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What factors underlie our experience of the passage of time? Theoretical consequences

Natalia Martinelli, Sylvie Droit-Volet

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1 Running head; What factors underlie our experience of the passage of time?
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10 **What factors underlie our experience of the passage of time? Theoretical consequences**
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12 **Martinelli¹, N. and Droit-Volet¹, S.**

13 ¹Université Clermont Auvergne, CNRS, LAPSCO, F-63000 Clermont-Ferrand, France.
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21 **Corresponding author:** Sylvie Droit-Volet, Université Clermont Auvergne, Laboratoire de
22 Psychologie Sociale et Cognitive (LAPSCO), CNRS, UMR 6024, 34 avenue Carnot, 63037
23 Clermont-Ferrand, France. E-mail: sylvie.droit-volet@uca.fr.
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Abstract

The aim of this study was to examine the factors that explain variations in the conscious experience of time. The level of difficulty of the task, emotional valence and duration of stimuli were tested in three different experiments with two ranges of durations, one of seconds and the other one of minutes. The results showed that the passage of time was judged faster with durations in the seconds than in the minutes range. However, for all duration values, each change in the features of the task produced changes in the judgment of the passage of time. The subjective feeling of an acceleration of the passage of time therefore increased linearly with the increase in the level of difficulty of the task and with the positive valence of the emotional stimuli. It also varied linearly with the length of real time, increasing in the same proportion as the decrease in stimulus duration, regardless of the associated range (seconds or minutes). Our theory is that the judgment of the passage of time might be a generic way of describing the most salient internal or external contextual changes experienced.

Keywords: Time; Experience of time; Consciousness

42
43 Judging the different aspects of time is part of our daily activities. Every day, we estimate the duration
44 of events or that of the interval between two events. Every day, we notice that time passes faster or slower than it
45 really does. For decades, researchers have used an experimental approach to examine human abilities to judge
46 durations and the factors explaining their variations. However, the judgment of the passage of time (PoT) has not
47 been subject to the same experimental analysis involving supposedly more objective tests (Larson 2004; Wearden
48 2015; Droit-Volet 2018). The aim of this exploratory study was to fill this gap in the literature by experimentally
49 examining the factors behind variations in our awareness of changes in the speed of the passage of time.

50 Nonetheless, in recent years, the PoT judgment has been examined in more details in correlation studies
51 using the Experience Sampling Method (ESM), which makes it possible to evaluate PoT judgments in daily life
52 (Larson and von Eye 2006; Droit-Volet and Wearden 2015). With this method, participants are informed that they
53 will have to judge the speed of the passage of time at different times of the day, for several days of the week. They
54 receive phone calls during which they have to rate the speed of the passage of time using a Likert scale going
55 from “very slow” to “very fast”. They also have to answer a series of questions designed to assess the context in
56 which the temporal judgment is made. Droit-Volet and Wearden (2015) asked participants questions about the
57 valence of their emotion at the time of the temporal judgment as well as about the difficulty of the activity they
58 had just been performing and its level of attentional demand. Larson and van Eye (2006) asked about “emotional
59 engagement” (“how emotionally involved were you in the activity”) and “intellectual engagement” (“how
60 intellectually involved or 'into' the activity were you?") (p. 124). The statistical analyses performed in these ESM
61 studies have shown that the activity undertaken and the emotion felt are significant predictors of the judgment of
62 the passage of time. Indeed, the participants experienced an acceleration of the passage of time when the activity
63 performed was judged difficult and attentionally demanding or required more “intellectual engagement”. They
64 also reported that time passed more quickly when they felt happier, and that it slowed down when they felt sadder.
65 These results have been replicated in subsequent ESM studies demonstrating that emotions and task difficulty are
66 two major predictors of PoT judgment in daily life (Droit-Volet and Wearden 2016; Droit-Volet, et al. 2017;
67 Droit-Volet 2019a).

68 To account for fluctuations in the awareness of the passage of time with activity and emotion, Droit-
69 Volet juxtaposed the PoT judgment based on “Self-duration” with that based on “World-duration” (e.g., Droit-
70 Volet 2018; Droit-Volet & Dambrun 2019). The first corresponds to judgments of the passage of time resulting
71 from intra-individual analyses of a temporal extension or contraction of the minimal self. The minimal self is the
72 consciousness of oneself as an immediate subject of experience (Gallagher 2000, 2013). In other words, the
73 passage of time is judged to accelerate or decelerate relative to participants’ awareness of changes in their different
74 states, including the prevailing emotional feelings. The second is the representation of external time, as indicated
75 by our watches, that flows at a constant rate in a uniform and universal way. World-duration is therefore used as
76 a reference allowing individuals to state that time passes faster or slower than it really does. In sum, according to
77 this theoretical approach, the awareness of the passage of time would be based on the introspective analysis of the
78 self in its context and not the processing of event-durations.

