multiple times. The philosopher Bergson (1968) once stated that 'on doit mettre de côté le temps unique, seuls comptent les temps multiples, ceux de l'expérience' (we must put aside the idea of a single time, all that counts are the multiple times that make up experience). Previous works have already suggested that, for young children, there is no unique, homogeneous time that can be easily transferred from one action to another, but multiple times, each intrinsically associated with the experienced action (Droit-Volet 1998; Droit-Volet & Rattat 1999; Rattat & Droit-Volet 2002). Other recent works have also suggested that different mechanisms are responsible for different durations (Eagleman *et al.* 2005; Karmarkar & Buonomano 2007; Ivry & Schlerf 2008). Overall, this calls the internal clock model into question, or at least in its current form. How can a simple pacemaker clock system track and adapt to these multiple times? Finally, is the internal clock only a metaphor, useful for the investigation of temporal behaviour by psychologists?

ENDNOTE

[1]The faces had been tested for the quality of the depicted expression by Beaupré & Hess (2005). Furthermore, in our experiment, we selected faces of women and the participants, with the exception of the children, were all women.

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