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The perceived position of a moving object is not the result of position integration

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Abstract

The flash-lag effect is a robust visual illusion in which a flash appears to spatially lag a continuously moving stimulus, even though both stimuli are actually precisely aligned. Some research has been done to test how visual information has been integrated over time. The position integration model suggests motion integration is a form of interpolation of past positions, and predicts that we cannot perceive the reversal point at its actual position on the trajectory of a moving object which reverses abruptly. In current research, we demonstrate that subjects could perceive the reversal point accurately while the psychometric function measured by a flash does not pass through the actual turning point. These results do not support the position integration model. We propose that the flash-lag effect is more likely to be a temporal illusion.

Keywords: Flash-lag effect; Motion perception; Postdiction model

1. Introduction

The world we live in is always changing. Our visual system must deal with information changing time from time. One important task of visual system is to perceive the position of moving objects. Current work on the flash-lag effect has helped us to understand how the visual system solves this problem. The flash-lag effect is a robust visual illusion in which a flash appears to spatially lag a continuously moving stimulus, even though both stimuli are actually precisely aligned (Nijhawan, 1994; Whitney, 2002).

It has been argued intensely whether the flash-lag effect is a temporal illusion or a spatial illusion (Eagleman & Sejnowski, 2002). The "latency difference" model takes the flash-lag effect as a temporal illusion, which asserts that moving objects are processed more quickly than flashed objects, so by the time the flashed object reaches the "perceptual end point", the moving object has already moved to a new position (Whitney & Cavanagh, 2000; Whitney & Murakami, 1998; Whitney, Murakami, & Cavanagh, 2000). Alternatively, some other researchers suggested that the flash-lag effect is a spatial illusion. Eagleman and Sejnowski proposed a "postdiction" model of the flash-lag effect, which assumes that the position of moving objects is estimated by integrating continuous positional signals within a time window; the flash resets all the integrals, so only those starting immediately after the flash will produce a position estimate, and the forward average is necessarily in advance of the position of the flash (Eagleman & Sejnowski, 2000a, 2000b, 2000d, 2002). Krekelberg and Lappe proposed a similar model, and according to their model, the perceived position of flashed and moving objects is based on the temporal integration of moving objects' position after the flash within a larger time window than that in Eagleman (Krekelberg & Lappe, 2000a, 2000b).

The spatial model has aroused much attention in recent years. These two spatial models both assume that the positional perception of moving objects is the result of integrating positional signals over time. This "position integration" hypothesis predicts that if a moving object abruptly reverses direction, the perceived moving object

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would never reach the actual reversal point, and the perceived trajectory has a rounding reversal point (Fig. 1). Eagleman demonstrated that the perceived trajectory of the moving object is smooth at the reversal point (Rao, Eagleman, & Sejnowski, 2001), and the rounding reversal point was also observed in other experiments (Whitney & Murakami, 1998; Whitney, Murakami, & Cavanagh, 2000). However, the basic latency difference model proposed by Whitney et al. cannot by itself explain the rounding reversal point (Rao et al., 2001), and predicted that there is a sharp reversal on the perceived trajectory. To solve this problem, Whitney, Murakami, and Cavanagh (2000) had to add a spatio-temporal averaging filter to their latency difference model, suggesting the perceived position is the result of a spatio-temporal integration, which gives their model an extra ''position integration'' hypothesis.

The ''position integration'' hypothesis could well explain the experimental phenomena, but the hypothesis itself sounds unintuitive in that it suggests the perceived position is not the actual position of the moving object but is the result of spatio-temporal integration of the position signals over time. So this hypothesis is proposed to need strict examination. While taking a look at the experiments wherein the rounding reversal points were observed, we note that the perceived trajectories were all measured by reporting the instantaneous position of moving objects relative to the flash. However, it has not been explored thoroughly whether the ''perceived trajectory'' measured by this ''spatial alignment'' task is really the trajectory we perceived. Note that the flash-lag effect occurs in the ''spatial alignment'' task, therefore, the psychometric curves obtained with this paradigm may 'merely' reflect the magnitude of the flash-lag effect over time, rather than the perceived trajectory of the moving object. It is probable that we can perceive the moving object at its actual position, but somehow fail to sample the reversal point during the ''spatial alignment'' task, resulting in an ''illusory'' round perceived trajectory. Thus the ''position integration'' hypothesis should be further examined, and new paradigms independent of the flash-lag effect should be used to measure the perceived trajectory.

