Surround modulation of visual motion integration and segregation

Hiromasa Takemura*,*2 and Ikuya Murakami*

The University of Tokyo* and JSPS Research Fellow*2

The Japanese Psychonomic Society

The visual system integrates or segregates two motion components in the same visual field depending on direction difference. We examined how the surrounding motion modulates such integration or segregation. In the experiment, participants were presented with motion components in two nearby directions (e.g., ±45 deg from vertical). We found that participants reported two segregated motions more frequently when the direction of the surrounding motion was equivalent to the averaged direction of central motions. In contrast, participants reported one integrated motion when the direction of the surrounding motion was opposite that of the center. The present results suggest that motion integration and segregation was determined based on a representation of motion direction modulated by the surrounding motion.

Key words: visual motion, motion integration, illusion

The visual system uses two motion segmentation mechanisms to extract object motion. One mechanism is center-surround interaction. It is well known that a central stationary stimulus appears to move in the opposite direction of surrounding motion (induced motion, Duncker, 1929). Another mechanism is motion segregation and integration in the same visual field. When two motion components are presented in the same visual field, we will perceive two transparent motions when the directional difference is sufficiently large. If it is not large enough, we will perceive one integrated, coherent motion (van Doorn & Koenderink, 1982). The visual system segregates or integrates motion components depending on directional differences.

In the present study, we examined the functional relationship between these two processes.

Experiment 1

Methods

The participants were eight adults (aged 19–25) with normal or corrected-to-normal vision. The stimuli consisted of a central white random-dot surrounded by a red random-dot display. The central stimulus consisted of two populations of random dots; half of the dots moved leftward while the remaining half moved rightward. Under the “Moving Surround” condition, a vertically moving random-dot was presented within a surrounding annulus. Under the “Baseline” condition, half of the dots moved upward while the remaining half moved downward. Each dot moved at 1.78 deg/s in both the central and surround stimuli. The fixation point was located 4.5 deg above the center. Both central and surrounding stimuli were presented for 507 ms. Participants were then asked to judge how many motion directions were simultaneously perceived in the center (one coherent or, two transparent motions). After the judgment, they were asked to report the per-

Figure 1. Results of Experiment 1. Vertical axis indicates the average of perceived direction of central stimulus where “0” indicates purely horizontal. Error bars represent ±1 SEM.

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ceived direction of the central stimulus through direction matching.

Results

Participants reported "two transparent motions" in most trials under both conditions. In Figure 1, we plot the direction matching results in trials where participants reported two transparent motions. Under the "Baseline" condition, participants frequently reported two horizontal directions, which was equivalent to the physical directions. Under the "Moving Surround" condition, participants reported two oblique directions, which was biased toward the direction opposite the surrounding motion. These results indicate that surrounding motion modulates the perceived direction of two central motions simultaneously.

Experiment 2

Methods

The stimulus and experimental protocol were the same as for Experiment 1. We presented motion components in two nearby directions (±15, ±19, ±27, ±45 deg from vertical) in the center. Central stimulus speeds were different across directional difference conditions: 6.71, 5.15, 3.64, and 2.3 deg/s, respectively. Three surround stimulus conditions were tested. Under the "Baseline" condition, half of the dots moved upward while the other half moved downward. Under the "Same Surround" condition, all surrounding dots moved in the average direction of central motions. Under the "Opposite Surround" condition, all surrounding dots moved opposite the central direction. The surrounding stimulus speed was 1.78 deg/s under all conditions.

Results

Figure 2 displays data on the judgment of motion numbers in Experiment 2. Under the "Same Surround" condition, participants reported two transparent motions more frequently than under the "Baseline" condition when central motion directions were ±19, ±27, and ±45 deg (p < .001, two-tailed Z test). Under the "Same Surround" condition, perceived direction was strongly biased toward the direction opposite the surrounding motion. The reported directions (median: ±80.5 deg from the vertical) deviated significantly from the physical direction (p < .001, two-tailed Z test). In contrast, under the "Opposite Surround" condition, participants reported one coherent motion more frequently than "Baseline" under the ±45 deg condition (p < .001, two-tailed Z test). In trials where participants reported one coherent motion, perceived direction was almost always in a purely vertical direction.

Discussion

In the present study we found that motion integration and segregation were strongly modulated by surrounding motion. These results suggest that motion integration and segregation were determined based on the representation of motion directions modulated by surrounding motion.

References
