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BRIEF REPORT

# Faster is briefer: The symbolic meaning of speed influences time perception

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**Abstract** The present study investigates how the symbolic meaning of the stimuli presented for marking time intervals affects perceived duration. Participants were engaged in a time bisection task in which they were first trained with two standard durations, 400 ms and 1600 ms, and then asked to judge if the following temporal intervals were closer to the short or to the long standard. Stimuli were images of vehicles representing speed, with a motorbike representing fastness and a bicycle representing slowness. Results showed that presenting images with different speed meanings affects time perception: an image representing a fast object, the motorbike, leads to shorter perceived time than presenting an image representing a slower object, the bicycle. This finding is attributed to an impact on the memory mechanism involved in the processing of temporal information.

**Keywords** Symbolic meaning of speed · Time perception · Bisection task

## Introduction

Because time is tightly embedded within most human experiences, it is fundamental to understand how humans deal with it. There are many models for accounting for the capacity to judge time with some accuracy. A classical model is the one associated with the Scalar Expectancy Theory (SET; Gibbon, Church, & Meck, 1984). According to SET, timing behaviors are based on the output of an internal clock, which is indeed described as an internal pacemaker emitting pulses. The pulses are accumulated in a counter, and it is this accumulation that is the basis of the representation of time: time is perceived as longer when more pulses are accumulated. Depending on the task to be performed, this accumulation will likely have to be compared with the representation of past temporal events in memory.

This internal clock is known to be affected by different factors. Amongst the factors known to influence the internal clock and, therefore, subjective time, are the matter of paying attention to time or not, the quantity of events occurring during a period to-be timed, and the emotional content of the stimuli marking time (Grondin, 2010). Less is known about the impact on perceived duration of images with different semantic meaning.

Every stimulus we perceive is subjected to a semantic analysis which produces its meaning across various dimensions (McKoon & Ratcliff, 1989). For example, if we express the concept of weight, we can easily recall the idea of a light (e.g., feather) or a heavy (e.g., stone) object. If we want to illustrate the concept of speed, we can refer to a lion and contrast its speed with that of a turtle. Or similarly, if we express the concept of quantity, we know that the number 1 is smaller in quantity than the number 9. Glenberg and Robertson (2000) stated that "meaning is the goal of communication. Meaning underlies social activities and culture: To a great degree, what distinguishes human cultures are the meanings they give to natural phenomena, artefacts, and human relations … meaning arises from the syntactic combination of abstract, amodal symbols that are arbitrarily related to what they signify" (p. 379). The question addressed in the present study is to what extent does the semantic elaboration of the stimuli we perceive influence temporal processing.

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It has been mainly with the use of numbers that the effect of meaning on time perception has been investigated. In the field of time perception, small numbers (e.g., 1 and 2) bias estimation towards short durations whereas large numbers (e.g., 8 and 9) bias estimation towards long durations. Oliveri and collaborators (2008) used a time comparison task in which digits representing different quantities (Experiment 1: 1, 5, or 9) were presented for short temporal intervals (standard duration 300 ms and comparison ranging from 250–350 ms). Participants were required to determine whether a digit (either 1or 9) had been presented for a time interval shorter or longer than a reference digit (always the digit 5). Results showed that the duration judgments were influenced by the quantity expressed by the digit presented on the screen: thus, the duration of digit 1 was consistently underestimated and the duration of digit 9 was consistently overestimated compared to the reference cue (Oliveri et al., 2008). This finding implies that subjects keep track of magnitude when judging time even when processing the numerical magnitude is not required by the task (Oliveri et al., 2008; Vicario, 2011; Vicario, Pecoraro, Turriziani, Koch, Caltagirone, & Oliveri, 2008). It has also been shown that temporal judgments can be influenced by other abstract magnitudes. Xuan, Zhang, He, and Chen (2007) asked participants to perform three duration discrimination tasks and specifically instructed the participants that the visual patterns of the stimuli were irrelevant to the temporal judgment tasks. The results revealed that temporal judgments were significantly affected by the magnitude of non-temporal dimensions, including number of dots, size of squares, luminance of solid squares, and, most importantly, the numerical value of digits. Despite the fact that the magnitudes were in four different categories with different forms and physical attributes, these authors showed very similar interference effects on temporal judgments. Stimuli with larger magnitudes in these non-temporal dimensions were judged to be temporally longer (Xuan et al., 2007).