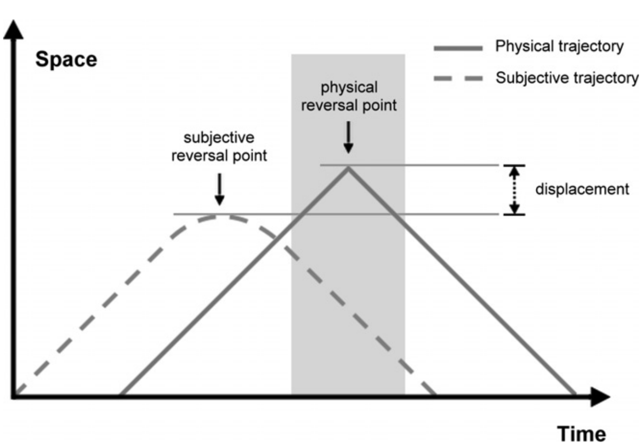

Fig. 1. The prediction of ''position integration'' model. The vertical axis is the position along the moving object's path, and the horizontal axis is time. The solid line shows the physical trajectory of moving object which has an abrupt reversal; the dashed line shows the subjective trajectory predicted by ''position integration'' model. The subjective reversal point integrates the position information around the physical reversal point (the shadow shows time window for integrating), so the subjective reversal point is displaced.

To test the ''position integration'' hypothesis, we used different paradigms to measure the perceptual reversal point. The first experiment was modeled on Whitney, Murakami, and Cavanagh (2000) in which participants were asked to report the position of a moving object relative to a flash, and the results replicated their study. In Experiment 2, to avoid the influence of the flash's temporal uncertainty (Murakami, 2001a, 2001b), a paradigm independent of the flash-lag effect was used to measure the perceived reversal points, in which participants judged whether two objects moving vis-à-vis touched each other before their reversal. To rule out the possibility that participants used extra clues to detect the touch event rather than used processed position information, we designed the third experiment, in which participants directly reported the perceptual reversal point relative to the flash. If the ''position integration'' hypothesis was correct, to anticipate, the perceptual moving object would never reach the actual reversal point in Experiment 1, the participants would perceive the two moving objects to have reversed before they touched each other while the moving objects reversed at the moment they just touched in Experiment 2, and participants would report the moving object was never aligned with the flash at the reversal point when it reached the position of the flash in Experiment 3. The results in our study, however, are exactly on the opposite, indicating the ''position integration'' hypothesis does not work properly.

2. Experiment 1

This experiment was designed to measure the perceptual trajectory of a moving object near the reversal point. We varied the position of the flash to find out the alignment position between the flash and moving object.

In this experiment, two square rings moved toward each other along a circular trajectory. The two rings reversed their directions just at the point they touched each other. A flash occurred at variable positions before or after the ''impact''. Participants reported the perceived position of rings relative to the flash. Psychometric functions were fit to the data to find the point of subjective equality (PSE), at which the flash appeared aligned with the ring. By connecting each PSE at different flash-present time, we obtained a perceived trajectory. According to the ''position integration'' hypothesis, it would have a rounded reversal point.

2.1. Method

2.1.1. Participants

Four naïve observers and one of the authors participated in this experiment. All participants had normal or corrected-to-normal vision.

2.1.2. Apparatus

Stimuli were presented on a 17 inch Atrmedia AS797T17 monitor (resolution was set to 800×600 pixels with a refresh rate of 100 Hz) controlled by Tsinghua Tongfang chaoyuee 3500D computer. Participants were seated in a darkened experimental room 57 cm from the monitor.

