The Time Perception in the Flash-Lag Effect

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Abstract
Flash-Lag Effect (FLE) is known as a phenomenon in which a moving stimuli position is perceived with a lag relative to a flashing stimuli when the flash appears physically aligned with the moving one. In previous accounts both the moving object and flashing stimuli are unconditionally believed as something to be recognized. In this study, we conducted several experiments for FLE involved the problem of segregation between figure and ground. We found that interaction between moving objects and flashing stimuli as compatibility and complementarity of figure/ground effectively influences FLE. The results show us one aspect of the temporal perception, so that the subjective segregation between internal (as figure) and external (as ground) recognition would drive the time.
Keywords : Flash-Lag Effect, Time perception, Simultaneity, Complementarity of Figure/Ground, Kanizsa's triangle.

1 Introduction

It is well known that the time perceived by our visual processing plays different roles from the time measured by a clock, and the perceived time would work for judgment of timing of any events and for determination causality. You may automatically understand its causality when an event occurs just after another's occurrence, in other words each of the former and later events are regarded as the cause and the result respectively. Furthermore you don't have to confuse your own action in dairy life even if you couldn't clearly identify each event (Eagleman *et al* 2003; Libet 1978). Amount of recent psychophysical studies has unveiled that our time order judgment under some situation would be flexible and distorted and that representation and construction of perception of time is the result of interpretation of the information of environment via visual processing (Blake 2005; Warren *et al* 1969, 1970; Watanabe 2006).

2 Flash-Lag Effect

Knowledge of Flash-Lag Effect (FLE) is one of the psychophysics' outcome. FLE is the phenomenon in which a moving stimuli position is perceived with a lag relative to a flashing stimuli when the flash stimuli appears for a split second, physically aligned with the moving object (Nijihawan 2002).

Sheth *et al* 2000demonstrated with their experiments that FLE would not be only mislocalization but also a temporal phenomenon, in which stationary stimuli with continuously changing its characteristic (color, luminance, pattern and spatial frequency) which is presented as a role of moving stimuli is perceived with the condition after the moment of appearance of flashing stimuli. Several considerable accounts are outlined below for readers' information.

2.1 Motion extrapolation

Motion Extrapolation is supposed to be one of the earliest models of FLE. This account suggests that perceived position of the moving object is compensated to deal with the signal delays caused the distance from retina to the cortex (Nijihawan 2002). This account is naturally acceptable without a particularly technical matter, however, is incompatible with a well-known knowledge (Brenner 2000), which we leave the description here.

2.2 Differential latency

Stimuli with different attributes are processed with different delays. The authors of the differential latency account suggest that the visual system processes moving objects more efficiently than flashes, leading to a difference in latencies that corresponds to the FLE (Baldo & Klein 1995; Witney & Murakami 1998). This account raises concerns as indicated by others. What detects the unpredictable events to cause the difference? This account assumes that the visuosensory awareness appears at the same instance of the input of the retinal signals (Zeki & Bartels 1998), then is insufficient to make mention to subjective awareness. Also the matter of the physiological mechanism which detects and separates moving or stationary objects and transmits their information is dissolved still (Eagleman & Sejnowski 2000; Nijhawan 2002).

2.3 Time integration / Postdiction

Krekelberg and Lappe suggest that the FLE due to slow temporal integration of position signals of the moving object over a time window. And Eagleman and Sejnowski suggest that in estimating position of moving objects the visual system collects position signals not only from the past but also from the future. These assertions are compatible to other visuosensory phenomena like the backward masking(Beitmeyer 2000), and successfully explain the perceived position of moving objects. However, this model has difficulty dealing with a stationary object (Nijhawan 2002).