79 This assumption is supported by the results of ESM studies which have found that the PoT judgment in
80 everyday life was related to the non-temporal context of judgment (activity, emotion) and not to temporal
81 information (Droit-Volet and Wearden 2016; Droit-Volet et al. 2017). Indeed, these studies showed no
82 relationship between the feeling about the speed of the passage of time at a given time and the values of estimated

83 durations (< 60 s); An overestimation of short durations did not translate into the feeling that time is passing faster.
84 The ESM studies nevertheless found that the PoT judgment was significantly correlated with the judgment of long
85 durations of several minutes. The mechanisms underlying estimates of short and long durations are likely to differ.
86 The processing of short durations involves an internal clock-like system, as has been well established in the
87 literature (e.g., Gibbon et al. 1984, for a review Merchant et al. 2013). In contrast, the processing of long durations
88 of several minutes would involve memory reconstruction processes that make use of non-temporal information
89 stored in memory during the interval to be processed (Droit-Volet et al. 2018). Similar results on the dependence
90 of time estimates on non-temporal information have been found in studies on retrospective timing in which
91 participants do not know in advance that they will have to judge time events and the internal clock is not activated
92 (Block 1992; Block et al. 2018). Therefore, Droit-Volet et al. (2017) concluded that the PoT judgment, even in a
93 prospective timing condition, would be based on memory mechanisms like in the retrospective time judgment.

94 The hypothesis that there is no relationship between PoT judgment and duration processing is deduced
95 from ESM findings on the lack of correlation between the PoT judgment and the judgment of short durations (<
96 60). However, although interesting, the ESM studies pose various methodological problems. First, the interval
97 duration considered by participants in their PoT judgments was not controlled, even if we may suppose that in
98 their everyday lives, they considered the duration of their current activity, i.e. a period of several minutes. Second,
99 the results of these ESM studies are based on correlation analyses, and not the causal link between the non-
100 temporal factors and the PoT judgment. There are very few studies that have experimentally investigated PoT
101 judgments in the laboratory (Sucala et al. 2011; Wearden et al. 2014). As in the ESM studies, they showed that
102 the task was perceived as passing faster when it was difficult than when it was easy. However, these studies have
103 only examined one factor (task difficulty) and not other factors on which PoT judgments could also depend, such
104 as emotion. In addition, and more critically, they have only examined one duration, namely of several minutes.
105 The participants had to judge the passage of time for a single interval of 4 minutes in Sucala et al.'s study (2011),
106 and of 3 minutes in Wearden et al.'s study (2014). None of these studies tested different durations in different
107 time ranges from a few seconds to several minutes, as would be necessary in order to examine the real influence
108 of durations on PoT judgments.

109 There still has not enough laboratory-based research into PoT judgments. The aim of the present study
110 was thus to begin to investigate the effect on the PoT judgment of different types of non-temporal factors, i.e. task
111 difficulty (Experiment 1) and the emotional valence of the stimuli (Experiment 2), with the duration maintained
112 constant, for durations in the range of seconds and minutes. Another aim was to examine the effect on the PoT
113 judgment of varying temporal information (Experiment 3) when the non-temporal information was controlled for.
114 Our hypothesis was that the PoT judgment would vary with the changes in the non-temporal factors, whatever
115 they were (task difficulty or emotion) for the interval durations in the minutes range, and those in the seconds
116 range. However, in a prospective PoT judgment paradigm, i.e. when participants know that they have to judge the
117 passage of time, we can assume that stimulus durations have a greater influence on the PoT judgment in the
118 seconds than the minutes range because the former involves the mobilization of an internal clock system as
119 explained above.

120

121 **1. Experiment 1 – Task Difficulty**

122 **2.1 Method**

123 2.1.2 Participants

124 The final sample was composed of 83 participants (72 women and 11 men), all of them students at
125 University Clermont Auvergne (mean age = 19.10, $SD = 1.49$), who received a course credit for their participation.
126 All individual participants signed an informed consent form describing the procedure used, that was in accordance
127 with the 1964 Helsinki declaration and approved by the Research Ethics Committee of the University Clermont-
128 Auvergne (IRB00011540-2019-33) following the French Ethical law.

129 2.1.2 Material

130 The experiment was presented on a 17-inch PC screen with a 1920x1080-pixel resolution, and a 60 Hz
131 refresh rate. Obviously, no temporal information (clock, watch, etc.) was available. Data collection and stimuli
132 presentation were handled with E-prime software v 2.0 (*Psychology Software Tools, Pittsburgh, PA, USA*). The
133 participants sat in front of the screen (50-cm distance) and responded using the computer keyboard. For the non-
134 temporal task, we used sequences of digits displayed (black on a white background) in “Courier New”, font size
135 18, in the center of the screen. Based on a pilot study involving five participants, the non-temporal task was
136 subdivided into 3 levels of difficulty. The difficulty level was defined in terms of the number and order of the
137 digits to be reproduced. The digit sequences contained different numbers presented in random order. For the first
138 level of difficulty of the non-temporal task, named “Easy”, a sequence consisted of two digits (e.g., 85), and the
139 participants had to type the digits on the normal computer keyboard in the same order in which they had appeared.
140 For the second level, “Medium”, a sequence consisted of six digits (e.g., 716483) and the participants again had
141 to reproduce it in the correct order. For the “Difficult” level, six digits were also presented per sequence (e.g.,
142 284106), but the participants had to reproduce it in the reverse order (601482). As explained in the procedure, the
143 number of digit sequences per trial obviously depended on the trial duration.