2.1.3. Stimuli

In each trial, a pair of green (CIE $x = 0.4035$, $y = 0.4823$, 111.40 cd/m^2) square rings were presented as moving objects. Each square ring occupied 1 deg in visual angle, with 0.32 deg width border. The flash used in this experiment was a red (CIE $x = 0.7301$, $y = 0.2364$, 29.73 cd/m^2) square which occupied 0.68 deg in visual angle. All the stimuli were presented on a gray (CIE $x = 0.2981$, $y = 0.3340$, 14.22 cd/m^2) background. The rings moved in two offset circular trajectories (radius 5.33 deg in visual angle). The speed of rings was 16.75 deg s^{-1}, and the flash was presented for 20 ms.

2.1.4. Procedure

Fig. 2 shows a schematic diagram of this study. In each trial, two square rings appeared at the right side of the screen and began to move in two offset circular trajectories immediately. The rings moved to the opposite side and reversed their direction at the point where they just touched each other. Then the two rings backtracked to the original position. A flash occurred on the trajectory of one of the two rings in a random order. The flash occurred at seven different positions: −1.12 to 1.12 deg relative to the ring (in visual angle, 0 deg means the flash just fills in the ring, negative means the flash is above the centre of the ring), the relative positions of the two square rings to the flash were calculated, respectively. The flash was presented −40, −20, 0 or 20 ms relative to the reversal of motion (negative means before the reversal) in four separate blocks.

Participants were asked to report whether they perceived the flash to be above or below the center of the ring (force choice). By varying the position of the flash, a psychometric function was calculated for a given time that yielded a setting of perceived alignment where the flash appeared aligned with the ring. There were 30 trials for each of the seven positions of the flash.

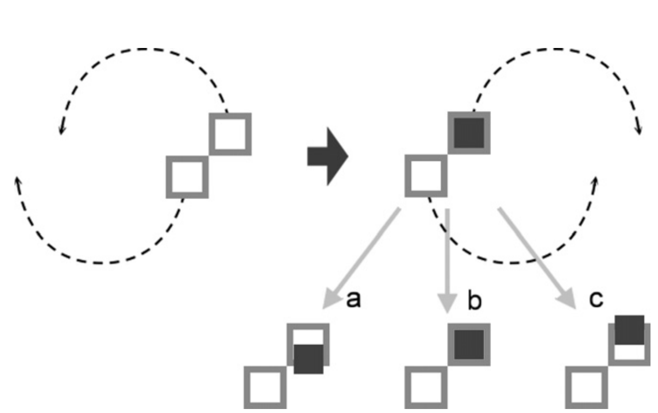

Fig. 2. The procedure of Experiment 1. Two rectangular rings moved form the right side of the screen to the opposite side in circular trajectory. They reversed at the moment they touch each other. Flash was present in one ring's trajectory at position (a) blow the center of moving object; (b) just fill in the ring; (c) above the center of moving object.

2.2. Results and discussion

Fig. 3 shows the perceived trajectory of two square rings. The perceived trajectories were rounded at the reversal point, and without intersection. The perceived displacement of reversal point was about 0.4 deg in visual angle (4.3 deg in angle of circumference), which was consistent with the demonstration by Whitney, Murakami, and Cavanagh (2000) wherein the displacement is about 0.5 deg in visual angle and also the demonstration by Eagleman and Sejnowski (2000b) wherein the displacement is about 5 deg in angle of circumference.

There are two possible explanations for this finding. The first explanation is that the result confirmed previous research (Whitney, Murakami, & Cavanagh, 2000) and Eagleman's prediction (Eagleman & Sejnowski, 2000b; Krekelberg & Lappe, 2000a; Rao et al., 2001), indicating that we cannot perceive the actual reversal point because of position integration. The alternative explanation is that we can perceive the actual position of the reversal point but it cannot be measured by using this paradigm. The major reason might be that the flash is a special visual stimulus

