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Awareness of time distortions and its relation with time judgment: A metacognitive approach

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ABSTRACT

The perception of time cannot be reduced to a simple percept produced by an internal clock. The aim of the present study was therefore to investigate the role of the individual consciousness of time on temporal judgments. In the present study, the participants' awareness of attention-related time distortions was assessed using a metacognitive questionnaire. The participants were also required to verbally judge a series of stimulus durations in a single or a dual task condition. The results revealed that time was underestimated in the dual task compared to the single task. However, the accuracy of time judgments improved in line with the participants' individual awareness of attentional time distortion: The more aware they were of the role of attention in time perception, the lower the time distortions they exhibited. Conscious awareness of time therefore plays a role in the accuracy of the time judgments made by human beings.

1. Introduction

Most psychologists consider that human beings possess a primitive sense of time. They have found evidence of this in the ability of infants to estimate time accurately in different temporal discrimination tasks (Brannon, Suanda, & Libertus, 2007; Provasi, Rattat, & Droit-Volet, 2011; VanMarle & Wynn, 2006). Authors have therefore proposed models in which an internal clock mechanism provides the raw material for the representation of time (e.g., Gibbon, Church, & Meck, 1984; Treisman, 1963). According to the most popular internal clock models, a pacemaker-like system emits pulses that are transferred to an accumulator via a switch that closes and opens at the beginning and end of the stimulus to be estimated, respectively. The time judgment therefore directly depends on the number of pulses accumulated: The more pulses that are accumulated, the longer the duration is judged to be. The most widespread time distortions, such as the temporal underestimations observed in the dual-task paradigm, are therefore explained in terms of a loss of this temporal raw material (e.g., Fortin & Breton, 1995; Macar, Grondin, & Casini, 1994; Vanneste, Perbal, & Pouthas, 1999). When attention is diverted away from the processing of time by a non-temporal task, the switch is thought to open and a number of pulses are lost (Coull, Vidal, Nazarian, & Macar, 2004; Zakay & Block, 1996). Consequently, durations are judged to be shorter in dual than in single temporal tasks.

However, in time estimation tasks, temporal judgment cannot be explained solely in terms of the functioning of an internal clock mechanism. Decision processes may also affect temporal judgments. However, as pointed out by Wearden and Grindrod (2003), these processes have generally been neglected in studies devoted to the perception of time. In the main, the few studies to examine this topic have manipulated participants' decisions by using payoffs or feedback in temporal

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tasks (e.g., Brown, Newcomb, & Kahrl, 1995; Droit-Volet & Izaute, 2005, 2009; Franssen & Vandierendonck, 2002; Montare, 1985, 1988; Wearden & Grindrod, 2003). The results have generally shown that feedback increases the accuracy and reduces the variability of time estimates. This observation is explained in terms of the idea that feedback either improves the representation of durations in reference memory or modifies the decision criteria. In conditions which make temporal discrimination difficult, participants would adopt a more conservative decision criterion when feedback is provided than when it is not, thus improving their time discrimination. However, by modeling the temporal discrimination performance of children of different ages characterized by different levels of temporal memory representation, Droit-Volet (2002) showed that the decision processes are closely related to the representation of durations in memory. Thus, the participants who have a fuzzier memory representation of time are more conservative in their temporal decisions. In a temporal bisection task, in which participants have to categorize stimulus durations as more similar to a short or a long anchor duration, Droit-Volet and Izaute (2009) allowed their participants not to respond when they were not sure of the answer and the results showed that temporal judgments also depend on the feeling of knowing. In this study, the participants who were less confident in their knowledge were indeed more conservative in their decision to respond short or long. By providing feedback in temporal tasks, these different studies have therefore shown that the participants' temporal knowledge may influence their time judgment through decision processes. The question is: do participants possess general knowledge about their sense of time that affects their time judgments independently of the implemented experimental manipulation.

Knowledge about knowledge is referred to as metacognition (Koriat, 2007; Nelson, 1996). Studies of metacognition have shown that individuals are conscious of their cognitive ability in a specific domain, and that this consciousness directly affects their strategies and their performance (Kornell & Metcalfe, 2006; Son, 2004; Son & Kornell, 2009; Son & Metcalfe, 2000). For example, when people have to learn a list of items in a short period, they prefer to choose the easier rather than the difficult items. However, when a longer period is available to them, they prefer to choose the more difficult items. It is therefore their awareness of their level of knowledge about the items which determines their learning strategies as a function of context.