144 2.1.3. Procedure

145 All the participants performed 18 trials, i.e. 6 trials for each of the 3 difficulty levels of the non-temporal
146 task (easy, medium, and difficult). Each trial therefore consisted of a series of 2- or 6-digit sequences to be
147 reproduced either in the forward order or in the backward order. The trials were presented randomly. For each
148 digit sequence, the participants were presented with a fixation mark (+) displayed for 500 ms in the center of the
149 screen. The digit sequence then appeared for up to 1000 ms followed by a 500-ms blank screen. A text box was
150 then presented for 5000 ms with the response instruction and the participant reproduced the digit sequence as
151 quickly as possible. The inter-sequence interval varied according to the trial duration.

152 The participants were randomly assigned to one of two duration groups, one with trial durations in the
153 range of seconds ($N = 42$) and the other with trial durations in that of minutes ($N = 41$). In the seconds group, the
154 trials varied between 30 s, 33 s and 36 s, and in the minutes group between 90, 99 and 108 s. Consequently, the
155 number of digit sequences to be reproduced per trial varied as a function of the trial duration. To avoid the
156 methodological bias linked to the number of sequences, we maintained the same number of sequences for the
157 different trial durations by varying the length of the inter-sequence intervals. In the seconds group, all trials
158 contained 4 digit sequences with an inter-sequence interval varying between 400 and 650 ms for 30 s, 1000 and
159 3000 ms for 33 s, and 1000 and 3000 ms for 36 s. In the minutes group, the trials were composed of 12 digit
160 sequences with inter-sequence intervals between 375 and 625 ms for 90 s, 1000 and 1450 ms for 99 s, and 1200
161 and 2750 ms for 108 s. The 6 trials for each task-difficulty level therefore consisted of two trials for each of the 3

162 trial durations. However, the trial durations were similar across the different levels of difficulty of the non-
 163 temporal task.

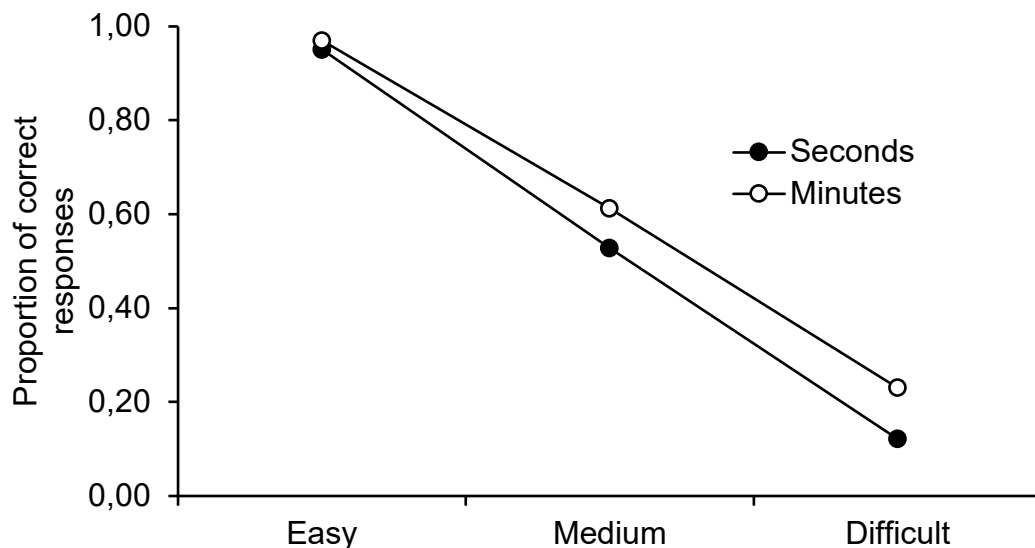
164 After each trial, the participants gave their judgment of the passage of time. The question “How did time
 165 pass for you during the activity compared to the time of a clock?” appeared with a 7-point Likert-type scale going
 166 from (1) “very slowly” to (7) “very fast”, and the participants responded on the computer keyboard. Before the
 167 testing trials, the participants were given 2 demonstration trials.

168 2.2 Results & Discussion

169 Non-temporal performance

170 For each participant, we calculated the number of correctly reproduced digit sequences as a proportion
 171 of the total number of sequences presented in each difficulty condition of the non-temporal task. An ANOVA was
 172 carried out on the non-temporal performance with the level of task difficulty (easy, medium, difficult) as within-
 173 subjects factor and the duration group (seconds, minutes) as between-subjects factor. The ANOVA showed a
 174 significant main effect of task difficulty, $F(1.88, 151.93) = 888.12, p < .0001, \eta_p^2 = .92$ (Fig. 1). The non-temporal
 175 performance therefore decreased with the level of task difficulty, as indicated by the linear effect of task difficulty
 176 ($M_{\text{easy}} = .96, SE_{\text{easy}} = .004, M_{\text{medium}} = .57, SE_{\text{medium}} = .02, M_{\text{difficult}} = .18, SE_{\text{difficult}} = .017, F(1, 81) = 2067.01,$
 177 $p < .0001, \eta_p^2 = .96$). The main effect of duration also reached significance $F(1, 81) = 9.22, p = .003, \eta_p^2 = .10$, as
 178 did the duration x task difficulty interaction, $F(1.88, 151.93) = 3.20, p = .045, \eta_p^2 = .038$, although the effect size
 179 was low. This indicates that the proportion of correct responses tended to be higher in the minutes range ($M_{\text{long}} =$
 180 $.60, SE_{\text{long}} = .017$) than in the seconds range ($M_{\text{short}} = .533, SE_{\text{short}} = .017$), especially for the highest task-difficulty
 181 level.