Interestingly, a recent study showed that the semantic elaboration of a temporal concept generates an effect on estimating short duration in a duration reproduction task (Vagia, Orfanidou, & Vatakis, 2013). Stimuli were words with non-temporal meaning (e.g., room, work, etc.), or words evoking "long duration" (e.g., annual, slow, etc.) or "short duration" (e.g., quickly, rapidly, etc.). Participants were required to read the words and generate synonyms for 5, 8, or 12 s. The semantic elaboration of temporal concept leads to an overestimation in the 5-s condition when the words presented were part of the "long duration" group.

Finally, other studies showed the effect of implied speed of an individual's action on the estimation of event duration (Burt, 1999; Burt & Popple, 1996). Participants were asked to watch a 25-s action on a stage and to estimate (verbal estimation) the duration of the actor's presence on the stage. The question was the same for all participants ("How long did it take the person to […] through the lecture theatre?": Burt & Popple, 1996, p. 56), except for the use three different verbs, either "walk," "run," or "pass," when completing the question. Results indicated that subjects who were led to believe the actor engaged in fast actions (e.g., running) generated significantly shorter duration estimates than those led to believe the speed of the actor was slow (e.g., the actor walked). Similarly in Loftus and Palmer (1974) study participants were asked to watch short movies about car accidents and to describe what had happened. They were then asked specific questions, including the question "About how fast were the cars going when they […] each other? Participants in different groups had the question formulated with one of these possible verbs: smashed, collided, bumped, hit, or contacted. Participants that had smashed gave faster speed estimates for the cars than subjects who were told the cars hit. The authors concluded that the verbs implied different vehicle velocities.

This series of findings suggest that time perception can be compressed and expanded by a number of environmental factors. The present work investigates how the symbolic meaning of the stimulus marking time influences time perception. More specifically, we are interested in the case of speed: how does the presentation of stimuli representing fastness affect time perception, compared to stimuli representing slowness? To this end we used stimuli representing a "motorbike" (fastness) and a "bicycle" (slowness). We also presented stimuli in a "no-driver" condition (only the vehicle) or "driver" condition (vehicle + driver). We reasoned that including the driver could have created a greater engagement than presenting the vehicle alone (Chambon, Droit-Volet, & Niedenthal, 2008; Goodwin, 2000; Iacoboni, Molnar-Szakacs, Gallese, Buccino, Mazziotta, & Rizzolatti, 2005; Krüger, Kragic, Ude& Geib, 2007; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996).

In the present study, a temporal bisection task is employed. The time bisection task is an absolute identification task where stimuli are classified into two categories (short and long) (Nachmias, 2006; Oberfeld, 2014). The shortest and the longest anchor intervals are first presented several times and are then followed by all temporal intervals (including the standards) that have to be categorized as being closer to one of the two anchor durations (Gil & Droit-Volet, 2011; Grondin, 2010).

We expect that observing a stimulus representing the meaning of speed will affect participant's performance. The relationship between time and speed is well known (Brown, 1995; Matsuda, 1974) and this relationship is mainly driven by the relationship between time, speed, and distance. If the distance is kept constant, we can reach a destination in a shorter time if we go faster (Bonnet, 1967; Matsuda, 1974).

