Modality And Intermittency Effects On Time Estimation

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Abstract

The modality of a stimulus, and its intermittency, both affect time estimation. The present experiment explores the effect of a combination of modality and intermittency, and its implications for internal clock explanations of the effects. Twenty-four participants were tested on a temporal bisection task with durations of 200 - 800 ms. Durations were signaled by visual steady stimuli, auditory steady stimuli, visual flickering stimuli and auditory clicks. Psychophysical functions and bisection points indicated that the durations of visual steady stimuli were classified as shorter and more variable than the durations signaled by the other stimuli. An interpretation of the results is that there are two speeds for the internal clock, one slow for the visual steady stimuli and one faster for the auditory steady and for the visual and auditory intermittent stimuli.

Keywords: Humans; Modality; Visual Flicker; Temporal Bisection; Time Estimation

Introduction

A main feature of time estimation is that it is marked by events, such as the onset or termination of stimuli or responses. It has been reported that some characteristics of the stimuli affect time estimations. For example, there are differences in timing filled and empty intervals in both, animal (Santi, Miki, Hornyak & Eidse, 2006) and human (Grondin, 1993) experiments. Another feature of the stimuli that has an effect over time estimations is their modality. Durations signaled by auditory stimuli are judged longer than durations signaled by visual stimuli. The modality effect has also been reported in both, animal and human experiments (Roberts, Cheng, & Cohen, 1989; Penney, Allan, Meck & Gibbon, 1998). Finally, in human experiments it has been reported that durations signaled by visual intermittent stimuli, i.e., visual flicker, are judged longer than durations signaled by visual steady ones (Ortega & Lopez, 2008). We will refer to this effect as the visual intermittency effect.

Both, the modality and the visual intermittency effect have been attributed to a difference in the speed of the internal clock, such as the one proposed by Scalar expectancy theory (SET). This theory proposes an internal clock that can be stopped, restarted and has a variable speed (Church, 1984). An increase of the speed has been manipulated pharmacologically and by the presentation of intermittent stimuli. It has been proposed that, with auditory steady stimuli and with visual flickering stimuli, the clock runs faster than with the visual steady stimuli, and therefore, the durations signaled by auditory steady and visual flickering stimuli are judged longer than with the visual steady stimuli. However, there has not been reported an auditory intermittency effect, i. e., if auditory clicks are judged longer than auditory steady ones. The present experiment explores in a temporal bisection task the possibility of an auditory intermittency effect and attempts to replicate the modality and the visual intermittency effect, in order to investigate the interaction of the modality and the intermittency effects, and the interpretation of the effects in terms of changes in the speed of the internal clock.

Method

<u>Participants</u>: Sixteen undergraduate students and eight members of the Timing Laboratory from the Psychology Department of Brown University were randomly allocated to two groups (16

women and 8 men, mean age = 22.4 years, S. D. =3.88). The students participated for partial course credit.

Materials and Apparatus: The stimuli and the experiment were controlled by the Psychophysics Toolbox Version 3 (Brainard, 1997; Pelli, 1997) for Matlab Version R2007b. There were four types of stimuli that varied in modality and intermittency: Visual steady stimuli (V) were gray circles (4.5 cm in diameter), auditory steady stimuli (A) were 500 Hz tones. Visual intermittent stimuli were gray flickering circles (F) with a 10Hz frequency which were alternating sequences of 50 ms presentations of a gray circle followed by 50 ms of white background, auditory intermittent stimuli (Clicks; C) were 500 Hz, also in a 10Hz frequency which were sequences of 50 ms presentations of the tone followed by 50 ms of silence. (Note that there was no signal to differentiate between the last 50 ms of silence and the following ITI). The visual stimuli were displayed at the center of the monitor, and the auditory stimuli were presented via headphones.

The duration range was formed by two reference durations, a Short (S) duration (200 ms), and a Long (S) duration (800 ms), and by five intermediate durations with a linear spacing of 100 ms between the referents (i.e., 300, 400, 500, 600, and 700 ms).

Procedure Each participant was tested individually in one session that lasted approximately 45 minutes. A temporal bisection task was presented, divided in 36 blocks. Each block was divided into a training phase and a test phase. Each training phase consisted of three alternating presentations of the two reference durations, i. e., SLSLSL. The presentation of the training phase was as follows. A display indicated that the training phase would begin after a press of the space bar and participants were instructed to pay attention to the reference durations that will follow. A 4s display indicated which referent was going to be presented next (e.g. “THIS IS A SHORT STIMULUS”). Then, a 1-s white screen was introduced, followed by the correspondent reference duration. One-hundred and fifty milliseconds after each referent, a response from the participants was required: if an S duration were presented, participants were instructed to press the “S” button of the keyboard, whereas after a L duration, participants were instructed to press the “L” button. After each referent was presented three times, a display indicated that the Training phase was over and that a press of the space bar would begin a Testing phase.