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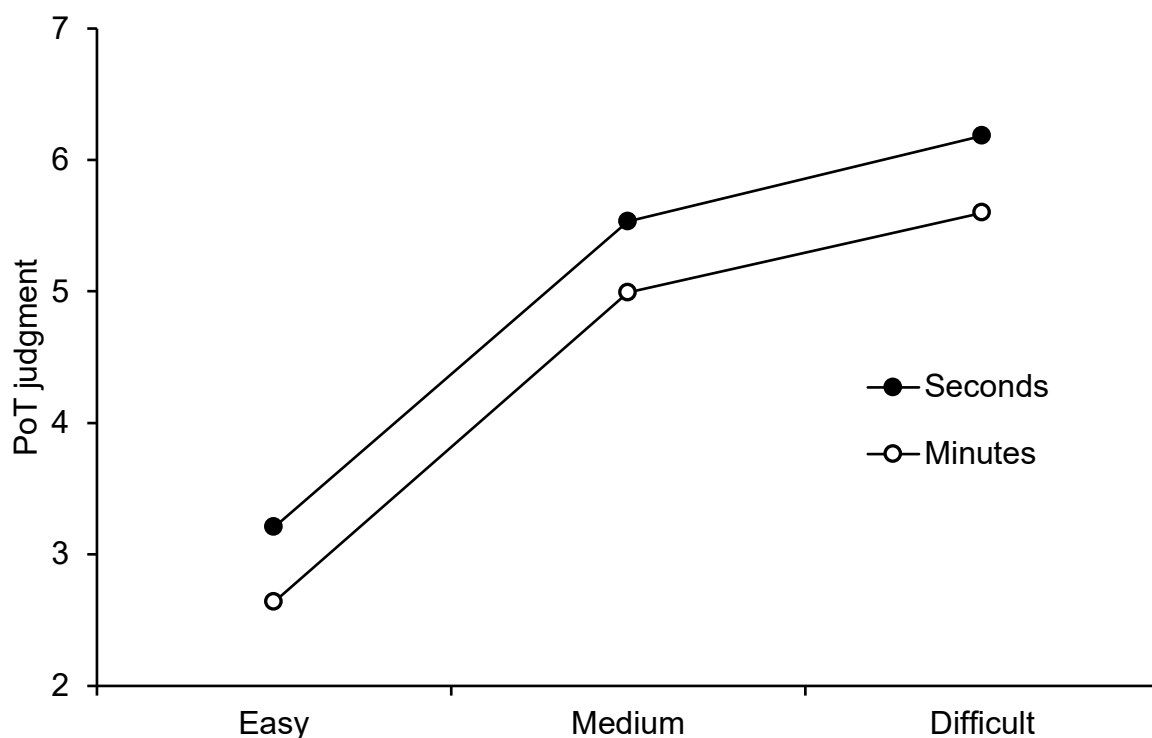
185 **Fig. 1.** Proportion of correct responses for the non-temporal task plotted against the task-difficulty level
 186 for the durations in the seconds and the minutes ranges.

187

188 Passage of time judgment

189 Fig. 2 shows the mean PoT judgments plotted against the three task-difficulty levels for the seconds and
 190 the minutes groups. An ANOVA was performed on the PoT judgment with the two factors described above (task

191 difficulty, duration group). This ANOVA revealed a significant main effect of task difficulty, $F(1.50,$
 192 $121.82) = 347.62, p < .0001, \eta_p^2 = .81$, with no interaction involving this factor ($F > 1$). There was only an
 193 additional main duration effect, $F(1, 81) = 15.13, p < .0001, \eta_p^2 = .16$, indicating that the passage of time was
 194 judged as slower for the durations in the minutes range ($M = 4.41, SE = .103$) than those in the seconds range (M
 195 $= 4.97, SE = .102$). Therefore, the statistical analysis demonstrated that the PoT judgment varied directly with the
 196 difficulty of the task as indicated by the linear effect of task difficulty, $F(1, 81) = 419.63, p < .0001, \eta_p^2 = .84$.
 197 Time was thus judged as passing slower for the easy task ($M = 2.92, SE = .115$) than for the medium ($M = 5.26,$
 198 $SE = .09$) or the difficult task ($M = 5.89, SE = .093$), and for the medium than for the difficult task (all Bonferroni
 199 tests, $p < .0001$).



