Effect of Adaptation to Velocity on Time Estimation

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1. Introduction

While a number of factors have been reported to affect subjective time, Jones and Boltz (1989) proposed a model suggesting a relationship between expectancy of events and subjective time. Their model hypothesized that the subjective duration of an event changes with the contrast between the expected ending time and the observed ending time of the movement. Their model assumed that a perceiver estimates the temporal duration of an event using the expected ending time of the event. Based upon this assumption, if the event ends earlier than expected, then the observed duration of the event is shorter than the expected duration and, as a result of this contrast, the duration of the event is perceived as shorter. If the event ends later than expected, the duration of the event is perceived as longer. This model has been tested using various situations and methods (Boltz, 1993; Jones & Boltz, 1989; Jones, Boltz, & Klein, 1993).

In the previous studies, the focus was on the expectation of the ending time of events. Events experienced by people in everyday life, however, cannot always be expected. Moreover, even in situations where the ending time can be expected, people do not always expect only the ending time. Rather, people estimate the transition of events in the world continuously and revise their expectations according to the progress of the events. It is reasonable to assume that expectancy of the ending time is only one specific aspect of a continuous process of expectation. Therefore, when a perceiver continuously expects the transition of an event, this continuous expectancy should have the same effect as expectancy for the ending of an event on time estimation. The present study proposes a more generalized model than Jones and Boltz (1989), that expectancy for the transition of an event affects subjec-tive duration even without cues for expecting the ending of the event. In other words, subjective duration for an event that progresses more slowly than a perceiver expects is perceived as longer, and an event that progresses faster than a perceiver expects is perceived as shorter.

In the present study, participants observed a circle of light moving on a CRT screen at a constant velocity (called the "estimation stimulus") and reproduced the duration of the movement of the circle. Before they were presented with the estimation stimulus, they observed repeatedly a circle moving at a different velocity (called the "adaptation stimulus") from the estimation stimulus. The purpose of presenting the adaptation stimulus was to give participants a cue for expectancy for the movement of the estimation stimulus. The experiment consisted of two sessions to investigate the effect of presentation of the ending point of the movement on subjective duration. In Session NC (No Cue), the cue for the ending time of the event was not presented. In Session EC (End Cue), before the movement started, the position where the movement was to end was given to the participants as a cue for expecting the ending time. The contents of the two sessions differed from each other only in presence or absence of the ending point. If the effect of the velocity of the adaptation stimulus is greater when the ending point is presented (Session EC) than when it is not presented (Session NC), it can be concluded that expectancy for the ending time of the movement affects subjective duration. If the expectancy for the ending time does not affect subjective duration, then the effect of the velocity of the adaptation stimulus will not differ between the two sessions.

2. Method

2.1 Apparatus

Stimuli were controlled using an NEC PC9801VM personal computer and displayed on a NEC PC-TV451n monitor with a 26 cm×16.4 cm screen. Participants' time reproductions were recorded using a Nihon Assembla JAC Timer Board II. A chin rest was used to fix the viewing distance at 1m.

2.2 Participants

Twenty-two undergraduate and graduate students, whose ages ranged from 20 to 24 years, participated in the experiment. All had normal (or corrected to normal) visual and auditory acuity. Each participant completed two sessions, which were conducted on different days. The order of the two sessions was counterbalanced across the participants.

2.3 Stimuli

The estimation stimulus in Session NC was as follows. First, a vertical line (8.2

mm in length) indicating the starting position of the target was shown on the left side of the screen. Two seconds after the appearance of the line, a circle target (4.1 mm in length) appeared with its left border adjacent to the line. Immediately it started to move 121 mm to the right at a constant velocity and then disappeared. The line indicating the starting position disappeared when the target disappeared. The temporal duration of the presentation of the target, i. e., the time it took for the target to move 121 mm, was 0.75 seconds or 1.50 seconds.

The adaptation stimulus was identical to the estimation stimulus with the exception that the velocity and the distance moved differed from those of the estimation stimulus. The velocity of the adaptation stimulus was one-third or triple that of the two types of the estimation stimuli. The distance moved by the adaptation stimulus is described below in the Procedure section.