2.4 Attentional capture

Baldo and Klein invoke reduced latency for moving objects due to attentional capture, and the shift of attention caused by the flashing object. Kirschfeld and Kammer also suggested that greater attention to moving objects leads their faster processing than flashing. The former authors explain the FLE as following; the smoothly moving object sustains the observer's attention, while a flashing stimulus captures and draws the observer's attention away from the moving object. During the time it takes for the observer's attention to shift back to the moving object, the moving object has shifted in position in the 'real' world. Although this account also successfully explains the FLE, several recent evidences contradict it (Nijihawan 2002; Khurana *et al* 2000; Chappell *et al* 2004, 2006; Wakatsuki 2006; TSE 2004).

2.5 Comparing the accounts

Either account however has not been the conclusive explanation model in recent arguments. Both authors of motion extrapolation and differential latency accounts have became not to assert their own idea itself (Khurana 2000; Nijihawan 2002). Because a lot of empirical evidence have illustrated that it is hard to prove its account simply. It seems that either authors of motion extrapolation and differential latency look at their cause for "motion integration" and "attention capture" accounts respectively. It's contemplated that either has respected other aspects of time perception. If the simultaneity that was perceived would depend on the time window, which has width including direction of time (from past to future), a concept, an extrapolation of motion by nerve processing, is based on an attitude of an attention to present form of agents of moving. On the other hand, the idea that several events go into the nerve system without a concept of simultaneity has an affinity to the idea that the perceived temporal order of each events is computed by the nerve system to be as the measured temporal order even if the attention interposes. That is to say, it seems that the controversial point in the debate noted in the foregoing is whether "the moving object from recognized as the present in a way of top-down" or "the flash stimulus perceived as the past form in a way of bottom-up" is marked.

3 Introduction to Figure/Ground Segregation

Now we are introducing the matter of segregation of figure and ground to retreat the point of the debate as the relation of interior and exterior worlds of recognition(Kanizsa 1970). The moving object is regarded as an object in continuous time. It means that the moving object is already in the interior world. On the other hand, the flashing stimulus is not regarded as an object yet when the moving object appears in our visual space. The background which has potential to occur any events is non-conscious. The brief flashing stimulus would come from the external world.

The bottom line is, each event doesn't have same status for our recognition. Hence we are not able to deal with them on the equal rank. Let us confirm the concept of segregation of figure and ground. Both terms "figure" and "ground" are originally used in the Gestalt laws of visual perception states that a figure stands out from its surroundings as they're consciously watching a figure. Needless to say, neither of them can be recognized without the other. Moreover it can be said that a ground plays a role of putting the other part in a visual field to a figure and vice versa (Gunji 2003). Now we let this character be called complementarity of a figure/ground. Any perceived physical features are regarded as objects in the interior world by operation of segregation between figure and ground, where the objects are being to be figure and the exteriors are being to be ground.

All of previous works described above depend upon the idea that both objects are unconditionally recognized as itself. Top-down-like time integration account pays attention to those objects which is already segregated as figure from surroundings. Bottom-up-like attentional capture account pays attention to the process where the event is being recognized as figure. In this way of considering the matter of complementarity between figure and ground those accounts do not have to be opposed to each other so that both events in FLE should be put on same rank of tenses. Complementarity can be regarded as a degree of difference between figure and ground so that either of the moving and flashing stimulus in FLE is controlled as representation of complementarity of figure and ground.

In our series of experiments, Kanizsa-like figures are used as stimulus for controlling the complementarity. Kanizsa's triangle is one of the most popular figures as stimulus attracting subjective shape, which contains three element figures those are sectors with long arcs and induce the perception of a subjective contour "a triangle on three circles" when those elements are faced with each other. Although the part enclosed in three elemental components is exactly same to the background in aspects of physical characters, observers easily perceive the subjective contour of interior triangle (Kanizsa 1979; Goto 2005). By controlling the element component figures, we are able to represent in several ways, the three components as figure on background and a triangle as figure on three component as ground.

4 Experiments

Three experiments were carried out. The first one was the main and the second and third were conducted to support the first.

4.1 General Methods

4.1.1 Purpose

In this series of three experiments we estimated FLE's properties with changing degree of segregation between figure/ground as complementarity between the interior and the exterior of recognition. Kanizsa-like figures were used in order to control segregation of figure/ground.