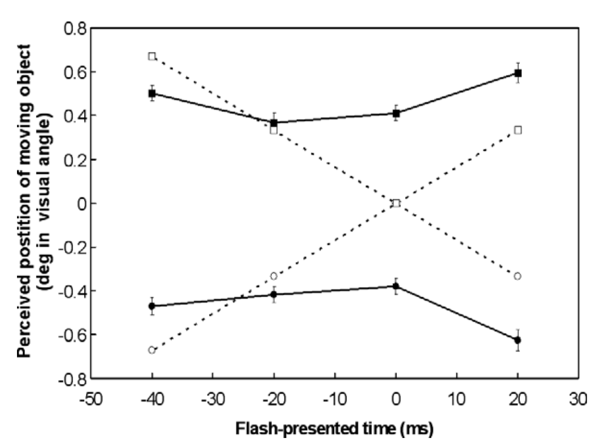

Fig. 3. The result of Experiment 1. The vertical axis is the perceived position of moving object measured by "spatial align" task (negative means below the reversal point), and the horizontal axis is time at which flash was presented (negative means before the reversal). The position was present by degree in angle of circumference. Solid lines show the average subjective trajectories of upper (filled squares) and lower (filled circles) rings. Error bars represent the average standard error. Dashed lines show the physical trajectories.

with high spatial and temporal uncertainty (Brenner, Beers, Rotman, & Smeets, 2006; Murakami, 2001a, 2001b), thus it is possible that the moving object at an incorrect time was sampled when participants were asked to report the relationship between the flash and moving object. To exclude the possible spatial and temporal uncertainty of the flash, we designed Experiment 2 in which participants reported where the moving object had been rather than where the moving object was at the moment the flash occurred.

3. Experiment 2

Experiment 1 demonstrates that the perceived trajectory measured by the spatial alignment task is rounded at the reversal point. In Experiments 2, we examined whether we could not perceive the veridical reversal point, or the information of reversal point could not be integrated to the perceived trajectory measured by this paradigm. Participants were asked to judge whether two moving objects had touched each other rather than report their instantaneous position at the moment the flash occurred. If the perceived trajectory was rounded at the reversal point, participants should not perceive the two moving objects to have touched each other when the moving objects reversed direction at the moment they just touched. Experiment 2 was designed to examine whether this kind of "impact" would be perceived, wherein Experiment 2a and its control Experiment 2b were included to provide a more stringent test.

3.1. Experiment 2a

3.1.1. Method

3.1.1.1. Participants. All the participants in Experiment 1 took part in Experiment 2a. All participants had normal or corrected-to-normal vision.

3.1.1.2. Apparatus. The apparatus in Experiment 2a was identical to that used in Experiment 1.

3.1.1.3. Stimuli. Stimulus parameters were the same as those in Experiment 1.

3.1.1.4. Procedure. Fig. 4 shows a schematic diagram of Experiment 2a. In each trial, two square rings were presented at the right side of screen, and began to move immediately. The rings met each other at the opposite side, at the same time, two flashes appeared at the center of each ring. Then two rings reversed directions and moved back to the original position. We varied the distance between two rings at the moment they met each other, to find at what distance the rings appeared just touch each other. Seven different distances were set: −0.160, −0.107, −0.053, 0, 0.053, 0.107, 0.160 deg in visual angle (negative means two rings overlap). Participants were asked to report whether two rings overlapped when they met. There were 30 trials for each of the seven distances. A psychometric function was calculated to find at what distance the two rings appeared just touch each other.

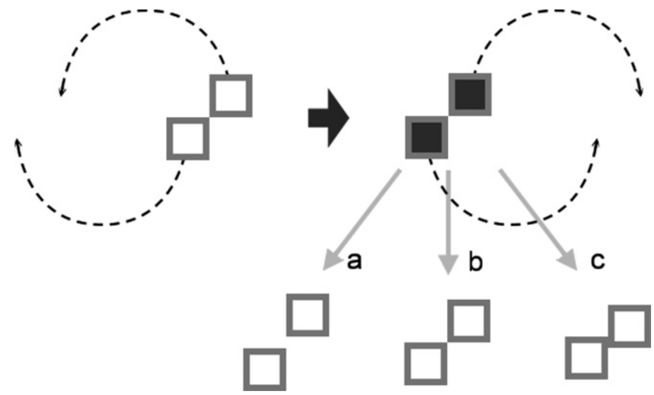

Fig. 4. The procedure of Experiment 2. Two rectangular rings moved form the right side of the screen to the opposite side in circular trajectory. They reversed at the moment they "impact". The spatial relationship between two rings at the impact moment is (a) separate from each other; (b) just touch each other or (c) overlap. Flash was presented on both rings.