In line with the research reported above, our assumption is that, in their everyday lives, individuals have direct introspective access to the content or character of their experience of time (Lamotte, Chakroun, Droit-Volet, & Izaute, in preparation). They are thus aware both of their own sense of time and of the factors that may distort their experience of time (Wittmann & Paulus, 2007). Very few studies have adopted this metacognitive approach to time perception. Recently, however, Sackett, Meyvis, Nelson, Converse, and Sackett (2010) revealed that the enjoyment of a task depends directly on the belief that time is thought to pass quickly independently of the actual time elapsed. In this study, the subjects used the subjective time as a cue on the basis of which the task was judged to be more or less enjoyable. The metacognitive experience of the progress of time therefore acts as an input into metacognitive judgments (Efklides, 2006).

As far as time knowledge and time estimation *per se* are concerned, everyone has experienced the fact that time flies when performing an interesting activity (Danckert & Allman, 2005; London & Monell, 1974; Sackett et al., 2010). In other words, people are conscious that perceived time shortens when their attention is distracted away from time. Consequently, by using a temporal dual task paradigm, the purpose of the present study was to examine whether the attention-related time distortion in a dual task compared to a single temporal task differs as a function of individuals' beliefs concerning the extent to which time perception is distorted when attention is distracted away from its processing. In addition, we have tested the effect of sex in oder to verify that this control factor did not modify the time judgments (Block, Hancock, & Zakay, 2000).

2. Method

2.1. Participants

Thirty-three undergraduate students (15 men, 18 women; mean age = 21.2 years, *SD* = 1.80) from Clermont University participated in this experiment in return for course credits.

2.2. Material

The participants were seated in a quiet room in the laboratory in front a PC that controlled the experimental events and recorded the responses via E-prime software. The stimulus to be timed was a blue rectangle (361 mm $\times$ 270 mm) presented in the center of the computer screen. In addition, the participants were asked to complete a time distortion metacognition questionnaire (TDM questionnaire) with a series of different items such as «*when I am sad, I feel I am being slower*», «*when I drink coffee or tea, I find that the time goes faster*» or «*when I am in pain, I feel I am being slower*» and a specific item on attention "*The more I focus attention on time, the slower time goes.*" (Lamotte et al., in preparation). The participants completed the entire questionnaire in order to disguise the goal of the study related to attentional time distortions. However, the only item that we took account of for our specific experiment using the dual-task paradigm was: "The more I focus attention on time, the slower time goes." The participants answered on a 5-point scale from 1 (totally disagree) to 5 (totally agree).

The participants were asked to complete a verbal temporal estimation task and the TDM questionnaire. The questionnaire order was counterbalanced across subjects (i.e., given before the temporal task for half the participants and after the temporal task for the other half). In the verbal temporal task, the participants had to judge the stimulus duration in milliseconds

