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A relationship between space and time in the early stage of visual processing

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In this study, we report on a new illusion that we call a perceptual offset phenomenon. This is a phenomenon where illusory phase offset is perceived between two motion stimuli defined by different attributes although they are physically in phase and moving at the same speed. The subsequent examination showed that the delay in frame onset of motion stimuli did cancel the perceptual offset. These results not only show that the temporal lags produced inside the visual processing were converted to the spatial lags, but show that both spatial and temporal lags did cancel this apparent spatial lag. This uncovered the interchangeability of space and time in our visual processing.

Keywords: Spatio-temporal vision, motion, second-order motion, Perceptual offset

Purpose

In this study, we report a new illusion where positional errors were perceived sustainedly, which we call a perceptual offset phenomenon. In this phenomenon, illusory phase offset is perceived between two motion stimuli defined by different attributes although they are physically in phase and moving at the same speed.

The most possible origin of this phenomenon is a difference in processing time between two motion stimuli. We used luminance and motion-defined motion (LDM/MDM, as for MDM see Zanker, 1993) as the two motion attributes and investigated this possibility. For this purpose, we measured the illusory spatial offset with either physical spatial or temporal offsets and compared those data.

Method

The stimulus consisted of two vertical square wave patterns defined by two different attributes. Each of them consisted of 1024 dots that were scattered randomly within a stimulus field of 120 (V) x 300 (H) pixel. This corresponds to 4 x 10 arc deg. The background was uniform black (0 cd/m^2) field. The square wave pattern was generated by modulating these dots' motion directions (up/down, Motion-defined) or their luminance (luminance-defined). The modulation wave's spatial frequency was 0.2 c/d for both MDM and LDM. For LDM stimuli, dots were static and the luminance of each dot was modulated in two steps. That is, the luminance-defined square wave pattern consisted of two areas with different luminance levels. One was the light-area where lighter dots were scattered in a black background. The other was the dark-area where darker dots were scattered in a black background. The contrast between light and dark dots (dot contrast) was fixed at 0.75. For MDM stimuli, dots were shifted up or down by 8 min every 20 ms except for the perceived speed experiment. This corresponds to 400 arc min/sec.

In the spatial measurement experiment, the physical (spatial) phase offset between LDM and MDM varied in ten steps. In the temporal measurement experiment, we introduced a physical delay between frame onsets of LDM and MDM. We used six different levels of delay between 0 and 100 ms. The SOA of pattern motion was fixed at 120 ms. The pattern was shifted once every 120 ms by 15, 30, 45 deg phase angle. This corresponds to the 1.74, 3.48, 5.22 arc deg/min.

The task for the subjects was to discriminate the offset direction of LDM with a 2-AFC method. The experiment was conducted in sessions each using a different fixed pattern motion speed. Each session had 200 trials, and within a session, ten offset conditions were presented 20 times in randomized order. Subjects conducted 2 sessions for every global motion speed condition.

Results and discussion

We estimated the null point between the physical spatial offset or delay and the perceptual offset with a probit estimation method.

The estimated values were negative for all of the pattern speed condition. This indicates that LDM is perceived to be out of phase in the direction of pattern motion when MDM and LDM are physically aligned. Furthermore, we converted estimated temporal offset amount to the spatial offset. Those values were consistent to estimated amounts of perceptual offset by actual spatial measurement.

This demonstrates an interchangeability of time and space. Time lags are translated into the spatial domain, and perceived as spatial offsets.

A method involving a cancellation of spatial offsets from temporal offsets, similar to what we used for the temporal cancellation experiment, has been used by past studies that reported spatial offsets caused by temporal phase lags (Morgan, 1976, 1980; Burr 1979). However, the stimuli used in those studies were introduced by manipulation of stimulus parameters or by presentation methods (e.g. density filter used in Purfrich effect). In the present study, we showed that the interchangeability in space and time also exists in the temporal lag produced by the difference in processing time. That is, the present study broadens the scope of the interchangeability between space and time including natural and realistic situations.

Conclusion

An illusory phase offset is perceived between two motion stimuli defined by different attributes although they are physically in phase and moving at the same speed. The origin of this phenomenon is processing time differences between two motion stimuli. This time difference is converted to the illusory spatial offset on the basis of interchangeability of space and time in the early visual processing.

Footnote

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References

Burr, D.C. (1979). Acuity for apparent vernier offset. *Vision Research*, **19**, 835-838

Morgan, M. J. (1976). Pulfrich effect and the filling in of apparent motion. *Perception*, **5**. 187-195.

Morgan, M. J. (1980). Analogue models of motion perception. *Philosophical Transaction of the Royal Society of London.* B., **290**. 117-135.

Zanker, J. M. (1993). Theta motion: A paradoxical stimulus to explore higher order motion extraction. *Vision Research*, **33**, 533-569.