Each testing phase consisted in the random presentation of the five intermediate durations intermixed with the two referents. Participants were instructed to classify the durations as “Short” or “Long” according to their similarity to the S and L referents. The presentation of the testing phase was as follows. A duration, selected randomly without replacement, was presented and 150 ms afterwards, a display requested to the participant to classify it. If the participant considered it to be a Short duration the “S” button should be pressed, otherwise the “L” button should be pressed. One second after the response, the next duration was presented, and the testing phase continued until all seven durations were presented.

The stimuli presented in the training phase differed for two different groups. One group was trained with visual steady stimuli, whereas the other group was trained with auditory steady stimuli . In the testing phase both groups classified the durations of the four types of stimuli: visual steady stimuli, auditory steady stimuli, visual flicker and auditory clicks. Each type of stimuli was presented in nine consecutive blocks, counterbalancing the order of presentation between subjects in each group.

Results

Due to the lack of a signal that differentiated between the last 50 ms of silence from the sequence of auditory clicks from the 150 ms of silence of the ITI, the following analyses for this stimulus condition were run against a 150/750 ms duration range. An individual psychophysical function was plotted for each condition. In addition, a four parameter ogive (start, end, center and slope) was fit to each individual function. From each one of these functions, the individual bisection points for each stimulus condition were calculated, following the method used by Maricq, Roberts & Church (1981). The bisection point is the duration at which subjects were indifferent, i.e., the duration they classified 50% as “Long”. An ANOVA with the individual bisection points was conducted, which showed no significant difference in the modality of the trained stimulus ($F_{(1,16)} = 0.23$, $p > 0.05$), and no significant order effect ($F_{(3,16)} = 0.95$, $p > 0.05$). Due to the lack of both a modality effect and an order effect, the proportion of long responses for each condition of the 24 participants was averaged. Figure 1 shows the mean psychophysical functions for each stimulus condition.

FIGURE 1 ABOUT HERE

Inspection of Figure 1 shows that, for all the stimulus conditions, the proportion of Long responses increased as a function of the duration presented. The lines for each psychophysical function are the bestfitting ogives (all $\omega^2 > 0.96$) with the mean of the parameters obtained from each individual fit.

The location of the V function is located to the right of the other three functions, which seem very similar to each other. This displacement was confirmed by the previous ANOVA conducted with the individual bisection points for each stimulus condition, which also showed a significant effect of stimulus condition ($F_{(3,48)} = 11.11$, $p < 0.001$). Planned comparisons showed significant differences between the V and A bisection points ($F_{(1, 16)} = 14.82$, $p < 0.01$), the V and C ones ($F_{(1, 16)} = 28.01$, $p < 0.001$) and the V and F ones ($F_{(1, 16)} = 16.84$, $p < 0.001$). In contrast, there were no differences between the A and C bisection points ($F_{(1,16)} = 1.16$, $p > 0.05$), nor between the A and F ($F_{(1, 16)} = 0.003$, $p > 0.05$) ones. Table 1 shows the mean bisection points for each condition.

Table 1 about here

Table 1 also shows the difference limen and the Weber fractions. The difference limen is half the difference of the duration that was classified 75% of the presentations as “Long” minus the duration that was classified 25% of the presentations as “Long”. The Weber fraction is the difference limen divided by the bisection point. Two separated ANOVAs in these measures were conducted. With regard to the difference limen, there was no effect of modality of the trained stimulus ($F_{(1,16)} = 0.44$, $p > 0.05$), but a significant effect of the stimulus condition ($F_{(3,48)} = 6.67$, $p < 0.05$) was found. Scheffé tests indicated that for the significant differences were between the V and A conditions ($MS_{(3,48)} = 84.60$, $p < 0.05$) and the V and C ones. For the Weber fraction there were no- significant differences for the modality of the trained stimulus ($MS_{(3,48)} = 1.65$, $p > 0.05$), or for stimulus condition ($MS_{(3,48)} = 1.09$, $p > 0.05$).