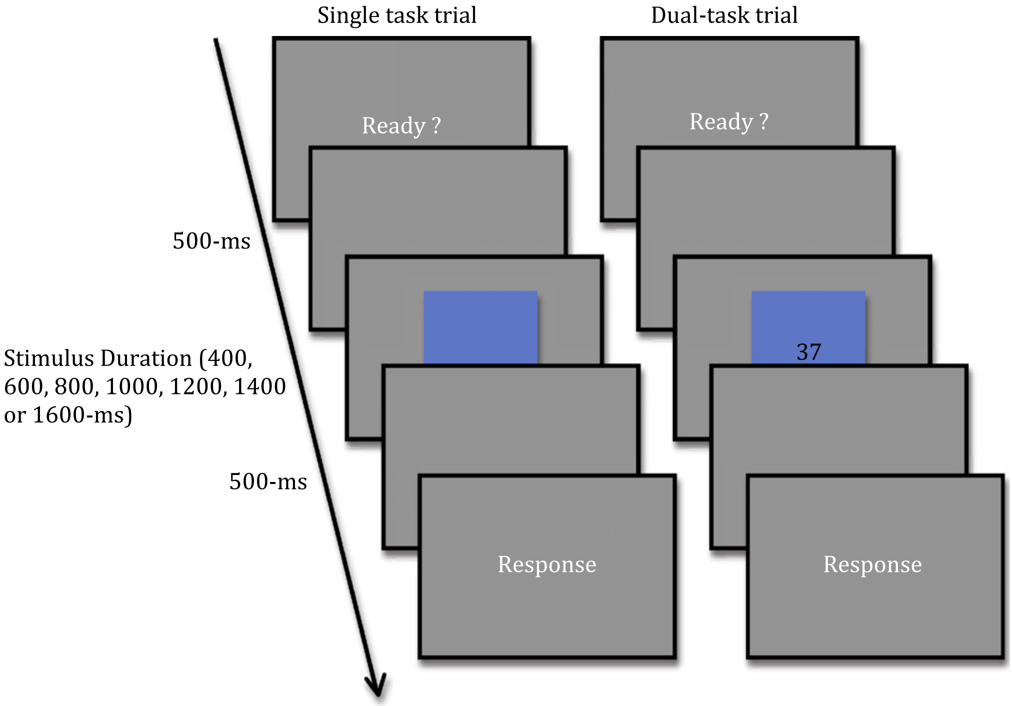

Fig. 1. Study design.

by giving their responses on the numeric keypad without being forced to make any particular estimate. They were nevertheless instructed that the stimulus durations were between 100 ms and 2000 ms and were reminded that 1000 ms = 1 s. There were 7 stimulus durations: 400, 600, 800, 1000, 1200, 1400 and 1600 ms. Two other durations (200, 1800 ms) were used during a preliminary demonstration phase which consisted of 8 trials, i.e. 4 for each duration. In the temporal task, each stimulus duration was presented in two conditions: a single-task condition and a dual-task condition (Fig. 1). In the single-task condition, the rectangle (stimulus) was presented alone. In the dual-task condition, the rectangle contained a series of digits presented in the center of the rectangle. The participants had to read this series of digits aloud backwards while simultaneously estimating the duration of the rectangle. The number of digits in the rectangle increased as a function of the stimulus duration from 2 to 4 as a function of the stimulus duration (2 for 400, 600 and 800-ms, 3 for 1000 and 1200-ms, 4 for 1400 and 1600-ms). Each number in the digit series was randomly chosen between 1 and 9 from one trial to another trial (e.g. 2 6, 8 3 or 3 7 for the series of 2 digits). At the beginning of one trial, the word «ready» appeared in the center of the computer screen. When the participants were ready, they started the trial by pressing on the space bar. 500-ms after the press bar, the rectangle was presented without (single task) or with the series of digits (dual task). When there were digits in the rectangle, the participants started and stopped the digit reading at the onset and the offset of the rectangle presentation, respectively. 500-ms after the end of the rectangle presentation, the word «response» appeared and the participants gave their response on the numeric keypad that ended the trial. The participants were therefore exposed to 9 blocks of 14 trials each (126 trials), i.e. 9 trials for each stimulus duration presented in the 2 experimental conditions.

3. Results

Two indexes of temporal estimation were used: (1) the mean accuracy and (2) the coefficient of variation. The mean accuracy corresponds to the difference between the estimated duration and the stimulus duration divided by the stimulus duration. An index value close to zero indicates that the stimulus duration is judged accurately while a value less than zero indicates that it is underestimated. The coefficient of variation is the ratio between the standard deviation and the mean duration. Analysis of variance (ANOVA) was performed for each index, with 2 between-subjects factors (sex and questionnaire order) and 2 within-subjects factors (task and stimulus duration), and with the score on the «attention» question mentioned above (TDM score), extracted from the TDM questionnaire, being used as covariate factor.

Fig. 2 presents the mean accuracy plotted against stimulus duration for the single and the dual task. The ANOVA on the mean accuracy revealed no significant effect of questionnaire order, $F(1,28) = .19$, $p = .67$. This indicates that the position at which the questionnaire was administered, i.e. before or after the temporal task, did not affect time estimation. There was also no significant effect of sex, $F(1,28) = 3.24$, $p = .08$. More interestingly, the ANOVA revealed a significant effect of task, $F(1,28) = 14.41$, $p = .001$. In line with the results of studies conducted using a dual-task paradigm, the stimulus durations

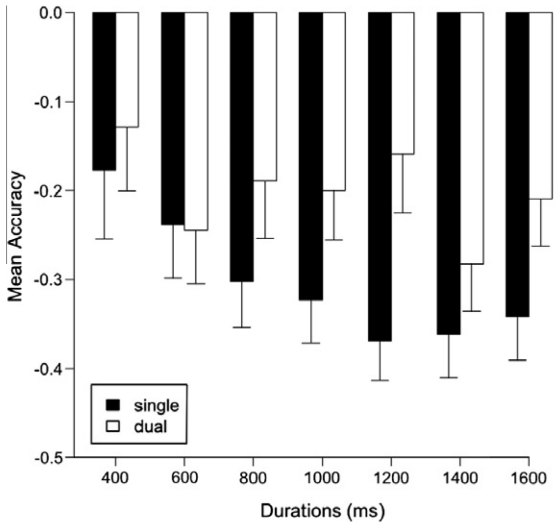

Fig. 2. Mean accuracy plotted against stimulus duration for the single and the dual temporal task.

