Selective bias in temporal bisection task by number exposition

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Temporal experience can be modulated by a number of environmental factors such as quantity. Here I show that merely looking at numbers causes a bias in imaginative (but not perceptual) time bisection task that depends on the number's magnitude. This suggests that automatic shifts of spatial attention to the left and right side, as a result of exposure to numbers, modulates temporal as well as spatial behaviour (2,3,4). This finding suggests that the representation of time and space produce certain patterns in neural maps that are decoded by means of the similar neural mechanisms.

The line "bisection task" is a sensitive test for attentional and motor biases in both healthy and brain damaged subjects (1). In healthy subjects, performance is strongly influenced by intrinsic perceptual features of stimulus like quantities: when a line is composed of digits, or words (2, 9; or two, nine), pointing deviates leftwards or rightwards from the midpoint (2,3). It seems that numbers automatically bias attention to the left or the right, and consequently, that the bisection of the lines deviates in the same direction. This hypothesis fits with the Fischer study (4) in which it is suggested that merely looking at numbers determines a shift of attention in space. The results from this study showed that right targets were detected faster when preceded by a large digit (8 or 9), whereas left targets were detected faster when preceded by a low digit (1 or 2).

Recent neuroimaging studies of numerical cognition in humans, and physiological studies of spatial cognition in monkeys, suggest that numerical–spatial interactions arise from common parietal circuits concerned with attention to external space and the internal representation of numbers. Indeed, a recent meta-analysis indicated that the bilateral horizontal segment of the Intra parietal sulcus (IPS) might have a particular role in quantity representation. The activation of this area extends to dorsal parietal sites that are also thought to be involved in spatial attention orientation (5). Thus, it seems that the IPS region is crucial when attention, as well as spatial updating and number processing, are involved. Hubbard et al. (6) report similar proprieties in the lateral intraparietalarea (LIP). Indeed, these authors speculate, that shifts of attention along the mental number line might be mediated by shifts of attention in the LIP area in the same manner that shifts of attention are mediated in the external world. This hypothesis could explain the results obtained by Fischer (2,4), in which presentation of numbers led to automatic shifts of attention to the left or to the right depending on number magnitude.

Other studies document as much consistent relation between time and numbers.

Two recent articles show that numerosity affects human performance in temporal tasks (7,8), whilst there are neurophysiologic evidence supporting common processing between numbers, time, and attention in the primate brain. Leon and Shadlen, for example, have pursued the link between psychophysical performance of monkeys and single-neuron responses in the inferior parietal cortex and argue that LIP neurons possess response properties that are related also to the judgment of time (9). Moreover, the discovery of ”numerons” localized in the same region of IPS, selective both for space (10) and time perception further support the hypothesis of a numerical influence on time perception. The activation of the posterior parietal cortex by several visuospatial (grasping, pointing, saccades) and spatial attention tasks (11) is consistent with the studies above showing his activation for temporal and numerical tasks.

However the precise mechanism by which quantity affects temporal experience remains unclear.

My aim is to investigate if automatic shifts of spatial attention, caused by number exposition, influence temporal behaviour.

Several studies suggest, indeed, that attentive sources modulate temporal performance in healthy humans. Stelmach and Herdman (12), for example, provided evidence in favour of this assumption showing that the perception of temporal order is influenced by attentional allocation. Moreover, a recent study suggests that spatial attention has a particular role in temporal experience (13).

Authors show in fact that spatial attention modulation by means of optokinetic stimulation would cause a subjective sense of compression and expansion of experiential time in sub second intervals. Thus if digit perception is closely associated with space, suggesting the implication of attentional factors, and if attentional factors modulate temporal experience, this fact raises the question of whether attention shifting induced by number perception causes a bias in temporal as well as spatial behaviour.

In this study, the bisection method was adopted to investigate whether temporal accuracy of healthy participants would be systematically biased by the automatic activation of spatial codes from the visual processing of numbers

To address this question, I devised two experimental sessions in which numbers were combined with temporal information using an imaginative and perceptual time bisection task.

Imaginative time bisection task

In the imaginative time bisection task were required subjects to stop an imaginary mental timer at half duration of a reference cue. The reference cue varied in duration (sub second vs. over second) and in magnitude (low vs. large number).