200

Fig. 2. Mean passage of time judgments plotted against task-difficulty level for the durations in the seconds and the minutes ranges.

201

202 2. Experiment 2 – Emotions

203 3.1 Method

204 3.1.1 Participants

205 The sample was composed of 83 new students (80 women and 3 men; mean age = 19.07, $SD = 0.99$) who
 206 participated in this study conducted in accordance with the 1964 Helsinki declaration in exchange for a course
 207 credit. They signed an informed consent form with the procedure approved by the Research Ethics Committee of
 208 the University Clermont Auvergne (IRB00011540-2019-33).

209

3.1.2 Material

210 The material used was the same as that used in Experiment 1, except for the emotional stimuli. The
 211 emotional stimuli used consisted of videos from 3 emotional categories with a different emotional valence:
 212 negative, neutral and positive. Videos were used instead of static images in order to maintain the emotion induced
 213 in the case of long durations of several minutes (Droit-Volet et al. 2019b). The videos were composed of pictures
 214 of a given emotional valence extracted from the International Affective Picture System (IAPS; Lang, Bradley and
 215 Cuthbert 2005). All the pictures were thus assessed as positive on a 9-point emotional valence scale (from 7.01 to
 216 8.28) for the positive videos, or as neutral (from 4.03 to 4.99) and negative (from 2.06 to 3.16) for the neutral and
 217 the negative videos, respectively. The positive pictures showed people enjoying themselves, baby animals and
 218 facial expressions of joy. The neutral valence pictures represented inanimate objects and neutral facial
 219 expressions, and the negative pictures presented landfill sites, war images and people with sad expressions and/or
 220 crying. The negative pictures were thus associated with the emotion of sadness. To create smooth animated
 221 transitions between the images presented in the videos, we used the software OpenShot Video Editor (*OpenShot*
 222 *Studios, Rockwall, TX, USA*). The number of images used was similar for the different emotional videos, varying
 223 between 12, 14 or 16 images for the durations in seconds and 36, 42 and 48 images for those in minutes. The
 224 presentation duration of the images as well as the duration of the animated transition between the images varied
 225 between the videos. For each duration range (seconds, minutes), we created 27 videos (54 in total): 9 videos for
 226 each of the 3 emotional valences (negative, neutral and positive valence), i.e. 3 for each of the 3 durations (30,
 227 33, 36 seconds or 90, 99, 108 seconds).

228 3.1.3 Procedure

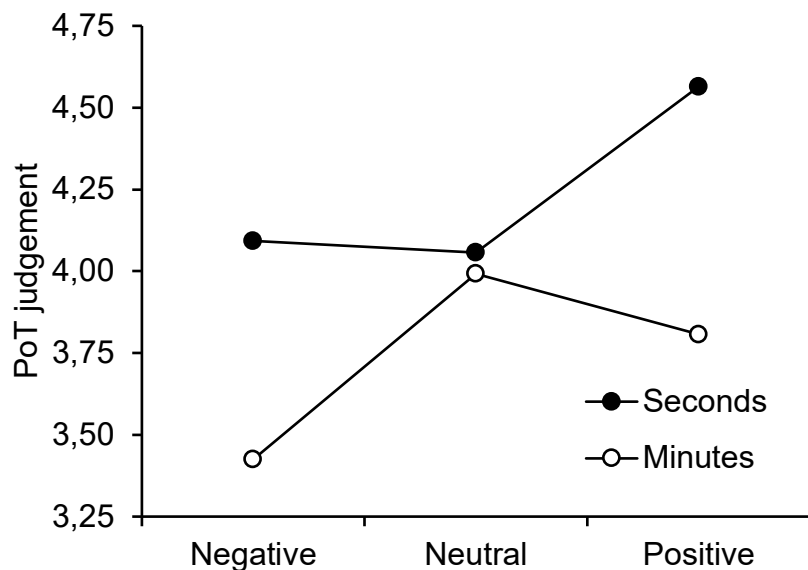
229 The participants were randomly assigned to the seconds ($N = 41$) or the minutes group ($N = 42$). The
 230 presentation duration of the emotional stimuli varied between 30, 33 and 36 seconds in the seconds group, and
 231 90, 99 and 108 seconds in the minutes group. In each group, the participants were presented with 18 trials, with 6
 232 trials for each of the 3 emotional stimuli (negative, neutral, positive), i.e. 3 trials per tested duration. The trial
 233 order was random. The emotional stimuli were also randomly chosen for each trial among the videos in such a
 234 way that the number of images and their presentation duration varied from one trial to another but were similar
 235 across the emotional conditions. On each trial, the participants pressed the space bar to watch the emotional stimuli
 236 when ready. Then, as in Experiment 1, they gave their judgment on the passage of time on a 7-point scale going
 237 from (1) “very slowly” to (7) “very fast”.