4.1.2 Subjects

Every subject was naive about the substance of this study. Their naked or corrected visions are normal. Each subject was allowed to have a break as long as they need. Some were not able to be tested all of experiments due to their convenience.

4.1.3 Stimuli

As a standard stimulus (ST), three black circle (diameter 3°) pointed on the vertex of an equilateral triangle (its circumscribed circle's radius was 5.5°) rotating with 60°/sec were presented. As examination stimuli three types of figure were presented. Stimuli A(SA) is so-called Kanizsa's triangle rotating at same degree to ST. Stimuli B(SB) is composed of ST and a white triangle presented on ST which color couldn't be distinguished with background, rotating at different degree (48°/sec) from ST. Stimuli C(SC) is composed of three rotating at 36°/sec Kanizsa-induced figures, so that the centers of the figures keep its position on the vertex of an rotating equilateral triangle as like ST. ST, SA, SB and SC are drawn on Fig.1.

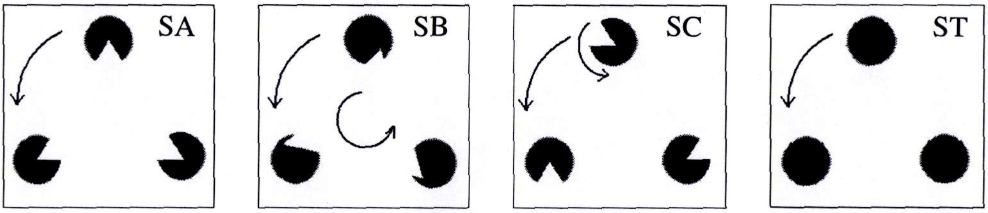


Fig. 1: Stimuli shown in experiments. Far right ST drawn as standard Kanizsa's triangle. From left to right, examination stimuli SA, SB and SC are shown. All the arraws indicate the ways of rotation.

Now we here call element figure (EF) as every black circle and circle-like figure. Flashing stimuli shaped an black equilateral triangle was presented for -15ms $\sim$ +15ms at the moment EFs form into Kanizsa's triangle.

In our experiments we define the FLE where the center of black circles is observed with lag to the vertexes of the briefly appeared triangle and the magnitude of is subjective distance between the center of circles and the vertex of triangle.

All stimuli were presented on LCD (BenQ FP92; refresh rate $60Hz$) via PC (eMashines J4442; CPU;Intel Pentium(R) $3.20GHz$; Windows XP) driven by a program written in C++.

4.2 Experiment 1.

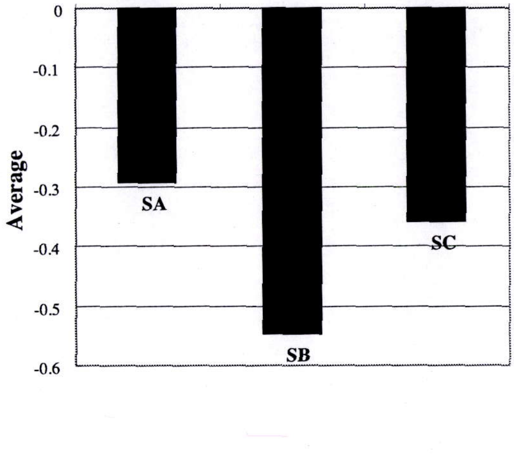
4.2.1 Stimuli

SA, SB, SC and ST described above were shown. A mark × is shown on the center of display as a gaze point.

4.2.2 Procedure

The twenty subjects in their 20's who had confirmed the FLE in ST are required to fix their point of view to the gaze point during each trial. In the process of one trial, subjects confirm the magnitude of lag in ST then compare the magnitude one in the stimuli (SA, SB or SC) shown next. Subjects were allowed to observe them as long as they needed. After comparing it, subjects select a button to answer "more", "equal" or "less". SA, SB and SC are presented in this order, subjects confirmed the magnitude before each stimuli were shown. Each stimulus was shown 4 times in a trial, and 3 trials were conducted for each subject.