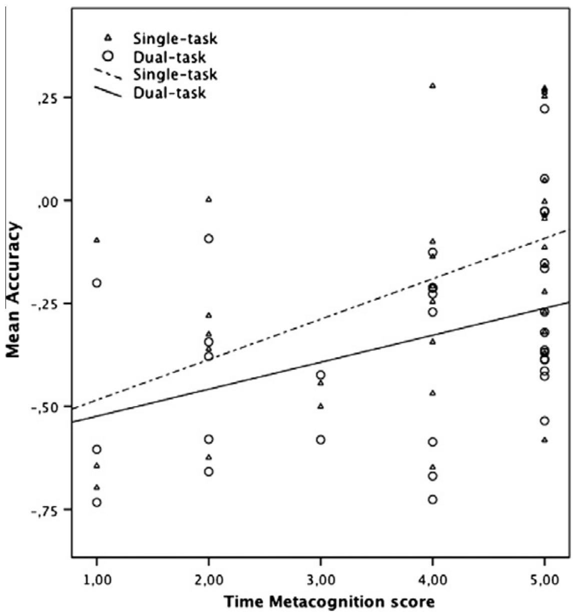

Fig. 3. Correlation between the time metacognition score and the mean accuracy for the single and the dual temporal task.

were underestimated more in the dual-task ($M = -.302$, $SD = .25$) than in the single-task condition ($M = -.202$, $SD = .29$). However, there was also a significant main effect of duration, $F(6,168) = 6.10$, $p = .001$, as well as a significant task x duration interaction, $F(6,138) = 5.61$, $p = .001$. Post-hoc Bonferroni tests revealed that the stimulus durations were systematically judged shorter in the dual than in the single task (all *p*s < .05), except for the two shortest stimulus durations (i.e., 400 and 600 ms).

More specifically, the ANOVA revealed a main effect of TDM score, $F(1,28) = 5.83$, $p = .02$, and the TDM score just failed to interact significantly with the task, $F(1,28) = 3.62$, $p = .07$. No other factor significantly interacted with the TDM score (all *p*s > .05). There was indeed a significant correlation between the TDM score and the mean accuracy for the two tasks collapsed together (Pearson correlation, $R = .42$, $p = .015$). Fig. 3 indicates the correlation between the TDM score and the mean accuracy for the single and the dual-task condition. There was a positive correlation between the TDM score and both the single, $R = .46$, $p = .007$, and the dual-task, $R = .34$, $p = .05$. In other words, the more the participants agreed with the idea that time is underestimated when attention is diverted away from it, the more accurate their temporal estimates were. However, this effect tended to be more pronounced in the single-task than in the dual-task condition.

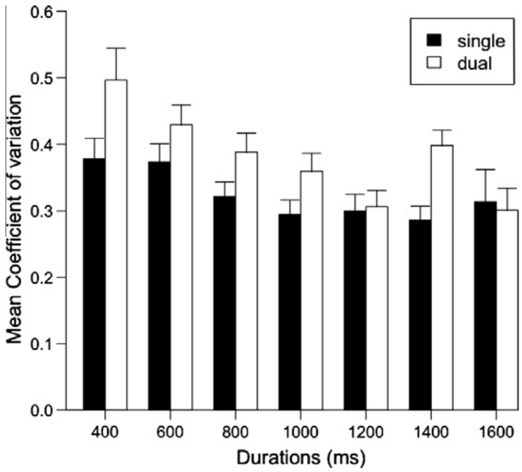

Fig. 4. Mean coefficient of variation plotted against stimulus duration for the single and the dual temporal task.