3.1.2. Results and discussion

In Experiment 2a, the subjective "just touch" relative distances for five participants were: −0.029, 0.025, 0.069, 0.008, and 0.042 deg in visual angle. In average, at the distance of 0.013 deg ($t(4) = 0.673$, $p = 0.538$), two rings appeared just touch each other. The displacement of the reversal point here was much less than that in Experiment 1, indicating that participants made much more accurate performance. This result was contrary to the "position integration" hypothesis.

However, there still existed two possibilities that should be excluded before we could make a solid conclusion based on Experiment 2a. First, in Experiment 1, the flash timing was randomized, so that the positional judgment was an unpredictable event; whereas in Experiment 2a, the reversal timing and the midpoint of two rings' position at the reversal moment were both fixed, making the judgment essentially predictable. It was possible that the difference in predictability led to different results in Experiments 1 and 2a. Second, because no fixation point was settled in Experiment 2a, the eye movement could influence the perceived position of moving objects, thus making the positional judgment of the reversal point accurate. Considering these two possibilities, we conducted Experiment 2b to confirm the results of Experiment 2a.

3.2. Experiment 2b

3.2.1. Method

3.2.1.1. Participants. Five new naïve participants participated in Experiment 2b. All participants had normal or corrected-to-normal vision.

3.2.1.2. Apparatus. The apparatus in Experiment 2b was identical to that used in Experiment 1.

3.2.1.3. Stimuli. Stimulus parameters were the same as those in Experiment 1.

3.2.1.4. Procedure. Experiment 2b was identical to Experiment 2a except that the flashes in the display were removed because they were essentially unrelated to the task, and the rings reversed at a randomly determined time and position in each trial to make the reversal point unpredictable to exclude the possibility that the accurate perception of reversal point is the result of predictability. Specifically, besides the variable distances between two rings, the midpoint of two rings' position at the reversal moment varied randomly from −0.5 to 0.5 deg in vertical position by shifting the whole trajectories; and the rings started moving at variable positions in the circular trajectories, making the time from the appearance of rings to the reversal point vary from 900 to 1000 ms. The rings appeared at one side of the screen randomly, and moved to the other side, rather than always move from right to left. A fixation point was settled 1.5 deg beside the average reversal point to control eye movement. Participants were asked to fixate on the fixation point and report whether two rings overlapped when they met. There were 30 trials for each of the seven distances. A psychometric function was calculated to find at what distance the two rings appeared just touch each other.

3.2.2. Results and discussion

A result very similar to Experiment 2a was observed in Experiment 2b, wherein the subjective "just touch" relative distances for five participants were: 0.057, 0.034, −0.006, 0.020, and −0.015 deg in visual angle. In average, two rings appeared just touch each other at the distance of 0.018 deg ($t(4) = -1.384$, $p = 0.238$), suggesting that the predictability of the reversal and eye movement contributed little to the accurate performance in Experiment 2a.

These results indicate that participants could perceive the position of the reversal point, which is exactly contrary to the "position integration" hypothesis. Hence, it is probable that the visual system does obtain the positional information of the reversal point, only that the information has not been integrated to achieve the perception of the relationship between the flash and moving object.

Though the effect was so clear-cut, another possibility still existed that participants might detect the touch event by using extra clues such as the overlap retinal image, or some impact detector, but not by using the processed position signal of moving objects. In addition, because there was no need to process the positional signal of the flash, more attentional resource might be engaged in processing moving objects (Baldo & Klein, 1995; Chappell, Hine, Acworth, & Hardwick, 2006), which contributed to better performance in perception. We next tried to confirm that participants were really able to perceive the veridical reversal point rather than perceive by using other clues.