238 3.2 Results & Discussion

239 We performed an ANOVA on the PoT judgment with the emotion as within-subjects factor and the
 240 duration group as between-subjects factor. The analysis showed a significant main effect of the emotion on the
 241 PoT judgment, $F(1.67, 134.99) = 8.17, p = .001, \eta_p^2 = .092$. As in Experiment 1, there was also a main effect of
 242 the duration group, $F(1, 81) = 10.74, p = .002, \eta_p^2 = .117$, indicating that time was judged to pass slower in the
 243 range of minutes ($M = 3.74, SE = .107$) than in that of seconds ($M = 4.24, SE = .108$). The emotion x duration
 244 interaction also reached significance, $F(2, 134,99) = 6.28, p = .002, \eta_p^2 = .07$.

245 Parsing the emotion x duration interaction indicated that the effect of the emotion was significant in all
 246 the duration groups, and was so for both the seconds and the minutes ranges ($F(1.773, 70.92) = 7.45, p = .001,$
 247 $\eta_p^2 = .16; F(1.446, 59.27) = 7.04, p = .002, \eta_p^2 = .15$, respectively). However, there was no difference in the PoT
 248 judgment for the neutral stimuli between the two duration ranges ($M_{\text{seconds}} = 4.057, SE_{\text{seconds}} = 0.144; M_{\text{minutes}} =$
 249 $3.992, SE_{\text{minutes}} = 0.142, F > 1$), while the PoT was judged slower in the minutes range than in the seconds range

250 for both the negative emotional stimuli ($M_{\min.} = 3.425$, $SE = 0.146$; $M_{\text{sec.}} = 4.093$, $SE = 0.148$; $F(1, 81) = 10.38$,
 251 $p = .002$, $\eta_p^2 = .114$), and the positive emotional stimuli ($M_{\min.} = 3.806$, $SE = 0.123$; $M_{\text{sec.}} = 4.565$, $SE = 0.124$);
 252 $F(1, 81) = 18.93$, $p < .001$, $\eta_p^2 = .189$). In fact, the PoT judgment for the neutral emotional stimuli did not differ
 253 from that for the negative emotional stimuli in the seconds condition (Bonferroni test, $p > .05$), or from that for
 254 the positive emotional stimuli in the minutes condition ($p > .05$). This suggests that the negative emotional effect
 255 is reduced with the short durations and that the positive emotional effect is reduced with the long durations.
 256 Nevertheless, whatever the duration condition (seconds or minutes), the passage of time was always judged faster
 257 with the positive than the negative emotional stimuli (4.565 vs. 4.093; 3.81 vs. 3.43, respectively, all $p < .05$).



258
 259 **Fig. 3.** Mean passage of time judgments plotted against emotional stimuli of negative, neutral or positive
 260 valence in the seconds and the minutes ranges.

261

262 3. Experiment 3 – Duration

263 4.1 Method

264 4.1.1 Participants

265 82 students participated in this experiment (72 women and 10 men; mean age = 19.59, $SD = 1.34$) in
 266 return for a course credit. They signed an informed consent form presenting the procedure validated by the
 267 Research Ethics Committee of the University Clermont Auvergne (IRB00011540-2019-33) and conducted in
 268 accordance with the 1964 Helsinki declaration.

269 4.1.2 Material and procedure

270 The material and the procedure were the same as those used in the previous experiments, except that the
 271 stimuli to be judged were static neutral images representing a geometric pattern in black and white. The image
 272 size was $21.77^\circ \times 16.1^\circ$. There were 54 images with different geometric patterns, i.e. 27 for each duration group.
 273 As in Experiments 1 and 2, there were therefore two groups of participants depending on whether the duration of
 274 the stimuli was in the seconds ($N = 41$) or minutes range ($N = 41$). However, in the present study, the manipulated
 275 factor was neither the task difficulty nor the emotional valence but the stimulus duration *per se*. The stimulus
 276 durations were of 22, 33 and 44 seconds in the seconds group and of 66, 99 and 132 seconds in the minutes group.
 277 The participants were thus presented with 18 blocks of trials, i.e. 6 trials per stimulus duration. The trial order was

278 random and the image presented on each trial was randomly chosen in such a way that the images used were
 279 similar for the different temporal conditions. As in Experiments 1 and 2, the participants gave their judgments
 280 going from 1 “very slowly” to 7 “very fast” after each trial.

281 4.2 Results

282 An ANOVA was performed on the PoT judgments with the stimulus duration (short, medium, long) as
 283 within-subjects factor and the duration group (seconds, minutes) as between-subjects factor. As illustrated in Fig.
 284 4, the main effect of the stimulus duration was significant, $F(1.70, 135,69) = 120.92, p < .0001, \eta_p^2 = .602$. No
 285 stimulus duration x duration group interaction was found ($F > 1$). There was only an additional main effect of the
 286 duration group, testifying to the fact that the stimulus durations in seconds ($M = 3.40, SE = .17$) were judged as
 287 passing faster than those in minutes ($M = 2.91, SE = .17$), $F(1, 80) = 4.17, p = .04, \eta_p^2 = .05$.

