Part V
Free Talk Session 2

APPARENT TIME COMPRESSION FOR SLOW-MOTION STIMULI

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A number of psychophysical studies have shown that moving stimuli appear to last longer than static stimuli. Here, we report that this fundamental assumption could be apparently dismissed under specific circumstances. We measured apparent durations of natural movies and artificial drifting gratings presented at various speeds by 2AFC method, using moving stimuli as the comparison. While fast movies were perceived as the longest in accordance with previous studies, slow movies were perceived as shorter compared to static images. However, time compression for slow stimuli disappeared if comparison stimuli were replaced by a white static disk that minimized repetitive exposures to moving stimuli. The results suggest that duration estimation is shaped by the specific distribution of prior visual stimuli to which observers are exposed. A simple model, which includes a rapid recalibration of human time estimation via adaptation to preceding stimuli, succeeds in reproducing our experimental data.

CAUSALITY REPLACES PERCEIVED TIMING OF TWO EVENTS: INVESTIGATION OF THE COMPETITION OF MULTIPLE CAUSAL CONTEXTS IN A SINGLE SEQUENCE

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Abstract

A previous study (Umemura, 2017) reported that causal contexts implied in stimuli modulate the perception of the temporal order of two events to accord with the causal contexts. In the stimuli, a ball falling from above and objects moving on the ground were sequentially displayed, and the perceived timings were modulated to accord with the context; a ball hit the ground and then objects moved. The study also reported that the effects of contexts were different among types of motion. It was considered that another context that could imply effects prior to the ball contacting the floor, such as wind pressure caused by the falling ball, competitively affected perceived timings. This suggestion leads to the prediction that this opposite effect would disappear in stimuli that do not comprise a preceding causal context. In the present study, this prediction was tested by using the stimuli that have the same object motions as those of the previous study, but have a different preceding event—the color change of a static object. Even in the display, participants perceived causality between the preceding event and the subsequent motion, e.g., objects were surprised and ran away from the static object that changed its color, while almost all participants did not perceive the preceding causal context. Results showed that the timings of the start of object motion were modulated to accord with the causal context. As expected, shifts of timings were not different among types of motion. This supports the speculation that different effects of causal context on temporal perception among different motions in the previous study would be due to the competitive causal context.

When one sees a ball flying toward a glass and breaking it, one also perceives causality between these two events. In this case, the ball contacting is a ‘cause’ and the glass breaking is an ‘effect’. The perception of causality has attracted many researchers since Michotte showed that simple visual stimuli could give the impression of a causal connection between events (Michotte, 1963). It is relatively recent that studies on the effects of causal perception on other perceptual processes, such as temporal perception, have appeared (Bechlivanidis & Lagnado, 2013, 2016; Buehner, 2012; Eagleman & Holcombe, 2002; Haggard, Clark, & Kalogeras, 2002).

Recently, the author demonstrated that causal contexts implied in stimuli modulate the perception of the temporal order of two events to accord with the causal contexts (Umemura 2017). In the stimuli, a ball falling from above and objects moving on the ground were sequentially displayed. Even though the context was given in subsequent events, the perceived timings were modulated to accord with the context; a ball hit the ground and then objects moved. This effect was strong so that even if the objects on the ground started movement approximately 80 ms before the contact of the ball, participants perceived the movement started after the contact. This study also showed that the effects of causality were different among types of motion. It was speculated that another context, which could have effects on objects before the ball contacted the floor, such as wind pressure caused by a falling ball, competitively affected the modulation of perceived timings. However, there remains a possibility that another cause arising from the difference of motion could affect the modulation of perceived timings.

In the present study, this speculation was tested by using the stimuli that have the same object motions as those of the previous study, but have a different preceding event—the color change of a static object. Although, one might wonder that this display is able to arouse causality perception, observers in the pilot study repeatedly reported the perception of causality. On the other hand, it is difficult to perceive causal effects that are effective before the color change of an object in the present stimuli (the preceding causal context). It is expected that the difference of the shift in temporal order judgement would be reduced with these stimuli.

Method

Apparatus and Stimuli

The experiments were conducted in a dimly lit room. A Windows PC was used to control the stimulus presentation on a CRT monitor placed 40 cm from the observer.

Each stimulus comprised two events. One event was the color change of a cube located at a fixation point (‘cause’ event). In the other event, ten rings on the floor moved or changed their color (‘effect’ event). I prepared four types of displays, which were the same as those used in (Umemura 2017). For type A, B, and C stimuli, ten rings moved on the floor in the subsequent event. They are roughly illustrated in Figure 1. For type D stimuli, the rings did not move, but changed their color. The timing of the first event to the start of the second event was chosen from nine inter-stimulus interval (ISI) conditions, -118, -94, -71, -47, -24, 0, 24, 47, and 71 ms, where negative ISIs indicate that a subsequent event started before the change of the cube’s color.

