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The role of physiological arousal in time perception: Psychophysiological evidence from an emotion regulation paradigm

N. Mella [a,b,*], L. Conty [c], V. Pouthas [a]

[a] Unit of Cognitive Neurosciences and Cerebral Imaging, CNRS, Paris, France
[b] University of Geneva, Switzerland
[c] Laboratory for Cognitive Neuroscience – ENS, Paris, France

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ABSTRACT

Time perception, crucial for adaptive behavior, has been shown to be altered by emotion. An arousal-dependent mechanism is proposed to account for such an effect. Yet, physiological measure of arousal related with emotional timing is still lacking. We addressed this question using skin conductance response (SCR) in an emotion regulation paradigm. Nineteen participants estimated durations of neutral and negative sounds by comparing them to a previously memorized duration. Instructions were given to attend either to temporal or to emotional stimulus features. Attending to emotion with negative sounds generated longer subjective duration and greater physiological arousal than attending to time. However, a shared-attention condition showed discrepancy between behavioral and physiological results. Supporting the idea of a link between autonomic arousal and subjective duration, our results however suggest that this relation is not as direct as was expected. Results are discussed within recent model linking time perception, emotion and awareness.

1. Introduction

Time perception is crucial in numerous everyday life activities and, more generally, in the generation of adaptive responses to the environment. Various studies have shown that humans and other animals are able to estimate time accurately in the millisecond to minutes range. This ability is however highly context dependent and recent studies have pointed out the influence of an emotional context on time judgment (Angrilli, Cherubini, Pavese, & Manfredini, 1997; Droit-Volet, Brunot, & Niedenthal, 2004; Noulhiane, Mella, Samson, Ragot, & Pouthas, 2007; Tipples, 2008). More specifically, emotional events are consistently reported to last longer than neutral ones. Such distortion of time is thought to be linked to fluctuations of the physiological arousal level (Droit-Volet et al., 2004; Droit-Volet & Meck, 2007; Noulhiane et al., 2007). Yet, no study directly tested this assumption. The present study aimed at exploring the relation between physiological arousal and the emotional effect on time judgment by (1) introducing a measure of autonomic arousal and (2) modulating arousal by cognitive control of emotion.

Dominant models of time perception assume that our ability to perceive time relies upon a pacemaker–accumulator clock, where an oscillator – or pacemaker – produces a series of pulses – i.e. temporal units – and the number of pulses recorded over a given timespan represents experienced duration (e.g. Triesman, Faulkner, Naish, & Brogan, 1990). According to such models, two mechanisms can affect the functioning of the timer: attention and arousal. A large number of studies using dual tasks or distracting paradigms have shown that when attention was distracted from the processing of time, duration was perceived as shorter (Brown, 1997; Macar, Grondin, & Casini, 1994). Attentional theories of time perception predict that less attention to time will result in fewer accumulated pulses (e.g. Zakay, 2005). By contrast, arousal is thought to increase the speed of the pacemaker, resulting in a longer perceived duration (e.g. Burle & Casini, 2001).

Only a few studies have focused on the question of how arousal induced by emotion influences the processing of time. Using a temporal bisection task, Droit-Volet and collaborators (2004) showed that the perceived duration of faces expressing emotion was longer than for those with a neutral expression. Replicating this finding, Tipples (2008) showed that this was particularly true of faces expressing anger. In a study using standardized emotional material, we manipulated positive and negative sounds lasting 2–6 s assessed in terms of arousal, in a reproduction and a verbal estimation task (Noulhiane et al., 2007). Results showed that emotional sounds were perceived as longer than neutral ones. Interestingly, the emotional effect was greater with negative stimuli (Noulhiane et al., 2007), which are thought to induce stronger physiological and cognitive responses than neutral or positive stimuli (Caccioppo & Gardner, 1999). Overall these studies thus

* Corresponding author at: University of Geneva, Department of Psychology, Boul. du Pont d'Arve, 40, 1211 Geneva 4, Switzerland. Fax: +41 (0) 22 389 90 29.
E-mail address: nathalie.mella-barraco@unige.ch (N. Mella).

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support activation-based models of time perception postulating that a higher level of arousal generates longer subjective durations.

However, while physiological activation is assumed to be responsible for the lengthening of experienced duration, none of these studies used physiological measures able to assess changes in activation level. Electrodermal activity is an indirect measure of the sympathetic autonomic activity frequently used to index modulations in global physiological arousal level (e.g. Boucsein, 1992). More specifically, skin conductance response (SCR) is widely used in the study of emotion and is thought to vary with the level of arousal induced by emotional stimuli (Kreibig, 2010). This measure thus seems to be a valid, non invasive method, to account for the assumed role of physiological arousal in the lengthening effect of emotion on time perception.