Table 1: Result of Experiment 1. Bars represent averages of differences between ST and each stimuli. In SB, the degree of lack of lag relative to ST is significatly decreased.



4.2.3 Result

For analysis, let "more" ,"equal" and "less" be quantified to be "+1","0" and "−1" respectively. The averaged value of SA, SB and SC is −0.29, −0.54 and −0.36 respectively. As a result of analysis of variance, the proportion of unbiased estimate of population variance is 5.6 between SA and SB, 2.4 between SB and SC, and 0.3 between SC and SA. SA and SB are significantly different. Note that data that is surely confirmed by subjects were analyzed. Videlicet, some of subjects reported that they intentionally selected difference alternatives because they assumed that each stimulus is different from others. Hence we decide that such data, which accounts exact sixth part of all, were irrelevance to be analyzed.

4.2.4 Discussion

At first we are reviewing properties of each stimulus.

Stimulus A: Three EFs circled the center of the display keeping being able to inducing the subjective contour so that interior triangle is recognized as figure in a similar way of perceiving Kanizsa's triangle. Meanwhile, the group of EFs is almost automatically recognized as figure as one moving object consist of objects with "common fate" in observer's global view. The whole figure shown on a display is in amount obviously assumed as a figure so that the obvious gap between interior and exterior recognition is robust. Therefore the flashing stimulus is regarded to be determinably unique.

Stimulus B: EFs are sometimes regarded as "figure" by background as "ground", and sometimes as "ground" by the interior triangle as "figure". Observers hardly see EFs as group globally with obscurely distinguishing from background. Also the flashing stimulus appeared where the triangle as "figure" had been shown to give EFs a function as "ground". Because EFs were not connected in a group as figure, the status of the flashing stimulus may not be unique as itself. It must be "figure" opposed to EFs as "ground". Hence the flashing stimulus cannot be clearly separated from the background or from EFs. That is to say, in SB the complementarity of figure and ground was emphasized demonstrably.

Stimulus C: Each EF rotating locally is regarded as "figure", at the same time the group of EFs with "common fate" is sufficient to be a object being recognized as "figure" by observer's global view. It resembles SA in its action. However EFs were not connected with the interior triangle as Kanizsa's triangle. It may be that the degree of the function as a group of EFs is lower than SA. Even so, we would be possible to assess that EFs were separated from background more clearly than the case of SB.

Comparing stimuli: We have seen the different qualities of each stimulus. We conclude that the magnitude of FLE locally decreases when each of events is not axiomatically identified as itself. We, the conductor of experiments, are not possible to assume that an events exists by itself, especially in the case of studies of FLE.

The lag between local points of each object relates the global contexture of each event.

Following experiments are supplemental for this purpose, confirming the interaction between local and global views. Experiment 2 leads 3.

4.3 Experiment 2.

4.3.1 Stimuli

Stimuli same to experiment 1 were presented without a gaze point.

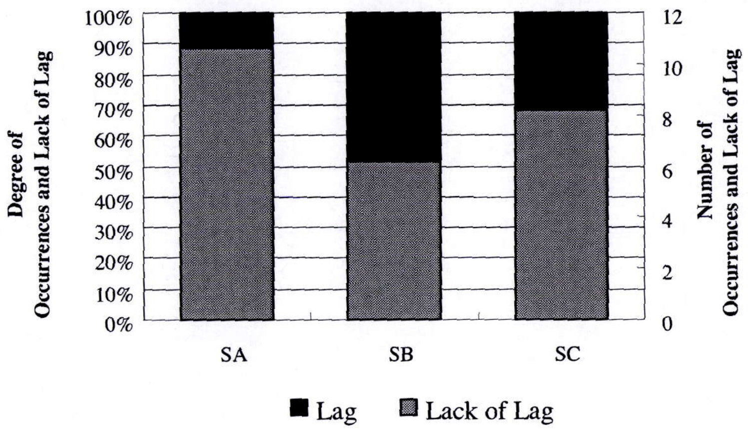
4.3.2 Procedure

The seventeen subjects in their 20's were required to follow the movement of arbitrary EFs during a trial. After confirming that the lag between the EF and the vertex of triangle presented briefly, they checked for the lag in each stimulus subsequently shown. SA, SB and SC are presented in this order in a similar way to experiment 1. Each stimulus was shown 4 times in a trial, and 3 trials were conducted for each subject.