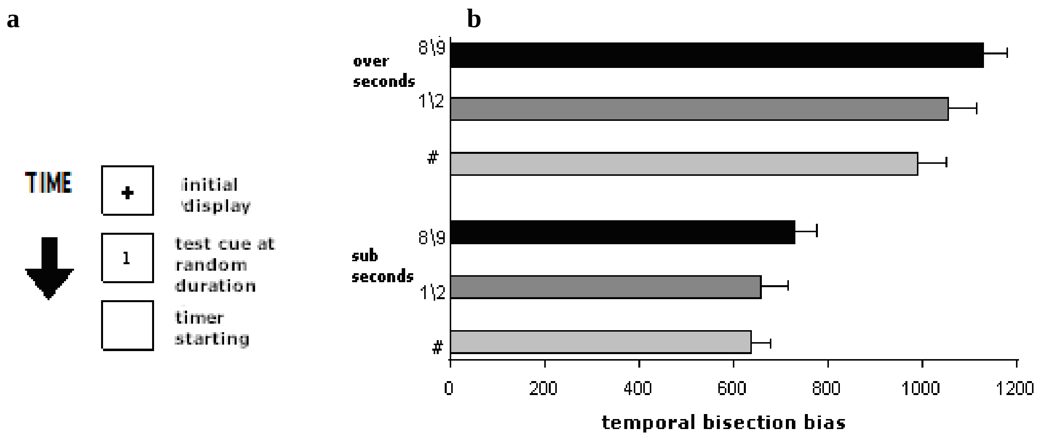

Figure 1 Imaginative time bisection task. Task sequences and average of time bisection.**(a)** Example of trial sequence **(b)** Rt average in the time bisection task for over-second and sub-second temporal intervals.

Thirteen right-handed participants (8 men, 5 women aged 20–32 years) were positioned 60 cm opposite a white computer screen to perform a time bisection task. After a brief training, participants were asked to confront durations of 60 stimuli (6 repetitions x 10 temporal intervals) centred on the screen in three randomised experimental blocks. They fixated a black cross of 0.2° in diameter and centred to the screen. After 500 ms., a test cue (a digit number, size 0.80°) appeared with random durations of sub-second (500,700,900 ms) and over-second (1800 2000 2200 ms) intervals.

Participants used their preferred hand. Their task was to mentally time the duration of each test cue and perform a temporal bisection task. They were instructed to imagine a timer starting a T0 from test cue disappearance and stopping it at half of test cue duration by pressing the space key. In the first block the test cue was a low digit (1-2). In the second block the test cue was a large digit (8-9). In a third block, the test cue was a non-numerical stimulus (#) – control stimulus.

The difference between time bisection with non-numerical stimuli (#) and digit cues is significant for sub seconds $t(12) = 2{,}20$, $p < 0.05$ and over seconds $t(12) = 4.14$, $p < 0.001$ intervals, and seems to indicate that, during time bisection task, numerical symbols receive specialized representative processing that differs from non numerical cue processing (**#**). This would indicate that, stimulus-specific cognitive processes affect performance on each type of stimulus differently.

Consider now the effect of number magnitude on bisection accuracy. To test this effect, I analyzed reaction times of data obtained with digits representing low versus large magnitudes. The average bisection score was **656,38** for low digits (1 or 2), and **729,07** for large digits (8 or 9) in sub seconds intervals; whereas the average bisection score was **1054** (low digits) and **1128,8** (large digits) for the over second intervals.

Importantly, the difference between these two sets of stimuli was significant, in the sub second $t(12) = 3.82$, $p < 0.002$ as well as over second $t(12)=2.22$, $p < 0.04$ intervals . It shows that low numerical quantities reduce bisection Rts, whereas numbers associated with relatively larger magnitudes induce a delay in bisection Rts.

The results suggest that, when participants were asked to perform a time bisection task imaging to stop a timer, numbers seem to modulate temporal performance, causing anticipation and delay biases in the pointing similarly to leftward and rightward biases founded in bisection of numerical strings (2,3).

Perceptual time bisection task

The perceptual time bisection task required subjects to time temporal duration of reference cue (#) and stopping temporal occurrence of test cue (a number) at half of reference cue duration. The reference cue varied in duration (sub second vs. over second) whereas test cue changed in magnitude (low vs. large numbers).