Moreover, we checked the correlations between temporal performance and the mean score to the TDM questionnaire on the whole included the series of different items (see method). As expected, there was no significant correlation between this general score and the mean accuracy neither for the single nor for the dual task (all *ps* > .05). There were only some significant correlations between the mean accuracy and the participants' response to some specific items : i.e., «when I am happy, I find time goes faster» (single task, $R = .46$, $p = .007$, dual task, $R = .43$, $p = .012$), «the more I am doing something difficult, the more faster time goes» (single task, $R = .46$, $p = .007$), «for most people, the action movies seems shorter than other movies» (single task, $R = 40$, $p = .04$), «for most people, difficulty tasks go faster» (Single task, $R = .47$, $p = .007$), «most of the people find that time longer when they are waiting» (dual-task, $R = .35$, $p = .04$), «I find time longer when I am waiting» (dual task, $R = .35$, $p = .05$). These different results confirmed that the better accuracy on our temporal task of laboratory was related to individual awareness of time distortions in certain contexts of everyday life.

The second ANOVA run on the coefficient of variation revealed no significant effect of questionnaire order, $F(1,28) = 1.69$, $p = .20$. There was also no significant effect of TDM score, $F(1,28) = .55$, $p = .46$, or any significant interaction involving this factor (all *ps* > .05). These results demonstrate that time distortion-related knowledge affected the magnitude of the distortion of the time estimates but not their variability (see Fig. 4). We only observed a significant effect of task, $F(1,28) = 23.70$, $p = .0001$, and of duration, $F(6,168) = 8.57$, $p = .001$, and the interaction between task and duration just failed to reach significance, $F(6,168) = 2.36$, $p = .06$. This tends to indicate that the temporal estimates were more variable in the single than in the dual task and that temporal variability increased with the length of the stimulus duration. In addition, although there was no main effect of sex, $F(1,28) = 1.04$, $p = .51$, the sex × duration interaction was significant, $F(6,168) = 3.05$, $p = .007$. The Bonferroni tests suggest that temporal variability was greater in the women than the men but only for the two shortest stimulus durations ($p < .05$), with temporal variability being similar in both women and men for the other durations (all *ps* > .05).

4. Discussion

We often observe that our sense of time is mistaken, with time seeming to pass faster or slower than its objective measurement would indicate. In other words, in our everyday lives we experience how and why time flies or drags as a function of the situations we encounter. The orignal contribution of our study is the finding that the time judgments in a simple laboratory time estimation task with short durations were related to participants' individual consciousness of the way time fluctuates with attention in the everyday life. In other words, the temporal judgment of short durations is in part linked with individual subject's beliefs that «the more I focus on time, the slower time goes» derived from experiences of everyday life activities that are generally of longer duration of longer durations (waiting for bus, boring night party). More precisely, our results showed that the level of awareness of attentional time distortions was not associated with variations in the precision of temporal discrimination, the variability in time estimates remaining similar irrespective of the participants' level of temporal awareness. By contrast, it was connected with the magnitude of time distortions, with the temporal shortening effect being more reduced in participants with a greater level of temporal awareness. Our results did indeed reveal that the more aware the participants were of attention-related time distortions, the more accurate their estimations of stimulus durations were.

In line with the results of temporal studies using the dual-task paradigm (e.g., Block, Hancock, & Zakay, 2010; Brown, 1997; Grondin, 2010; Zakay, 1989), we found that stimulus durations were underestimated more in the dual task than in the single task condition, except in the case of the shortest durations (i.e., 400, 600 ms) which are processed automatically (Lewis & Miall, 2006). The attention-based internal clock models (Block & Zakay, 1996) explain this shortening effect for long durations in terms of the attentional resources required for their accurate processing. When attentional resources are consumed by the processing of other non-temporal information, a lower level of resources is available for the processing of time, some pulses are lost, and time is judged shorter. However, the original feature of our study, which made use of a TDM questionnaire, was to show that the shortening did not depend only on a clock-related mechanism but also on the individuals' awareness of this temporal mechanism. Our results indeed showed a significant correlation between the time distortions in a temporal dual task and the subjective individual awareness of attentional time distortions. More precisely, our findings revealed that the shortening effect in a temporal dual task procedure decreased with the participants' increasing awareness that perceived time speeds up when we do not pay attention to time.