Discussion

The present experiment confirmed two well-known characteristics of stimuli effects on the classification of durations: the modality effect and the visual intermittency effect, and provided evidence that suggest that these effects are not additive. The modality effect refers to the common result in which auditory steady stimuli are judged longer than visual stimuli. In a bisection task, the visual psychophysical function is to the right of the auditory psychophysical function, so that the visual bisection point is larger than the auditory bisection point (Wearden, Edwards, Fakhri & Percival, 1998). This result was replicated in the present experiment (See Figure 1 and Table 1). This modality effect has been interpreted as the result of a slower speed of the clock for the visual stimuli than for the auditory ones, or as evidence for the existence of two clocks that run at different speeds (Grondin, 2003). Because this effect occurs only when both modalities are presented to the same participant in the same session (Wearden, Todd & Jones, 2006), it has been interpreted as a memory mixing (Penney, et al, 1998; Penney, Gibbon & Meck, 2000), i. e., independently of one or two underlying internal clocks, the pulses obtained in each modality are stored in a common memory, therefore, with a slower speed fewer pulses are accumulated than with a clock that runs faster.

The visual intermittency effect refers to the findings that stimuli preceded by visual flicker or auditory clicks are judged longer than without the intermittent stimuli (Grondin, 2001; Penton-Voak, Edwards, Percival, & Wearden, 1996; Wearden, Edwards, Fakhri & Percival, 1998). This effect has been replicated when participants judge the duration of visual steady stimuli themselves (Ortega & Lopez, 2008). In a bisection task, larger bisection points and a right location of the visual steady function, compared to the visual flicker ones, are obtained (Wearden, Philpott, & Win, 1999), this result was also obtained in the present experiment (See Figure 1 and Table 1). This effect has also been attributed to different speeds of an internal clock, but due to a different mechanism: a visual flicker increases the arousal level of the clock which results in more pulses released than with a normal arousal level of the clock, i. e., with visual steady stimuli (Treisman, Faulkner, Naish, & Brogan, 1990; Treisman & Brogan, 1992). This has been considered as an increase of the speed of the internal clock.

In the present experiment we examined the effect of a combination of the modality and the intermittency effects. Because no auditory intermittency effects were obtained, the possibility of additive effects of modality and intermittency is ruled out. The functions for the auditory steady function and the intermittency one are overlapped and there were no significant differences in the values of their bisection points (See Figure 1 and statistical analysis of the bisection points). On possibility is that, when timing auditory stimuli, the clock runs at the same speed and that this is the maximum speed of the clock. If the clock runs at its maximum speed with auditory steady stimuli, intermittency would not further increase the speed. In contrast, durations signaled by visual steady stimuli are judged shorter than durations signaled by visual intermittent ones, which could be produced by a clock that runs at a slower speed for the visual steady than for the visual intermittent stimuli. If the clock does not run at its maximum speed with visual steady stimuli, it could be possible to increase its speed with visual intermittent stimuli. In addition, the psychophysical functions and the bisection points for both auditory conditions were similar to the functions for the visual intermittent one, and these three conditions differed from the visual steady one, which supports the hypothesis that there is a maximum in the speed of the internal clock, reached by the first three stimuli. These results suggest that there are two speeds of the internal clock, one fast for the auditory stimuli (steady and clicks) and for the visual flicker, and one slow for the visual steady stimuli, which could result from differences in the salience of the stimuli.

The stimulus manipulations of the present experiment, not only affected the location of the psychophysical functions and the bisection points; they also affected the difference limen, a measure of absolute temporal sensitivity. The difference limen for the visual steady stimulus was significantly larger than the difference limens for auditory steady and the intermittent auditory stimuli, i.e., the timing of the visual steady stimulus was more variable than the timing of the auditory stimuli.

Previous results indicate better duration discrimination for the auditory stimuli than for the visual ones have (Grondin, Meilleur, Ouellette & Macar, 1998; Wearden et. al., 1998). In addition, more variability for the visual modality has been reported in the tapping task, that involves timing of stimuli and responses. In a tapping task, participants are instructed to synchronize their finger responses to a rhythmic signal. This signal can be presented in a visual modality, in an auditory one or in a combination of both. Finger synchronization is more variable with visual signals than with auditory ones (Barlett & Barlett, 1959; Klemmer, 1967; Repp & Penel, 2002), or with the combination of both (Chen, Repp & Patel, 2002). In addition, it has been reported a synchronization threshold (i. e., the rate at which subjects can synchronize their responses with a 50% of accuracy) of 459 ms for the visual stimuli, but only 123 ms for auditory stimuli (Repp, 2003). Therefore, the results from the present experiment add to the evidence of a higher variability of the timing responses for visual than auditory stimuli.