Procedure

This experiment included three tasks—temporal order judgement task, causality-rating task, and interview. In the temporal order judgement task, participants judged the temporal order of the change of the cube’s color and the start of the rings’ movements using a two-alternative forced-choice design. The causality-rating task was conducted after the temporal order judgement tasks were completed. In this task, animations with an ISI of -118, 0, or 71 ms were displayed for participants. Participants chose a higher score (maximum 9) when they strongly perceived causality. All the animations were rated twice. An interview was conducted after the causality-rating task. The same animations were used in the causality-rating task (ISI of -118, 0, or 71 ms). An experimenter showed a participant one of the animations, and asked them to express how the color change of the cube caused the second event if they perceived causality. Participants could freely express the causality they experienced. Eleven observers, oblivious to the experimental purpose, participated in the present study. All the experimental procedures were approved by the Ethics Committee for Human and Animal Research of the National Institute of Advanced Industrial Science and Technology (AIST). All subjects provided written informed consent in accordance with the Declaration of Helsinki before the experiment.

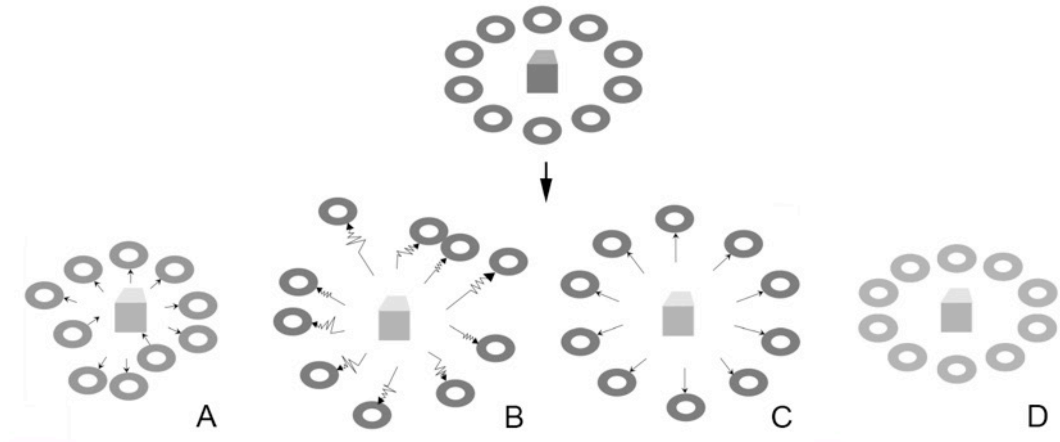

Fig. 1. Illustration of the stimuli. The arrows roughly indicate the directions of movement. D means the color change of the rings. These movements are the same as in (Umemura 2017), and one can watch these movements in the online supplemental materials of the article.

Results and Discussion

I first show the results of causality-rating task and interview here. Table 1 shows the averages of the rating obtained in the causality-rating task. One-way ANOVA for the rating with ISI=0 ms showed a significant effect of the stimulus type ($F(3,30) = 15.11, p < 0.001$), and a post-hoc comparison with a Bonferroni adjustment revealed significant differences between D and other three displays ($p < 0.001$ in all combinations), but there were no significant difference between any combinations of A, B, and C ($p > 0.5$). Further, the results of ANOVA for the ratings for ISI=-118 ms did not attain the significance level (F(3, 30)=2.33, p=0.09). The ANOVA for ISI=71 ms showed a significant effect of the stimulus type ($F(3,30) = 5.23, p = 0.005$). A post-hoc comparison showed significant differences between D and A ($p = 0.02$), and D and C ($p = 0.007$), but did not attain a significance level between D and B ($p = 0.06$). No significant effects were revealed between any combinations of A, B, and C ($p > 0.5$).

Table 1. Mean ratings in the causality-rating task and SDs.