Both the estimation stimulus and the adaptation stimulus in Session EC were identical to those in Session EC with the exception that the ending position of the target movement was presented in Session EC. A vertical line indicating the ending position of the target movement was shown when the line indicating the starting position appeared. This line disappeared when the target reached the line. The length of the line indicating the ending position was equal to that of the line indicating the starting position. The size of the target, the temporal sequence of stimulus presentation, the distance moved by the target, the composition of the temporal duration of the presentation of the target and the composition of the adaptation stimulus were identical to those in Session NC.

2.4 Procedure

The procedure in the two sessions was the same. At the beginning of each trial, the adaptation stimulus was repeatedly presented. The number of repetitions varied randomly from 7 to 12 times. The interval between the end of an adaptation stimulus and the start of the next was two seconds. Two seconds after the end of the last adaptation stimulus, an estimation stimulus was presented. Lastly, a beep sounded two seconds after the end of the estimation stimulus, which was a signal requesting the participant to respond. Since it was not until the signal was given that the participant could know which stimulus he/she was required to respond to, the participant had to be prepared to respond to all adaptation stimuli and the estimation stimulus. The participants' task was to reproduce the interval between the appearance and the disappearance of the stimulus marked by the signal (estimation stimulus) by pressing a response button for the duration they had perceived. Ten seconds after the end of the participant's response, the next trial started.

As described above, the adaptation stimulus was repeatedly presented. The distance moved by the target varied randomly with a range of 61 mm to 242 mm. The reason for randomizing the distance was that if the distance was kept constant, then the duration was also constant and then the participant would be affected not by the expectancy for the transition of the event but by a direct contrast between the duration of the adaptation stimulus and that of the estimation stimulus.

The experiment consisted of two sessions with a total of eight conditions defined by three factors: presence (Session NC) or absence (Session EC) of an ending point; the duration of movement of the estimation stimulus (0.75 second or 1.50 second); and the velocity of the adaptation stimulus (one-third or triple the velocity of the estimation stimulus). Each participant completed four blocks of trials (one practice and three experimental blocks). One block in each session consisted of 4 trials corresponding to the 4 conditions. The order of the four conditions in a block was random. Participants were given a few minutes of rest between the blocks.

3. Results and Discussion

For each participant, the reproduced durations for the three trials of each of the eight conditions were averaged. The mean reproduced durations and standard deviations for the eight conditions are shown in Table 1. The averaged values were subjected to a within-participants, three-way ANOVA with the factors being the duration of the estimation stimulus × the velocity of the adaptation stimulus × the presence or absence of the ending point.

Teble 1 Mean reproduced times as a function of the rate of the adaptation stimulus in cases of absence and presence of an ending point

		Rate of adaptation stimulus	
Ending point	Actual duration	Triple	One-third
Absent	0.75s	1.47 (0.42)	1.36 (0.40)
	1.50s	2.04 (0.42)	1.88 (0.45)
Present	0.75s	1.51 (0.46)	1.39 (0.48)
	1.50s	2.04 (0.40)	1.87 (0.49)

Note. Standard deviations are in parentheses.

The main effects of duration ($F_{1,21} = 762.481$, $p < .01$) and velocity ($F_{1,21} = 37.630$, $p < .01$) were significant. The main effect of the ending point was not significant ($F_{1,21} = 0.701$, $p > .1$). All one-way interactions were not significant (duration $\times$ velocity: $F_{1,21} = 0.941$, $p > .1$; velocity $\times$ ending point: $F_{1,21} = 0.008$, $p > .1$; duration $\times$ ending point: $F_{1,21} = 0.708$, $p > .1$). The two-way interaction (duration $\times$ velocity $\times$ ending point) was not significant ($F_{1,21} = 0.000$, $p > .1$).

The result that the main effect of the velocity of the adaptation stimulus was significant indicates that the subjective duration of the movement increased when the participants adapted to a fast movement compared with when they adapted to a slow movement. In addition, the finding that the interaction between the presence or absence of the ending point $\times$ velocity of the adaptation stimulus was not significant indicates that the effect of adaptation to the velocity of the previous stimulus did not differ between when the ending point of the movement was present and when it was absent. These findings support the hypothesis that expectancy for the transition of an event affects subjective judgment of duration even when there is not an expectation for the ending time of the event. Furthermore, the failure to find a significant main effect of the presence or absence of the ending point indicates that expectancy for the ending time of an event does not affect subjective duration at least in the situation used in this study. The change of subjective duration associated with the change of the velocity of the adaptation stimulus can be interpreted as being caused not by the contrast between the expected ending time and the observed ending time, which was proposed by Jones and Boltz (1989), but by the contrast between the expected transition rate of an event and the observed transition rate.