4. Experiment 3

To verify that no extra clues play a role in the perception of the reversal point, we conducted Experiment 3 wherein participants were asked to report directly the position of the reversal point relative to the flash (one white line). Note that the task was not reporting the position of the moving object at the moment the flash occurred but judging whether the reversal point of the trajectory was above or below the flash. This was a task to tell where the object had been, so the influence of flash's temporal uncertainty was avoided. Because the flashed line had a gap wider than the moving ring at the center, no spatial overlapping and no impact event would occur in Experiment 3, thus participants could not use this clue to make a decision. In this task, participants reported the spatial relationship between the reversal point and the flash, so the positional signal of the flash must be processed. Again, to prevent subjects from predicting the reversal, the reversal point varied randomly from trial to trial in this experiment.

4.1. Method

4.1.1. Participants

Four new naïve participants and one of the authors participated in this study. All participants had normal or corrected-to-normal vision.

4.1.2. Apparatus

The apparatus in Experiment 3 was identical to that used in Experiment 1.

4.1.3. Stimuli

Stimulus parameters were the same as those in Experiment 1, except that instead of a red square used in Experiment 1, a white line was used as the flash stimulus. The length of the line is 3 deg in visual angle. A gap of 1.33 deg width was set at the centre of the line. And a green square was used as the moving object instead of square rings used in Experiment 1. A 0.36 deg × 0.36 deg red (CIE $x = 0.6468$, $y = 0.3255$, 10.40 cd/m^2) square was presented 1.5 deg beside the average reversal point as the fixation point.

4.1.4. Procedure

Fig. 5 shows a schematic diagram of this experiment. In each trial, a square was presented at one side of the screen, and began to move in a circular trajectory immediately. The square reversed direction when it completed ~180 deg revolution (varied randomly from 165 to 195 deg, and the average reversal point was at 180 deg in the circle), so that the reversal was an unpredictable event. A flashed line occurred at the moment the square reversed. We varied the position of the flashed line to find where the reversal point was perceived. Seven different positions were set: −0.24, −0.16, −0.08, 0, 0.08, 0.16, 0.24 deg in visual angle relative to the reversal point (negative means the

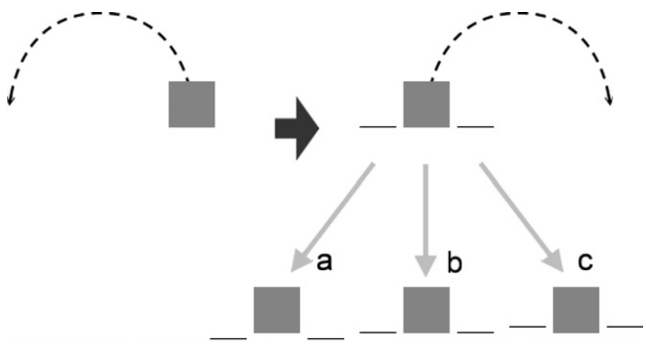

Fig. 5. The procedure of Experiment 3. The green square moved form the right side of the screen to the opposite side in circular trajectory then reversed abruptly. At the reversal moment a line with gap was flashed at position (a) below the bottom of square; (b) align with or (c) above the bottom of square.

flashed line was above the reversal point). Participants were asked to report whether the reversal point was above or below the flashed line. There were 30 trials for each of the seven positions. A psychometric function was calculated to find where the perceived reversal point was.

4.2. Results and discussion

The subjective reversal points of five participants were: 0.044, 0.009 −0.008, −0.008, and −0.001 deg in visual angle relative to the physical reversal point. In average, the subjective reversal point was 0.007 deg ($t(4) = 0.766$, $p = 0.487$) above the physical reversal point. No displacement was observed here.