With the aim to manipulate variation of arousal, we chose to study time perception in the framework of emotion regulation. Some studies have pointed out the key role of arousal – and not valence – in the conscious regulation of negative emotion (e.g. Dillon & LaBar, 2005). Such proposal leads to the idea that the cognitive control of emotion might constitute a good way to observe variation of physiological arousal and its related effect on timing. Several means of investigating emotion regulation exist and the most commonly used consists in asking participants to voluntary enhance or decrease emotion generated by a stimulus (e.g. Beauregard, Levesque, & Bourgouin, 2001; Kim & Hamann, 2007; Ochsner & Gross, 2005; Ochsner et al., 2004; Ohira et al., 2006). Another way to study emotion regulation is to manipulate attention to *versus* away from emotion. According to Gross and collaborators (Gross, 1998b; Gross & Thomson, 2007), this strategy, termed 'attentional deployment', have an impact early in the emotion-generative process. In that, it should ensure a good manipulation of top-down control of arousal induced by emotion and its related effect on time perception.

This hypothesis was tested in a duration comparison task, including neutral and negative sounds of varying emotional intensity. The choice of using negative stimuli was guided by the fact that negative events are thought to generate stronger physiological responses than positive events do (e.g. Cacciopo & Gardner, 1999). In a previous experiment, we showed that the effect of emotion on time judgment was maximal with short duration stimuli and progressively declined with the stimulus duration (Noulhiane et al., 2007). Therefore, we chose to focus on short duration processing – i.e. 2 s – in order to maximize the emotional effect on time perception. Attentional deployment was manipulated by prior instructions to attend either to time or to emotion or to both dimensions. These instructions may be linked to the three traditional conditions used in emotion regulation paradigms, i.e. increasing, decreasing and maintaining emotion. Attending to emotion is expected to enhance emotion, while attending to time is expected to down-regulate emotion. Attending to both dimensions may reflect an intermediate condition, which could be assimilated to the 'maintaining emotion' condition. We expected to replicate the relative overestimation of emotional compared to neutral sounds when participants directed their attention toward emotional intensity or divided their attention between time and emotion, but not when they had to focus their attention on time and ignore emotional features. Furthermore, we expected that longer time estimates will be associated to higher levels of SCR.

2. Material and method

2.1. Participants

Nineteen participants aged from 21 to 28 years (9 males, mean age: 26 ± 2.45, 90% postgraduates) gave their informed consent for the experiment. None reported a history of neurological or psychiatric disorders. None of them reported taking any medication. The experiment was approved by the local ethical committee and performed in accordance with the ethical standards laid down in the 1964 declaration of Helsinki.

2.2. Material and design

The experiment was conducted in a small dimly lit room. A specifically designed laboratory program (Stimulat) controlled both the presentation of standard durations and the recording of subjects' responses with an accuracy of ±0.5 ms. Auditory stimuli were presented binaurally via headphones at 70 decibels Sound Pressure Level (dB SPL). Participants' judgments were given with a three-button device held in their dominant hand.

The experiment was composed of two phases – a training phase and a test phase. During the training phase, participants had to memorize the standard duration (2 s). Training was conducted with a pure beep-like tone of 2 s duration which was first presented 10 times, followed by 30 trials in which the duration could either be slightly shorter (1800 ms), equal (2000 ms), or slightly longer (2200 ms). These durations occurred randomly and their probability of occurrence was equivalent. The inter trial interval varied between 1450 and 1550 ms. For each trial, participants decided whether the presented sound was shorter, equal or longer than the standard, using their index finger, middle finger or ring finger respectively to indicate their responses on the three-button panel. Three seconds after the end of the sound, feedback was provided on the screen: the three possible answers were presented, i.e. 'shorter', 'equal' and 'longer', with the correct response illuminated. The standard duration was considered to be correctly memorized when at least 80% of correct responses were reached. The training phase was repeated once if necessary.

In the test phase, 12 neutral sounds (mean arousal 4.39), six low negative sounds (mean arousal 5.71) and six high negative sounds (mean arousal 7.58) taken from the International Affective Digitalized Sounds System (Bradley & Lang, 1999) were used. Three levels of emotional intensity, based on the norms published by Bradley and Lang (1999), were thus manipulated. A list of the selected sounds is presented in the appendix. 80% of these sounds were of the same duration as the standard (2 s), 10% were shorter (1 s) and 10% longer (4 s). Instructions were given as follows:

"You will now hear different sounds. Your task will be twofold: first, you will have to judge for the duration of the sound and say whether it was shorter, equal or longer than the duration of the sound you have just learnt. Second, you will have to determine whether the sound was of low, medium or high emotional intensity. Prior to each sound, you will be asked to attend either to emotional intensity, or to time, or to both dimensions. If you see the letter "T" on the screen, you will have to focus attention on time and ignore emotion. If you see the letter "I", you will have to focus on emotional intensity. If you see the letters "ti", then you will have to attend equally to both dimensions."

The test phase was composed of three sequences of 24 trials with sounds lasting 2 s, counterbalancing the emotion and the attention conditions. Six trials with shorter and longer durations, considered as fillers, were added to each sequence and were excluded from the analyses. The inter-stimulus interval varied from 5500 to 6500 ms. Participants gave their responses by using their index finger, middle finger or ring finger on a three-button panel. Prior to the test phase, they were given some practice trials.

2.3. Physiological data collection and reduction

Skin conductance response (SCR) was recorded using an MP-150 psychophysiological monitoring system (Biopac Systems, Santa Barbara, CA).