288 Consequently, whatever the duration range tested, the subjective experience of the speed of time varied
 289 linearly with the real time, as indicated by the linear effect of the stimulus duration, $F(1, 80) = 176.978, p < .0001,$
 290 $\eta_p^2 = .69$. Indeed, as confirmed the Bonferroni tests, the PoT was considered to be faster for the shortest duration
 291 ($M = 3.79, SE = .136$) than for the medium ($M = 3.24, SE = .133$) or the longest duration ($M = 2.44, SE = .125$),
 292 and also for the medium than for the longest duration (all $p < .0001$). In addition, and as indicated by the non-
 293 significant interaction between the stimulus duration and the duration group, the experience of an acceleration of
 294 time with the changes in real time was similar for a wide range of durations as long as the ratio between stimulus
 295 durations was the same. This is, to our knowledge, the first demonstration of the scalar property of time in the
 296 domain of the subjective passage of time.

297

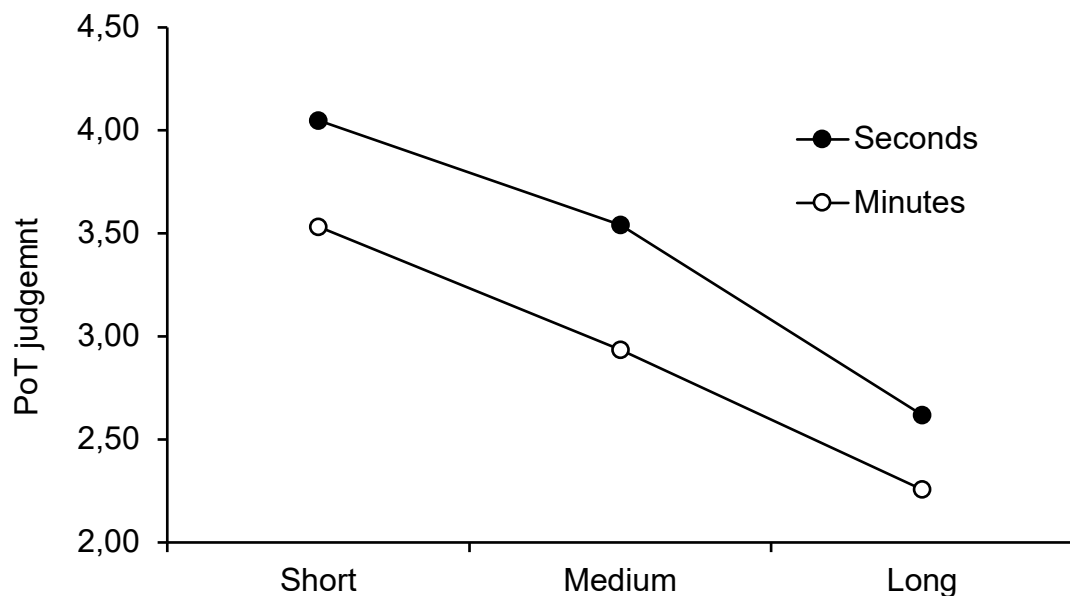


Fig. 4. Mean passage of time judgments plotted against stimulus durations in the seconds and the minutes ranges.

299 In three different experiments, we examined variations in the PoT judgment when the difficulty of the
300 task varied (Experiment 1), when the emotion valence of the stimuli shifted from negative to positive (Experiment
301 2), while stimuli durations were controlled and, finally, when the duration itself varied (Experiment 3). Our results
302 showed that time was judged to pass more slowly for durations in the minutes than for those in the seconds range.
303 However, for all duration ranges, we observed that each change in the feature of a given task (difficulty of the
304 task, emotional valence, duration) produced a change in the PoT judgment. The judgment of the speed of the
305 passage of time therefore increased linearly with the increase in the level of difficulty of the task, although the
306 duration of the task did not change. This result is consistent with those obtained by Sucala et al. (2011) and
307 Wearden et al. (2014) showing, with a single interval of 3-4 minutes, that the passage of time was felt to be faster
308 as the task difficulty increased. Moreover, our results showed that the PoT was judged to change not only
309 depending on the level of task difficulty but also the emotional valence of the stimuli. Indeed, the speed of the
310 passage of time was judged to increase with the positive valence of the emotional stimuli, regardless of their
311 presentation duration. The participants therefore judged the passage of time independently of durations on the
312 basis of non-temporal information. Nevertheless, when the stimulus durations changed, while the other
313 characteristics of the task remained constant, the PoT judgment also varied according to the duration values. We
314 observed that the speed of the PoT judgment increased as the stimulus durations decreased.