The meaning of the stimulus presented could exert an influence at different stages of temporal processing and different predictions can be made about performances, depending on whether the effect would occur at the clock stage (pacemaker rates) or at the memory stage. If the meaning of the stimulus acts on the pacemaker, when a stimulus representing the meaning of slowness is presented, the rate of pulses' emission should decrease but when the presented stimulus is representative of fastness, the rate should increase. If that is the case, showing a "motorbike" (fastness) should lead to a longer perceived duration than showing a "bicycle" (slowness). Chambon and colleagues (Chambon et al. 2008) showed that in a time bisection task the presentation of stimuli representing the faces of elderly people were underestimated compared to stimuli of faces of young individuals. They interpreted their results within the theoretical framework of embodied cognition by suggesting that the participants embodied the slow movements of elderly people. This would therefore have slowed down the speed of their internal clock.

However, if the meaning of the stimulus presented acts at the memory stage (semantic memory) we should observe a different pattern of performances. In such a case, if the representation stored in memory about objects' speed acts on temporal estimation, showing a "motorbike" (fastness) should lead to shorter perceived duration than showing a "bicycle" (slowness). Inferential processes may create individual differences in event duration estimates. There is, in fact, ample research demonstrating that specific characteristics of the stimulus can influence reconstructive outcomes. This inferential process can be explained by the space-time interaction and this interpretation is consistent with the results reported by Burt and Popple (1996) and Loftus and Palmer (1974). When having to reach a destination, riding a motorbike leads to the destination in a shorter time than riding a bicycle. This type of everyday experience has an impact on our representation of an object and should exert influence our temporal experience when this object is involved in the marking of time.

## Method

### Participants

Nineteen university students, 14 females and five males ranging in age from 19 to 38 years (mean ($M$) = 24.70; standard deviation ($SD$) = 4.65), took part in the study. All participants were undergraduate or graduate students at Laval University, Quebec City, QC, Canada, had normal vision, and were paid $8 (Can) for taking part in this study.

### Apparatus and stimulus

The presentation of the visual stimuli and the recording of participants' responses were computer controlled. The visual stimuli for marking time were four pictures displayed on a computer screen and representing a bicycle and a motorbike (Fig. 1A) and a bicycle and a motorbike driven by a person (Fig. 1B). During the learning phase, the stimulus used for marking time was a grey oval with a size similar to that of the four figures. Each participant was seated in a chair, about 60 m from the screen, in a dimly lit room where the light was kept constant for all participants.

### Procedure

Participants were engaged in a time bisection task (see Gil & Droit-Volet, 2011 for a similar procedure). The experimental session started with the learning phase in which participants were required to memorize the two standard durations: 400 ms (short standard) and 1600 ms (long standard). Both standard durations were presented ten times (first all short standards = 400 ms followed by all long standards = 1,600 ms). We used a neutral stimulus in the learning phase to memorize the temporal intervals; the stimulus was a grey oval with a similar size to the two experimental stimuli. No feedback was provided after the training phase.

After the training phase participants were required to perform four blocks; in each block, the four pictures were presented seven times for each of the comparison durations (400, 600, 800, 1,000, 1,200, 1,400, and 1,600 ms; a total of 196 trials in each block). After the presentation of the comparison durations, the participants were required to press the key labelled "C" ("C" refers to the French word "Court" = short) if the duration presented was closer to the standard short, or to press the key labelled with "L" ("L" refers to the French word "Long" = long). The participants were asked to respond with their left and right index fingers and response keys were counterbalanced between participants, therefore, half of the

**Fig. 1** Stimuli used in the experiment, a bicycle and a motorbike, without (**A**) and with (**B**) a driver

participants responded "long" with their right index finger and half with their left index finger. After the response, there was a 1,000-ms inter-trial interval. Each experimental session lasted approximately 30 min.

### Data analysis

All trials were kept for the analysis. Preliminary analysis was conducted to verify if there was any effect related to response keys. No effect was found ($p$ = .70), which indicates that no difference was observed between participants that use the left or the right index finger to respond "long." Therefore, the subsequent analyses were conducted excluding this variable from the analysis. For each participant in each experimental condition, a seven-point psychometric function was traced, plotting the seven comparison intervals on the x-axis and the probability of responding "long" on the y-axis.