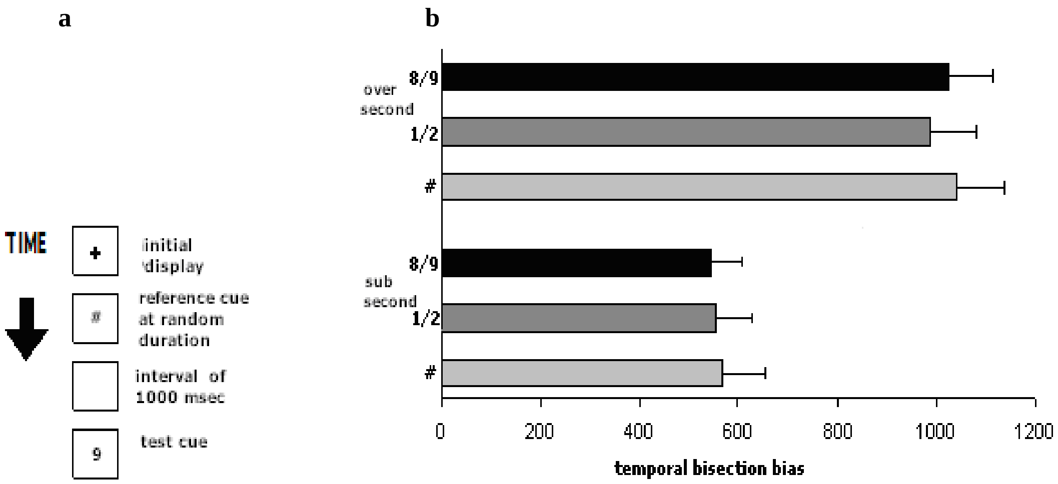

Figure 2 Perceptual time bisection task. Task sequences and average of time bisection.**(a)** Example of trial sequence **(b)** Rt average in the time bisection task for over-second and sub-second temporal intervals.

Eleven participants were positioned 60 cm opposite a white computer screen to perform a temporal estimation task of sub-second temporal stimuli. After a brief training, participant were asked to confront durations of 60 stimuli pair (6 repetitions x 10 time intervals) centred on the screen in three randomised experimental blocks. They fixated a black cross that was of 0.2 grades in diameter and centred to the screen. After 500 ms. appeared a test cue (a digit number) which duration assumed randomly sub-second (500,700,900 msec) and over-second (1800 2000 2200 msec) intervals. Using their preferred hand subjects had to time temporal duration of each reference cue (#) and perform a temporal bisection task stopping temporal occurrence of test cue at half of reference cue duration by press the space key. In the first block the test cue was constituted by digit 1 & 2. In the second block digits 8-9 constituted the test cue. In the session of control (third block) test cue and reference cue were constituted by non numerical stimuli (#).

In this session I use repeated measures Anova because t-test analysis doesn't show significant difference confronting performance in time bisection with non-numerical (#) and numerical (1-2;8-9) cues (sub second intervals $t(12)$ =0,80, p < 0.198; over second intervals $t(12)$ =0,61, p <0.99).

The average bisection score was **552,76** for digits (1 or 2), **546,17** for large digits (8 or 9) and **568,2** for not numerical stimulus (#)in sub seconds intervals; whereas **985,15** (digits) **1023,26** (large digits) and **1038,89** for not numerical stimulus (#) in the over second intervals.

Data analysis do not document significant difference between condition, in the sub second $F(2,38) = 0,29$ $p < 0,74$ as well as over second $F(2,38)$=2,34 $p<$ 0,10 intervals. The results suggest that, when participants were asked to bisect duration of perceptual cues, numbers doesn't induce biases in the performance similarly to that documented at imaginative one.

Conclusion

My results document a modulation effect of numerical magnitude on temporal behaviour.

There is a systematic bias in the temporal performance by the irrelevant magnitude information conveyed trough numerical digits. This result suggests that the mere observation of numbers activates spatial representations associated with the number magnitude, which in turn modulates timing task.

However the shift of attention focus induced by number processing is irrelevant for time bisection task using perceptual stimuli. In this sense I argue that, in humans' cognition, imagination and perception of time are two domains relatively dissociated. The present dissociation suggests indeed that time imagination and time perception are two activities involving separated cognitive processes affected differentially by number exposure. This means that human strategies to time representation are subject to dramatic changes related to paradigm features and goals of temporal task. This means that human brain processing to time representation is subject to dramatic changes related to paradigm features and goals of temporal task. A bias in time bisection task, as that documented in this study, provides for a *time line* model in which, left or right shifts in a classical bisection task with numerical strings correspond to deviation towards a temporal under-estimation or over-estimation. Thus, like in a classical bisection task with numerical strings, the time line centre seems subject to similar shifts revealing compression and extension phenomena when participant were asked to image temporal intervals. This would mean that the update of spatial attention induced by numbers biases temporal as well as spatial behaviour. I conclude that the link between time and number representation is characterised by the reference to a common spatial code.

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