4.3.3 Result

The number of that the lag was perceived in SA is more frequent than in both SB and SC significantly.

Table 2: Result of Experiment 2. Gray bars show the degree and number of lack of lag.



4.3.4 Discussion

It is naturally assumed that the lag between the vertexes and EFs would not occur in each stimulus because they don't move relatively with smooth pursuit. Indeed this assumption is right in SA. In the case of others, however, they reported the lag significantly. It can be interpreted that they reported the lag caused by the movement of the white lacked part of rotating EFs. It is confirmed that the FLE occurs in these situations, where the local relative motion is.

4.4 Experiment 3.

4.4.1 Stimuli

Stimuli same to experiment 1 were presented, but the diameter of EFs was decreased to 2° in the Small condition and increased to 5.5° in the Large condition. The flashing stimulus was presented in a same way to experiment 1 and 2.

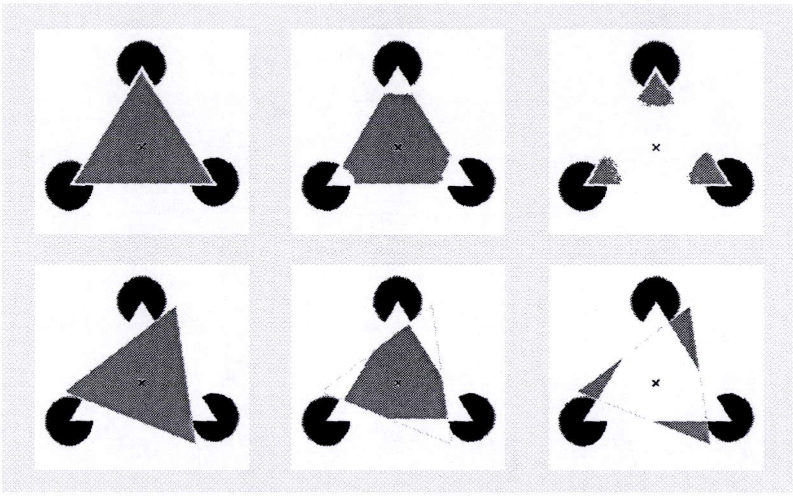


Fig. 2: Alternatives of experiment 3. The uppers and the lower respectively indicate perceiving the lack of a lag and perceiving a lag