The cumulative normal function was fitted to the resulting curves. More specifically, we used a non-linear least squares analysis, with a Levenberg-Marquardt algorithm. The temporal bisection point, defined as the x value corresponding to the .50 probability of "long" responses on the y-axis, served as an index of perceived duration. An observed shift of the bisection point for the different vehicles presented can be interpreted as an indicator of differences in these different conditions, with smaller bisection point values meaning longer perceived durations. Moreover, as an indicator of temporal sensitivity, the *SD* on each psychometric function was estimated (Grondin, 2008).

## Results

A psychometric function was traced for each participant in each of the four experimental conditions (two vehicles, with and without driver). For all participants, the goodness-of-fit was highly satisfactory, with $R^2$ values above .87. Fig. 2 depicts the global probability of "long" responses in each vehicle and driver condition, and Table 1 summarizes participants' performance in each of these conditions. Preliminary analyses were conducted to investigate the effect of response key on participants' performance. No main effect of response key was observed and this variable was excluded from the analyses.

A repeated measures ANOVA was conducted with *vehicle* (motorbike, bicycle) and *driver* (no driver, man driving) as within-subject factors. Results showed a significant effect of vehicle, $F(1,18) = 9.06$, $p = .008$, $\eta^2_p = .335$. The bisection point observed with motorbike ($M$ = 926 ms) was significantly larger than the bisection point observed with the bicycle ($M$ = 891 ms). No effect of driver was found ($p$ = .950), and the interaction was not significant ($p$ = .783). As for sensitivity, the ANOVA on *SD* revealed that none of the main or interaction effect was significant (all $p$s > .514).