The role of participants' time knowledge in time judgments has been largely neglected in the literature, with psychologists hitherto being more interested in providing evidence of the existence of an internal clock mechanism in the brain which is able to account for the observation of accurate time measurements in humans. However, the present study suggests that the participants' awareness of subjective time distortions improve their time estimates in a dual-task paradigm. In other words, the judgment of short durations (ms) in an attentional laboratory task would be linked to individual believes that «the more I focus on time, the slower time goes». This awareness of attentional time distortions is derived from experiences of activities of everyday life whom durations are longer (multiple seconds) than those used in the laboratory tasks (ms). Nevertheless, the result of our study suggested that this general temporal awareness affects temporal judgments for short durations (ms), even if the mechanism involves in the processing of short durations are totally different from those involved in the feeling of passage of time. The impact of awareness of time as function of duration ranges to be estimated must be further investigated. Nevertheless this raised question: what role does this time awareness play in time judgments? In our study, metacognitive beliefs (knowing that divided attention will result in durations being underestimated) were correlated with more accurate verbal time estimations. In some memory learning studies, individuals' awareness of their cognitive capacities has been found to improve their performance because it causes them to use more efficient strategies (Dunlosky, Kubat-Silman, & Hertzog, 2003). For instance, Son and Kornell (2009) demonstrated that when people have to both manage their study activities and enhance their performance, they choose to study the easiest items first, but also allocate more study time to the more difficult items. Knowledge of attention-related time distortions may therefore influence time judgments by encouraging participants to increase their monitoring of their own attention and allocate more attention to time processing. This finding is consistent with the results obtained by Macar et al. (1994) who used an attention-sharing method in which the participants were asked to allocate various proportions of attention (i.e. 75% or 25%) to a time task. Indeed, controlled attention instructions produced temporal shortening effects in the same way as the dual task and distracter stimuli. Since our study did not reveal any effect of questionnaire order (before or after the temporal task), we can assume that our findings were due to the participants' individual strategies of attention monitoring based on their time knowledge which was activated by the experimental context.

In our study, the effect of the participants' awareness of time was observed not only in the dual task but also in the single task in which attention was focused on time. Contrary to our expectations, there was not a stronger correlation between the participants' awareness of the attention-time relation and their time judgments for the dual than for the single task. This is likely due to the fact that the participants were given the dual-task and the single-task trials in the same session (within subject condition) and not in two separate tasks. Consequently a general disposition related to time awareness would have been adopted during the session on the whole, and the participants would have not change their behavioral tendency from one to another trial. It would be nevertheless interesting to investigate in which specific condition the individual time awareness does not affect time judgments. Finally, in line with the assumptions set out above, we can suppose that, irrespective of conditions, the consciousness of time distortions leads participants to pay more attention to time processing when they are explicitly instructed to estimate time. A number of studies have indeed shown that the magnitude of the underestimation of time in dual tasks decreases with the increase of attentional control capacities (for a review, see Droit-Volet, 2011). It is also possible that participants who are aware of time distortions are more conservative in the criteria they use when estimating time. As stated in the introduction, children who are less confident in their time judgments are more conservative (Droit-Volet & Izaute, 2005, 2009). Finally, further studies are now required in order to try to identify the processes (attention vs. decision) involved in this time awareness effect on time judgments. Whatever the case, the awareness of time might allow participants to compensate for the effects of time distortions in explicit time judgments, in other words to fight against their natural tendency to distort time. Indeed, metacognitive studies have provided ample evidence that individuals tend to correct or discount the effects of some factors (Begg, Duft, Lalonde, Melnick, & Sanvito, 1989; Begg, Vinski, Frankovitch, & Holgate, 1991; Koriat, 1997).

Our study also raises the question of the inaccuracy of explicit temporal judgments in humans. This is the paradox identified by Droit-Volet and Gil (2009): why are our time estimates so inaccurate if we possess a sophisticated mechanism for measuring time? What clockmaker would keep such a clock? Another alternative hypothesis is to consider that there is no mechanism dedicated to the estimation of time (Wittmann, in press). According to Craig (2009), human judgments derive directly from our awareness of our self and body. Following this line of argument, grounded time theory (Droit-Volet, in press; Droit-Volet & Gil, 2009) suggests that when participants make explicit temporal judgments of new events for which they have not experienced any associated regular duration, their time judgments derive from the emotional and bodily states (sensation) experienced or reactivated during their interaction with the environment. Consequently, it seems possible that individuals who are more conscious of time distortions estimate time more accurately because they directly experience less time distortion than other people. However, there is no reason why time judgments should fully coincide with experienced time. It is therefore possible that the awareness of time distortions that results from their past experience of time may lead participants to compensate for the time distortions they experience, i.e., to recalibrate experienced time distortions in a way that gives them a more objective appraisal of time. In sum, the study of the awareness of time and its effect on time judgments raises new questions and consequently opens up a new avenue of research.

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