As described in the introduction of this article, the focus of the model of Jones & Boltz (1989) is on the expectancy for the ending time of events. The concept of this hypothesis is that a starting point and an ending point segment many events, and that people anticipate the ending time of events. However, it is not necessary that the model should only focus on segmented events. Many real-life events are continuous without explicit segmentation and, therefore, people must have cognitive processes that enable them to adapt to a continuous transition. Thus, the effect of expectancy on subjective duration should not change with the presence or absence of an ending point, as was found in the present experiment. The stimulus used in the present experiment was the movement of a light with continuous transition. To adapt behavior to events with continuity, it is not necessary that expectancy for a particular point, e. g., the ending point, has a dominant influence, but it isnecessary to control behavior by estimating the transition of events successively. Accordingly, the relationship between the expected phase of an event and the observed phase would be estimated successively, and as a result, the contrast between the expected rate of transition of the event and the observed rate would affect subjective judgment of time.

Other studies have reported an effect of the rate of a movement on subjective duration in observing a moving object, as found in the present study. Bonnet (1968) and Rachlin (1966) reported that subjective duration lengthened as the velocity of a moving object increased (hereinafter called the L-effect). Conversely, Bonnet (1965), Brown (1931) and Matsuda (1968) all reported findings that subjective duration shortened as the velocity of a moving object increased (hereinafter called the S-effect). Matsuda (1974) analyzed the differences in the experimental situations between the studies obtaining the lengthening effect with velocity and those obtaining the shortening effect and predicted that the direction of the effect of velocity depended on whether participants chose velocity or distance from the elements of the observed movement as a cue for time estimation. Matsuda (1974) confirmed this prediction in a study that found that participants who were forced to choose distance as a cue for time estimation estimated the duration of the movement to be longer and participants who were forced to choose velocity estimated the duration to be shorter. Matsuda (1974) indicated that when participants had a set to choose distance as a cue for time estimation, subjective duration lengthened with the increase in velocity, and when participants had a set to choose velocity as a cue, subjective duration shortened with the increase in velocity. Further, Matsuda(1974) explained why these two types of effects existed. According to her explanation, when the cue for time estimation was distance, subjective duration lengthened with the increase in the perceived amount of stimulation accompanying the increase in distance, which was proportional to velocity. Inversely, when the cue for time estimation was velocity, subjective duration shortened because participants used the concept of an inverse proportion between velocity and distance.

As described above, Matsuda (1974) reported that the S-effect occurred when participants had a set to choose moving velocity as a cue for time estimation. Since the S-effect refers to the effect that subjective duration shortened with the increase in moving velocity, Matsuda's (1974) finding is closely related to the finding of the present study. The present findings indicate, in terms of the relationship of velocity between the adaptation stimulus and the estimation stimulus, that subjective duration is shorter when the velocity of the estimation stimulus is larger. The findings of the present study could be explained not only based upon expectations for the transition of events, but also by the following two factors: the set to use moving velocity and participants' concept about the relationship among time, distance and velocity. Thus, the present findings could also be interpreted according to the following scenario. The stimulus and procedure in the present study forced participants to have a set to use the moving velocity as a cue for estimation. Then participants perceived the duration of the standard stimulus, whose velocity was larger than the velocity of the adaptation stimulus, to be shorter; this was derived from the concept of an inverse proportion between velocity and time. However, it is also possible that the S-effect obtained in previous studies can be explained by expectations for the transition of events. Further investigation is necessary to clarify this.

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Jones and Boltz (1989) hypothesized that subjective duration of time is influenced by the contrast between the expected ending time of an event and the observed ending time. The present study proposes a more generalized hypothesis that subjective time duration is based on the contrast between the expected velocity and the observed velocity of an event, even with no explicit ending point. In the experiment, participants reproduced the duration of the movement of a target, both with and without presentation of the ending point, after they had adapted to a movement with a faster or slower velocity. Analysis showed that the duration reproduced by the participants varied with the velocity of the adaptation stimulus. The effect of the velocity of the adaptation stimulus was identical when the ending point of the movement was present and when it was absent. These findings indicate that it is not the contrast between the expected and observed ending time but the difference between the expected and observed velocity that is crucial to subjective duration of time.