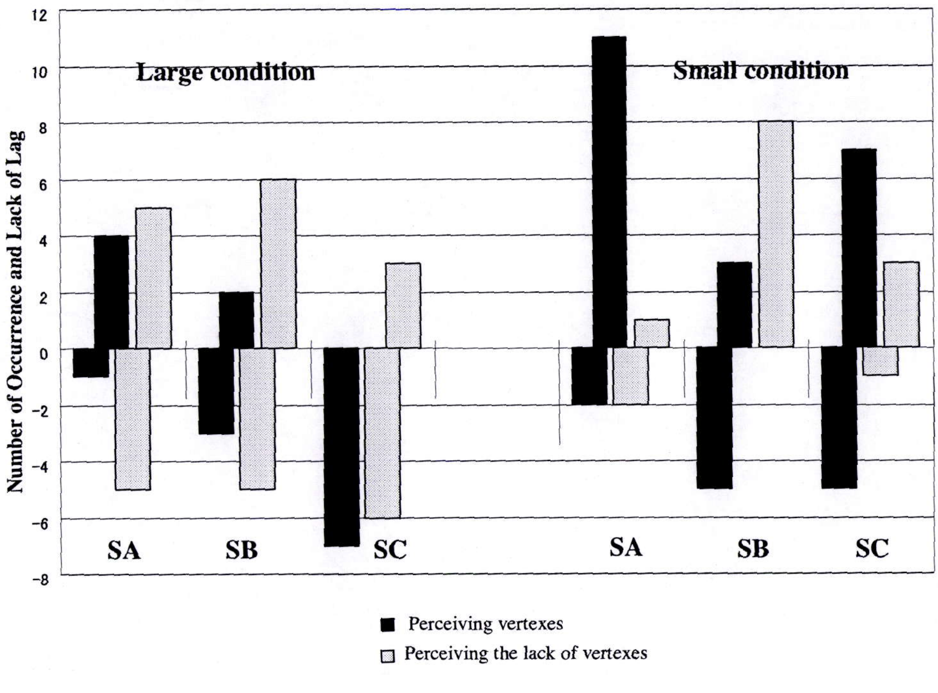
4.4.2 Procedure

The eight subjects in their 20's were required to confirm the perceived shape of flashing stimulus and to select an analogous shape from among 6 alternatives. The alternatives consist of combination of the lag between EF and the flashing stimulus and "obviously perceiving a triangle as flashing stimulus", "obviously perceiving only vertexes of flashing stimulus" or "obviously perceiving only an interior part of flashing stimulus".

4.4.3 Result

There was no answer of "perceiving only vertexes". The answer of "perceiving only an interior part" in the Large condition is significantly more frequent than one in the Small condition. Also, the answer of "not perceiving the lag" is significantly frequent in totality.

Table 3: Result of Experiment 3. Left and right groups of bars are the Large and the Small conditions respectively. Black and gray bars show the case of perceiving vertexs or not. Vertical scale means the number of lag, positive and negative numbers represent occurrence and lack of lag respectively.



4.4.4 Discussion

The result of experiment 3 is consistent with experiment 1 and 2. Actually the lag in experiment 1 and the one in 2 are incompatible. EFs globally circled in the counterclockwise direction, the perceived position of the moving object is out of alignment toward the direction.

In contrast, a local lag seen in experiment 2 is in backward direction under the assumption that local rotation of EFs causes the lag. Hence the flashing stimulus inducing different perception around vertexes may not be a formulaic triangle so that subjects perceived lacks of vertexes. It is presumed that this predisponency increased by enlarging EFs to cause the difference of the lack of vertexes in the Large condition. Also, the lack of FLE in the Large condition was reported. We clearly see that the complementarity of figure and ground was more emphasized because of the larger mutuality of two events of visible graphic form.

Hence we result that the characteristic differences of the global figure plainly caused other way of seeing local parts.

5 General Discussion

A phenomenon subjectively perceived as simultaneity is somewhat integration of various modality of moments. An assertion of measuring objects usually postulates an assumption that the objects are axiomatically separated from both of observers and their environment and that the aspects of the objects are quantified as a function of time. These assumptions, however, would be dissolved by reviewing the agents of the separation to make sure of the observers. Meanwhile the observation means ordering the objects, i.e. encoding events onto the time line by observers. In experiment 3, indeed, we saw that transforming the physical simultaneity to subjective one in the time that flows caused the transfiguration of perception. It would be assumed in amount that in our process of time perception we don't recognize objects in the flowing time but we realize the flowing time in the process of being segregating objects from the background.

6 Conclusion

We mounted the serious of experiments in that the flashing stimulus and moving objects which were drawn as Kanizsa-like graphic complementely supplied each function of figure and ground to the other, and as the result, the magnitude of FLE decreased in the case of emphasizing the complementarity. It is indicated that the process of the segregation of figure and ground influences the perception of flowing time. A study of FLE in which the function of figure and ground called into account had never been conducted. It prompts to ensure consistency with knowledge of previous works and to approach an alternative comprehensive model.

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