Event type	ISI = −181 ms	ISI = 0 ms	ISI = 71 ms
A	2.5 (2.2)	6.5 (2.5)	7.0 (1.6)
B	3.3 (2.6)	7.2 (1.5)	6.8 (1.8)
C	3.4 (2.3)	7.1 (1.5)	7.4 (1.6)
D	1.3 (2.1)	3.2 (2.4)	3.8 (2.5)

The results of the causality-rating indicate that participants perceived causality for this display when ISI=0 or 71 ms. The interpretations for these stimuli acquired through the interview were as follows: "the color of the cube changed and an impulse was generated ($n = 3$)", "the switch was turned on, and then the rings were moved (n=3)," and "the rings were surprised at the change of the cube's color ($n = 2$)." Two participants reported that they did not perceive causality, and one participant felt causality but could

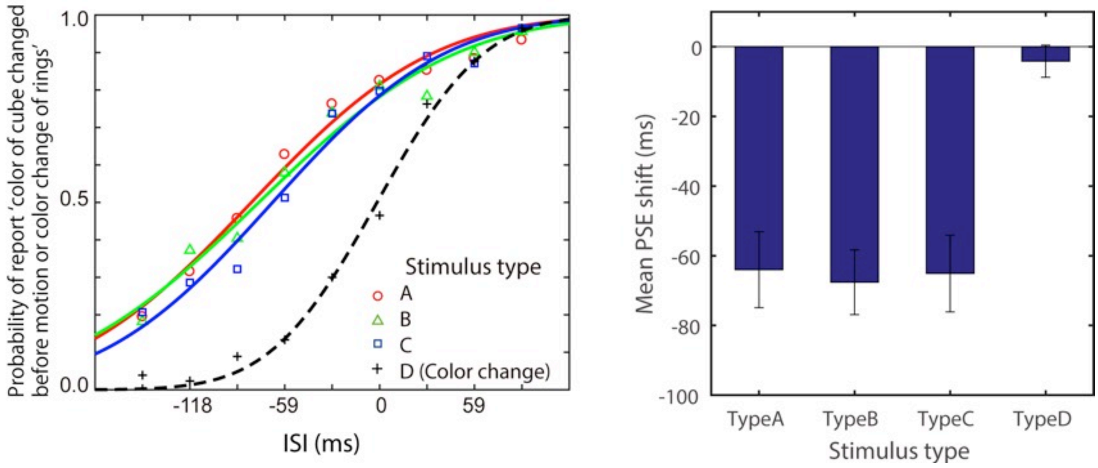

Fig. 2. Results of the temporal order judgment task. (Left) Example of curve fitting. (B) Averaged PSE shift from zero for all participants.

not explain it. Thus, interpretations varied among participants, but did not vary among the types of stimuli. This was different from those of Umemura (2017), in which different interpretations were obtained among different stimuli. More important results for the purpose were that when ISI $= -181$ ms, the ratings were small in three movement types, and almost all participants answered that there were no causal links between the two events.

Figure 2 shows the results of the temporal order judgement task in which participants were required to answer whether the rings started moving before or after the cube changed its color. The proportions of trials in which participants answered that the cube changed its color before the start of the rings' movement (or color change) were plotted and the point of subjective equality (PSE), which indicates that the end of the first event and the start of the second event were simultaneous, was calculated by fitting with a cumulative Gaussian function as an index of the extent to which the timing of the end of the first event and the start of the second event converged (Figure 2, left). The averages of the PSEs are presented on the right of Figure 2. The repeated measures ANOVA revealed a significant main effect of the stimulus type ($F(3, 24) = 31.87, p < 0.001, \eta^2 = 0.629$). A post-hoc comparison with a Bonferroni adjustment revealed a significant difference between D and other three displays ($p < 0.001$ for all pairs), but did not reveal significant differences between any combinations of A, B, and C ($p > 0.5$, for all combinations). This means that the perceived temporal order was transposed to accord with the causal context; the cube changed its color, and at the same time generated impulse. Then the rings started moving, for example. While, there would be no other causal context which differentiate the perceived timing among different motions.

Summary

The results showed that even if the color changing served as a 'cause', participants perceived causality between the event and motions of the rings, and that the timings of the start of the object motion were modulated to accord with the causal context. Almost all participants did not perceive the causal context when the color of the cube changed after the start of the ring's movement. Moreover, as we expected, the shift of timings did not show a significant difference among the three motion conditions. These results support the suggestion that different effects among different motions in the previous study could be due to the competitive causal context. Umemura (2017) suggested that these effects of causal contexts on the temporal order judgement would be explained in the framework of Bayesian estimation, and the difference of effects of the causal context among subsequent object motions would be due to the competition of two hypotheses (priors). Each prior should have a different contribution according to its probability or likelihood. The results of the current study supports this view by showing that equalizing (deleting) the effect of the preceding causal context leads to equalizing the shift of the PSEs.

Lastly, it is interesting that only the changing color of the cube could be a 'cause' for subsequent rings' motion, because I believe we merely encounter such situations. Therefore, we should have more studies on how causal links are acquired and how these links are applied to visual inputs.

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