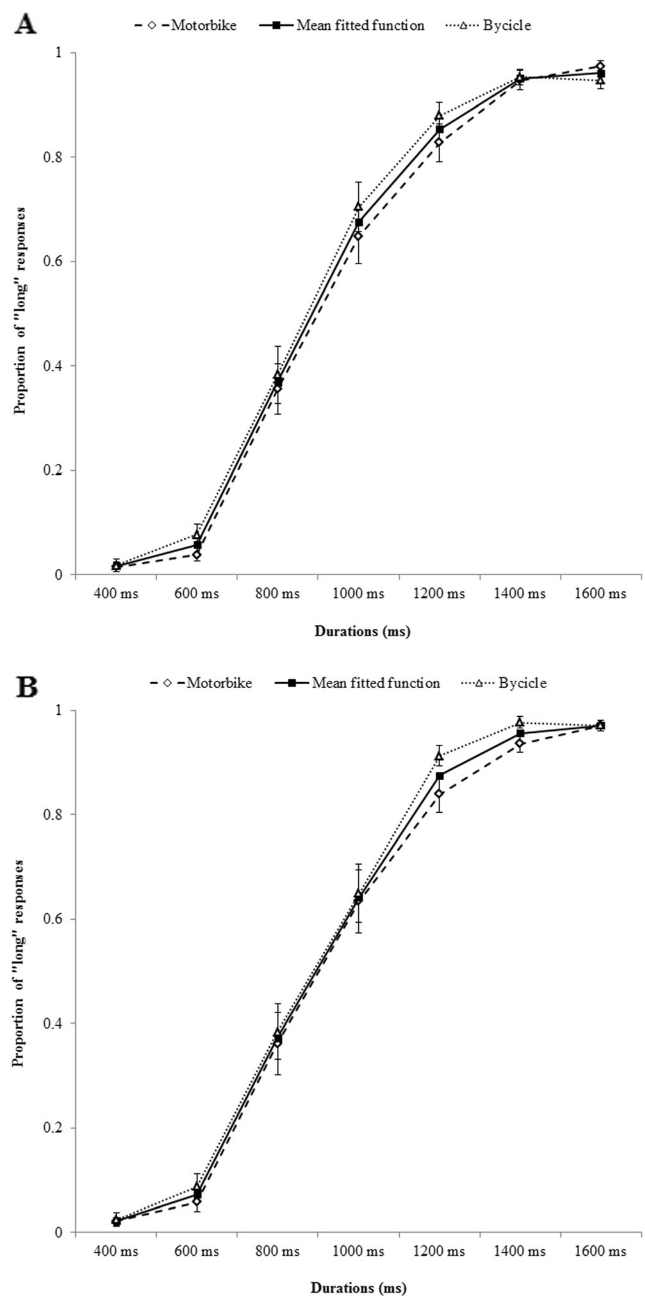


**Fig. 2** Psychometric function in each experimental condition (pooled data). (**A**) No driver; (**B**) man driving

## Discussion

The present work investigates how the symbolic meaning of the stimulus marking time influences time perception. The results showed that presenting stimuli representing the meaning of speed influences time perception. In particular, presenting a motorbike (fast object) leads to less "long" responses (larger bisection point) than presenting a bicycle (slow object). This result is consistent with the hypothesis stating that the effect of symbolic meaning on time perception would be acting at the memory stage (semantic memory). In fact, if the

**Table 1** Individual bisection point (BP) and standard deviation (SD) in each experimental condition

| | Motorbike | | Bicycle | |
|---|---|---|---|---|
| Participants | No driver BP (*SD*) | Man driving BP (*SD*) | No driver BP (*SD*) | Man driving BP (*SD*) |
| 1 | 946 (252) | 1,076 (239) | 975 (184) | 1,096 (139) |
| 2 | 904 (194) | 1,037 (216) | 969 (195) | 987 (212) |
| 3 | 823 (223) | 733 (86) | 835 (283) | 716 (207) |
| 4 | 800 (166) | 816 (126) | 768 (53) | 801 (146) |
| 5 | 836 (150) | 968 (216) | 963 (209) | 900 (157) |
| 6 | 1,076 (301) | 1,100 (345) | 1,049 (337) | 1,049 (279) |
| 7 | 818 (109) | 763 (150) | 735 (110) | 722 (100) |
| 8 | 1,076 (147) | 1,033 (35) | 1,083 (151) | 1,098 (133) |
| 9 | 739 (191) | 670 (198) | 720 (149) | 681 (255) |
| 10 | 957 (316) | 950 (337) | 843 (234) | 898 (221) |
| 11 | 818 (109) | 755 (105) | 769 (106) | 783 (125) |
| 12 | 935 (227) | 966 (239) | 864 (117) | 892 (178) |
| 13 | 1,172 (182) | 1,147 (200) | 1,045 (159) | 1,026 (135) |
| 14 | 1,076 (354) | 991 (371) | 970 (453) | 870 (423) |
| 15 | 733 (86) | 722 (100) | 747 (223) | 764 (138) |
| 16 | 1,003 (376) | 947 (285) | 864 (282) | 927 (216) |
| 17 | 861 (147) | 863 (202) | 766 (201) | 790 (182) |
| 18 | 942 (197) | 923 (128) | 923 (233) | 909 (275) |
| 19 | 1,082 (251) | 1,107 (283) | 997 (164) | 1,033 (201) |
| Mean | 926 (228) | 925 (219) | 889 (216) | 892 (210) |

effect of symbolic meaning had acted at the clock stage (internal clock), we would have observed more "long" responses in the motorbike condition, as a result of an increased rate of pulses' emission by the pacemaker that would have caused a symbol of fast speed.

The results showed that presenting a bicycle leads to longer perceived time than presenting a motorbike. In other words, slow takes more time than fast, just as if duration judgments are not independent of speed or distance. We hypothesized that the long-term representation information of speed (fast/slow) that we have stored in semantic memory influenced the subjective perception of time. In fact, our findings are consistent with what was observed about the remembered duration of long events (Burt, 1999; Burt & Popple, 1996). Indeed, just inducing with a question the idea of speed ("walk" vs. "run" vs. "pass") interfered with the memory of the duration of this action; actors are remembered to have spent less time on a stage by participants when asked how much time the actors were running (on the stage) than when asked how much time the actors were walking. These results are consistent with the prediction that the faster the action speed the shorter the estimated duration and are consistent with the assumption that the retrieval of speed and duration information types are both subject to a reconstructive process (see also Harris, 1973; Loftus & Palmer, 1974).