The higher variability of visual stimuli over auditory ones (steady or intermittent) suggests that the modality and the intermittency effects not only affect the speed of the internal clock. If this was the case, only the location of the functions and the values of the bisection points would have changed. The change in the absolute sensitivity suggests a different slope for the visual function, which can be observed in Figure 1. This could be the result of the different processing of the visual and the auditory signals. Visual signals are processed more slowly than the auditory ones; it takes an auditory signal 10 ms to get to the brain (Kemp, 1973), whereas it takes a visual one from 20 to 40 ms (Marshall, Talbot & Ades, 1943). In addition, reaction times for auditory stimuli are in the range of 140-160 ms, while for the visual ones in the 180-200 ms range (Woodworth & Schlosberg, 1954; Brebner & Welford, 1980). These faster processing of the auditory stimuli, in addition to the fact that these stimuli and visual flicker are more salient, and therefore, require more attention from the subjects, could have resulted in a reduction of the variability of their responses. However, although there was a difference in the absolute sensitivity, there was no effect over the relative sensitivity, as assessed by the Weber fraction. Therefore, although the visual steady stimuli generates more variable classifications of the durations, more research is needed to adjudicate this result to a change, for example, in the threshold of the decision stage of SET due to a slower processing of this modality.

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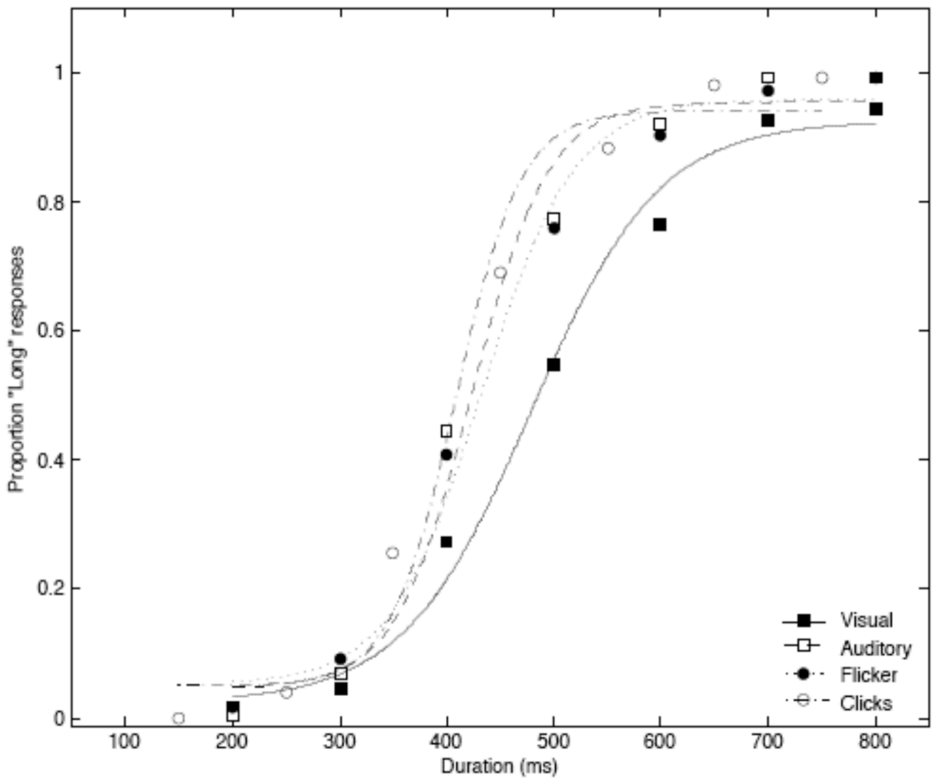

Figure 1. Proportion of "Long" responses as a function of stimulus duration (ms) for each stimulus type. Lines are the best fitting ogives (all $\omega^2 > 0.96$) with the mean parameters obtained from each individual fit.

Condition	Bisection Point		Difference Limen		Weber fraction	
	Mean	S.E.	Mean	S.E.	Mean	S.E.
V	487	77.30	52	2.20	0.11	0.007
A	427	75.83	43	2.09	0.10	0.005
F	426	64.03	47	2.52	0.11	0.006
C	460	75.76	41	1.66	0.10	0.004

Table 1. Bisection Points (in ms), difference limen and Weber fractions for each of the stimulus conditions. V = Visual steady, A = Auditory steady, F = Visual Flicker, C = Auditory Clicks.