Albeit we settled a fixation in the display, eye torsion would still be likely to influence the perceived reversal point, which could likewise contribute to the accurate performance. To confirm the results of Experiment 3, we conducted a control experiment almost identical to Experiment 3 except that the lines were continuously visible rather than flashed. The same result was observed in the control experiment, wherein six subjects perceived the reversal point accurately, and the averaged subjective reversal point was 0.009 deg ($t(5) = 0.730$, $p = 0.498$) above the physical reversal point. Hence, the accurate performance was not due to eye torsion.

Taken together, the possibility that the veridical perception of the reversal point is due to overlapping retinal image or the impact detector should be ruled out, and the visual system does obtain the positional information of the reversal point.

5. General discussion

In this study, we measured the perceptual displacement of the reversal point with different paradigms. In Experiment 1, we obtained participants' subjective trajectories by asking participants to report the position of moving objects relative to the flash. The subjective trajectories were rounded at the reversal point, indicating that the subjective reversal point did not reach the physical reversal point. In our second experiment, participants could detect the "impact" of two moving objects when they reversed direction at the moment they touched each other. In Experiment 3, we found no difference between the position of perceived reversal points and the actual ones. All the results suggest that the positional information of the reversal point was kept and available, but could not be integrated into the psychometric function measured by the spatial alignment task. It is contrary to the "position integration" hypothesis which predicts the perceived moving object would never reach the actual reversal point. So the major question is why the information that has been perceived cannot be integrated into the psychometric function. We propose that the question can be answered by the latency difference model with variable neural delay, which was first suggested by Murakami (2001b).

Some researchers assume that the neural latency is not fixed but changes as the tasks or the stimulus parameters vary (Murakami, 2001a, 2001b; Ogmen, Patel, Bedell, & Camuz, 2004), and temporal facilitation for moving objects is independent of changes in direction (Whitney, Cavanagh, & Murakami, 2000). In the same vein, we suggest that because of the noise involved in different levels of visual pathways, the neural latency should be variable. Essentially, the latency difference between the flash and moving objects should not be constant. It means that the flash which occurs at time t_0 is perceived as simultaneous as the moving object at time t_1 with a temporal delay ($t_1 - t_0$), and the temporal delay is a variable instead of being a constant.

Fig. 6 explains schematically how this variable temporal delay causes the result in Experiment 1. The vertical axis is the position along the target's path, and the horizontal axis is time. The solid line represents the moving target, with the vertical line indicating the moment of the flash and the horizontal line indicating the position of the flash. The temporal uncertainty is represented by a normal distribution with a mean delay (D) and a standard deviation (σ_t). In other words, the visual system chose a later moment of the moving object to compare with the flash, and this delay was fluctuant. When the moving object moved at a constant speed, the visual system would choose a moving object at $t_0 + D$ to compare with the flash at t_0. So the flash at position s_0 should be repositioned to s_1 (mean of the corresponding spatial distribution) to make the flash appear aligned with the moving object, and then a flash-lag effect ($s_1 - s_0$) can be observed. When the object moves smoothly in one direction, the psychometric function measured by the spatial alignment task (represented by dashed line) should parallel the physical trajectory. While the moving object has reversal on its trajectory, and while it is far away from the reversal point, the psychometric function parallels the physical one, but when it is near the reversal point, the distribution of temporal uncertainty bestrides the reversal point, so the corresponding spatial distribution is distorted and the mean of the spatial distribution (s_2) is less than the