Interestingly, our results can also be analyzed in accordance with the embodied cognition approaches to information processing. For example, using the temporal bisection task, Chambon et al. (2008) reported that the duration of presentation of faces of elderly individuals was underestimated compared to that of faces of young individuals. They explained their results within the theoretical framework of embodiment by suggesting that the participants embodied the slow movements of elderly people with a consecutive effect on temporal judgment.

Our results extend the finding of a second study conducted by our group (Mioni, Grondin, Stablum & Zakay, submitted ) with children between 6 and 15 years of age with a time reproduction task in which symbolic meaning stimuli were presented during the encoding phase (Experiment 2 with 11, 21, and 36 s). The results showed that participants under-reproduced temporal intervals but that only young children (6–8 years old) produced a greater under-reproduction of temporal intervals when the stimulus presented was associated with the meaning of fastness (motorbike) compared to a stimulus associated with the meaning of slowness (bicycle). These under-reproductions mean that participants between 6 and 8 years old perceived the stimuli associated with the meaning of slow speed (bicycle) as lasting longer than stimuli associated with the meaning of fast speed (motorbike) (see also Keshavarz, Landwehr, Baurès, Oberfeld, & Hecht, 2010). Interestingly, in this study, there was no effect of symbolic meaning with older children and adult participants. The fact that there was no symbolic meaning effect with adults in this study might be due to the temporal task used, namely, time reproduction (Gil & Droit-Volet, 2011; Mioni et al. 2014a). The non-effect of symbolic meaning might also be due to the temporal range used in the study. When intervals are longer than about 1,300 ms, participants often use additional cognitive strategies to perform temporal tasks (e.g., counting: Clément & Droit-Volet, 2006; Grondin, Meilleur-Wells, & Lachance, 1999; Mioni et al. 2014a, b). Therefore, by using additional strategies for performing the time reproduction task, older children and adults have likely masked the effect of symbolic meaning found in younger children. In the present study, we used a temporal bisection task, which is particularly sensible for investigating time perception (Droit-Volet & Zelanti, 2013), and we shortened the temporal intervals to avoid the involvement of additional counting strategies. As a result, the effect of symbolic meaning has been extended to adult participants.

Concerning the driver versus no-driver comparison, no effect on temporal performance was observed. It is well known that observing another individual performing an action activates the same brain areas in the observer as those that are involved in the action (Rizzolatti et al., 1996). We expected that observing someone driving the motorbike or driving the bicycle would have generated a greater engagement in the participants. However, the non-significant driver effect indicates that simply presenting the vehicle is sufficient to activate the memory representation of speed that is influencing temporal performance.

In sum, the present study shows that presenting images with different speed meanings affects time perception: presenting an image representing a fast object (i.e., motorbike) leads to shorter perceived duration than presenting an image representing a slower object (i.e., bicycle). In particular, our results are interpreted in accordance with an inferential/reconstructive process occurring in memory and acting on temporal judgments: Knowing the relationship between action speed and event duration influences temporal processing. It is well known that the motorbike goes faster than the bicycle, and that we can reach a destination in a shorter time if we drive a motorbike rather than a bicycle. This everyday experience might be the basis of the effect of the symbolic meaning of speed on time perception (Keshavarz et al., 2010). In other words, it is the utility of what is presented that would determine perceived duration. Such a perspective is consistent with the notion of affordance emphasized by J.J. Gibson in his ecological view of perception. Our data could be viewed as an extension of the Gibsonian perspective to the field of time perception. The affordance theory describes the relation between an object or an environment and an organism that affords the opportunity for that organism to perform an action. In our case the theory of affordance can explain why participants watching a motorbike or a bicycle, and recalling what these vehicles can be used for, were more prone to under- or overestimate temporal intervals.

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