315 In an experimental prospective timing paradigm such as the one used in our studies, it is assumed that
316 the internal clock system is activated and that it processes time. In other words, participants experience durations
317 by focusing their attention on time (Zakay and Block 1996, 1997; Zakay and Block 2004). However, our results
318 revealed that even if the participants were aware that time was an important feature of the task, their judgments
319 of the passage of time were not always based on temporal information. Indeed, in Experiments 1 and 2, the PoT
320 judgment varied in response to changes in non-temporal information while the target duration remained constant
321 (randomly controlled throughout the non-temporal conditions). We expected that the effect of temporal
322 information on the PoT judgment would be higher for the short durations of a few seconds than for the long
323 durations of several minutes since the mechanisms responsible for processing short and long duration do indeed
324 differ. An internal clock system is thought to provide an accurate representation of time in the case of short
325 durations (for reviews, Merchant et al 2013; Wearden 2016). By contrast, memory-based processes are thought to
326 be involved in the judgment of long durations (Droit-Volet et al. 2018). However, for the PoT judgment, and
327 contrary to our hypothesis, we obtained the same results for all durations. Indeed, a significant main effect of task
328 difficulty on the PoT judgment was observed in Experiment 1, regardless of the duration of the task and the
329 duration range (seconds vs. minutes). A main effect of emotion was also observed on the PoT judgment for the
330 different duration range in Experiment 2 as well as in Experiment 1. In Experiment 2, a significant interaction
331 between emotion and duration range was nevertheless found. However, this interaction only indicated that the
332 participants felt that time passed faster for positive emotional stimuli when presented for a few seconds than for
333 several minutes. Overall, therefore, our results in Experiment 1 and 2 suggest that PoT judgments obtained for a
334 wide range of durations were based on something other than duration processing itself.

335 However, in our study, the PoT judgment also changed with the real time when the duration was the only
336 feature of the situation that varied. Indeed, in Experiment 3, we found a linear relationship between the stimulus
337 duration and the experience of the passage of time when the difficulty of the task was experimentally controlled.
338 In particular, the participants experienced an acceleration of the passage of time as the duration decreased from

339 one value to the next, i.e. with a time step of 11 s in the range of seconds and of 33 s in the minutes range.
340 Therefore, a time-measurement mechanism (internal clock) may also contribute in part to the prospective
341 judgment of the passage of time. The fact that the PoT judgment varied in our studies not only when we
342 manipulated all the non-temporal information but also the temporal information suggests that the PoT judgment
343 is not based on a specific factor, but on a number of different factors depending on the salience of the context
344 encountered, i.e. the nature of the experienced or perceived changes. For example, in Experiment 3, the stimulus
345 duration might have influenced the PoT judgment because the variation in the duration of stimulus was the most
346 salient. But, in another context, time would have little or no influence on the prospective judgment of the passage
347 of time, being the level of task difficulty and emotion. Some correlation studies have suggested that other factors
348 may also play a role in PoT judgment such as time pressure, routine of everyday life (Winkler et al. 2017;
349 Wittmann et al. 2015), and boredom (Droit-Volet et al. 2020; Jokic et al. 2018; Witowska et al. 2020; Wittmann
350 et al. 2015). Consequently, one can assume that PoT judgments are inferred not from one and always the same
351 dimension (i.e. task difficulty) but from the most salient contextual (temporal or not) changes encoded and
352 memorized during the interval. PoT judgment would therefore be a generic way of describing the most salient
353 internal or external contextual changes experienced.

354 Our results therefore suggest that the PoT judgment can also be based on the processing of durations, at
355 least in the prospective PoT judgment paradigm. Finally, the PoT judgment is multi-faceted. We have identified
356 three main types of PoT judgment: Self-duration, World-duration and Self-time perspective. As reported in the
357 introduction, the first of these refers to the intra-subject malleability of time related to introspective analyses of
358 internal states. The second is the representation of external time as indicated by our watches and the third is related
359 to temporality of self in the past-present-future. We may add a fourth type of PoT judgment, namely the event
360 duration measured by an internal clock mechanism: "Event-duration". In this last case, there would be an
361 association between the speed of the passage of time and the measured event-duration values. As found in the
362 present study, the participants had no difficulty judging that time passed faster with short durations than with long
363 durations. In summary, many factors underlie PoT judgments. This would imply that there are different types of
364 PoT judgment, depending on the context and its significance during the interval to be judged as well as on whether
365 the PoT judgment is prospective or retrospective. Further studies are nonetheless needed to determine which of
366 the factors we have seen prevail over the others in the different types of PoT judgment and why.

367 Furthermore, our studies point out a linear relationship between the PoT judgment and the different levels
368 of any tested factor, regardless of the factor examined. However, it is likely that the PoT judgment curve might
369 not be as linear as observed in our experiments in other circumstances. Under extreme conditions, with a task that
370 is too difficult, or in the presence of more intense emotions, the participants might no longer be able to experience
371 the movements of time with its compression or extension. They could experience timelessness, a time that no
372 longer exists, a time that no longer flows at different speeds (Csikzentmihalyi and Csikzentmihalyi 1988). This is
373 what is reported in deep states of meditation experienced by meditation experts (Droit-Volet and Dambrun 2019)
374 or in car accidents (Noyes and Kletti, 1977; Arstila 2012). Further experimental investigations are thus required
375 to better understand what lies behind our awareness of variations in the speed of the passage of time and why we
376 translate our experience in the present into movements of time and self-duration.

377

378 **Compliance with Ethical Standards:** For the 3 experiments conducted in human adults, all individual
 379 signed an informed consent form presenting the procedure validated by the Research Ethics Committee of the
 380 University Clermont Auvergne (IRB00011540-2019-33) and conducted in accordance with the 1964 Helsinki
 381 declaration.

382

383 **Conflict of Interest:** Natalia Martinelli and Sylvie Droit-Volet declare that their have no conflict of
 384 interest.

385

386 **References**

387

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