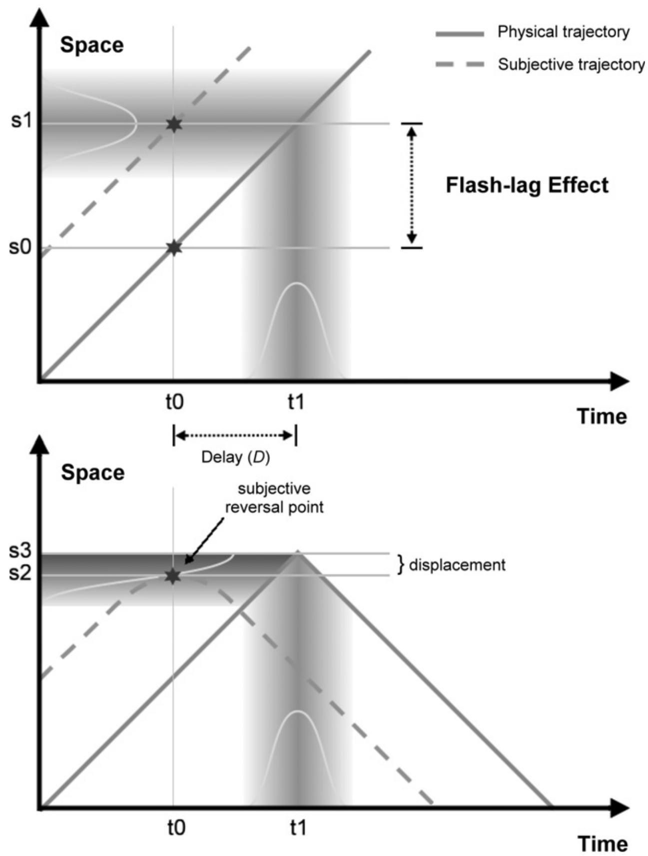

Fig. 6. The temporal uncertainty of flash can cause the subjective trajectory measured by "spatial align" task rounded at reversal point. The visual system select moving object at t_1 to compare with flash at t_0, and the time delay is fluctuant. The temporal uncertainty is present by a normal distribution, and leads to a velocity-dependent spatial uncertainty. The upper panel shows flash-lag effect. The lower one shows why temporal uncertainty of flash lead to rounded subjective reversal point.

physical reversal point (s_3). After averaging all the trials in every condition, the psychometric function appeared rounded at the reversal point just like that in Experiment 1. Whereas the task in Experiment 1 requested reporting the position of the moving object at a special moment defined by the flash, tasks in Experiments 2 and 3 required participants to report only where the moving object had been and no temporal comparison was required. Thus, the variation in temporal delay between the flash and moving object did not affect the positional judgment and the observers could report the reversal point accurately.

In sum, the smooth psychometric function observed in Experiment 1 is not because the perceived trajectory is really smooth but because the specific "spatial alignment" task is used. The visual system can obtain the actual position information, but cannot sample the position correctly every time when comparing with the flash which is of high temporal uncertainty. So we suggest that the latency difference model can explain the rounding reversal point by itself without the extra assumption of a spatio-temporal averaging filter proposed by Whitney et al.

In addition to the explanation for the rounded reversal point on psychometric function, the variable latency difference can also explain other experimental phenomena which have been taken as evidence supporting the "spatial integration" model. Eagleman and Sejnowski (2000c) discovered that visual events 80 ms after the flash would affect the perception of relative position but the flash-lag effect was only 26 ms, so he concluded the "temporal delay" hypothesis was not correct and assumed the positional information was integrated over a ~80 ms time window. However, considering the variable of temporal delay, it is not necessary to assume such a postdictive time window, since sometimes the visual system samples positional information 80 ms after the flash, but oftentimes earlier information is chosen, so in average, the flash-lag effect is only 26 ms. Murakami (2001b) had implemented a simulation program based on the variable latency difference modal to explain Eagleman's results, which proved to nicely mimic the human data. The simulation results indicated that the temporal delay in Eagleman's experiment obeys Gaussian with $(\mu, \sigma) = (20.7,\ 38.2\ \text{ms})$. We also estimated the value of the mean and standard deviation of the temporal delay in Experiment 1, with $(\mu, \sigma) = (16.3,\ 32.5\ \text{ms})$. The magnitude in our study was very close to that in Eagleman's experiment, and as mentioned above, we used similar research paradigm with Eagleman, thus confirming the idea that the postdictive time window actually reflects the variable temporal delay.

6. Conclusion

Our study suggests that the positional perception of moving objects is not the result of position integration. The rounded reversal point of subjective trajectories can be explained by the variable latency difference between the flash and moving object. We propose that the flash-lag effect is more likely to be a temporal illusion.

Acknowledgments

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