

Spatiotemporal attribution of visual size

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Abstract

This study examined spatiotemporal feature attribution for visual size of objects. A small or large prime disk, a test disk of variable sizes, and a probe disk of a fixed size were sequentially presented at the same position for durations of 16.7 ms with inter-stimulus intervals of 117 ms. Observers compared visual size of the test with the probe disk. The size of test disk was underestimated and overestimated when the test followed small and large disks, respectively (Experiment 1). The modulations of visual size occurred even when each of disks was sequentially presented so as to invoke apparent motion (Experiment 2). Furthermore, when two streams of apparent motion consisting of the three types of disks were diagonally overlapped, modulation of visual size occurred in accordance with the size of attended prime disk (Experiment 3). Retinotopic and non-retinotopic feature attribution mediated by attentional tracking were manifested for visual size.

Integrating visual features is a fundamental task for the visual system. In the brain, visual features such as color, motion, orientation, and so forth are separately analyzed, and later they are integrated so as to form an object representation with multiple features. On the other hand, it has been found that feature integration is a hard task for the visual system. For example, an inappropriate binding of visual features is reported as illusory conjunction (Treisman & Schmidt, 1982), and crowding (Pelli, Palomares, & Majaj, 2004; Pöder, 2006).

A recent study has shed light on spatiotemporal integration of visual features. Using a Ternus-Pikler display, Ögmen, Otto and Herzog (2006) showed that a vernier offset of an object in the first frame was attributed to another object in the second frame. In the Ternus-Pikler display, three elements with horizontal alignment in the first frame move towards right or left by the distance of an element in the second frame. Either of two motion percepts is obtained, depending the inter-stimulus interval (ISI): Only outside elements are perceived as having moved when the ISI was short (i.e. 0 ms), while both inner and outer elements were perceived as having been translated when the ISI was long (i.e. 100 ms).

Interestingly, Ögmen et al. (2006) showed that the pattern of feature attribution was dependent on the ISI between frames. Specifically, when the ISI was 0 ms, the vernier offset in the inner element in the first frame was attributed to the element in the second frame at retinotopically the same position. However, when the ISI was 100 ms, the vernier offset was attributed to an object that was presented at a different spatial position from the object with the vernier offset in the first frame, but which perceptually corresponded in apparent motion. Their results indicate that visual features can be non-retinotopically remapped in accordance with motion correspondence. That is, visual features may be attributed across space and time.

The present study examined whether feature attribution across space and time occurs for visual size. The visual size is a cue to approaching/receding movements in depth (Beverley & Regan, 1979). However, regardless of the importance of visual size in a dynamic context, it remained to be clarified how visual size is perceived and integrated into a coherent object. Although most of the previous studies treated only vernier offset to show feature

attribution phenomena, it was unclear whether merging visual features across space and time occurred for visual features other than vernier offset. Clarifying the integration of visual size in a dynamic situation should be essential for the understanding as to how visual features in moving objects are integrated across space and time since the dynamic change of visual size occurs usually and frequently. Therefore, it should be tested whether feature attribution can be extended to a visual feature other than a vernier offset. If the visual buffers are available for the visual size, it is expected that the sizes of preceding objects should alter the perceived sizes of trailing objects. In Experiment 1, I report that retinotopic feature attribution occurred for objects' sizes. In Experiment 2, I check that feature attribution was non-retinotopically caused. In Experiment 3, I show that feature attribution was affected by attentional modulation.

Method

Observers

Five, four and three observers including the author (TK) participated in Experiment 1, 2, and 3, respectively. Apart from the author, the observers were unaware of the purpose of experiments. All had normal or corrected-to-normal eyesight.

Apparatus

Stimuli were presented on a 19-inch CRT monitor (RDF193H, Mitsubishi, Japan) with a resolution of 1024 x 768 pixels and a refresh rate of 60 Hz. A Macintosh computer (MacBook, Apple) connected to the CRT monitor controlled stimulus presentation as well as data collection. A chin and head rest (TKK930A, Takei, Japan) was used to stabilize observers' visual fields.

Stimuli

Stimuli were generated and presented using MATLAB and the Psychophysics Toolbox extensions (Brainard, 1997; Pelli, 1997). In Experiment 1, a stimulus movie had a fixation cross [two orthogonal black (1 cd/m²) lines with 0.1 deg width x 1 deg length], prime, test and probe green disks [CIE xyY(0.289, 0.587, 21.8)], and a gray background (5.2 cd/m²). The fixation cross was presented for 500 ms, and followed by a sequence of prime, test and probe disks, with each presentation lasting for a duration of 16.7 ms, with an inter-stimulus interval of 117 ms. Fig. 1 shows a schematic diagram of the stimulus presentation. The fixation cross was presented at the center of the display, and the centers of prime, test and probe disks were positioned 5.7 deg above or below the center of the fixation cross. The radius of the prime disk was 0.94 or 2.84 deg. The radius of the test disk was randomly selected from seven alternatives (1.18, 1.42, 1.66, 1.9, 2.14, 2.38 or 2.62 deg). The radius of the probe was always 1.9 deg. Thus, the differences between test and probe disks were -0.72, -0.48, -0.24, 0, 0.24, 0.48 and 0.72 deg. In Experiment 2, prime, test and probe disks were presented in a translational apparent motion. Initially, a prime was presented 2.83 deg to the left or right of and 5.6 deg above or below the fixation cross. Second, the test was presented 5.6 deg above or below the fixation cross. Finally, the probe was presented 2.83 deg to the right or left of and 5.6 deg above or below the fixation cross.

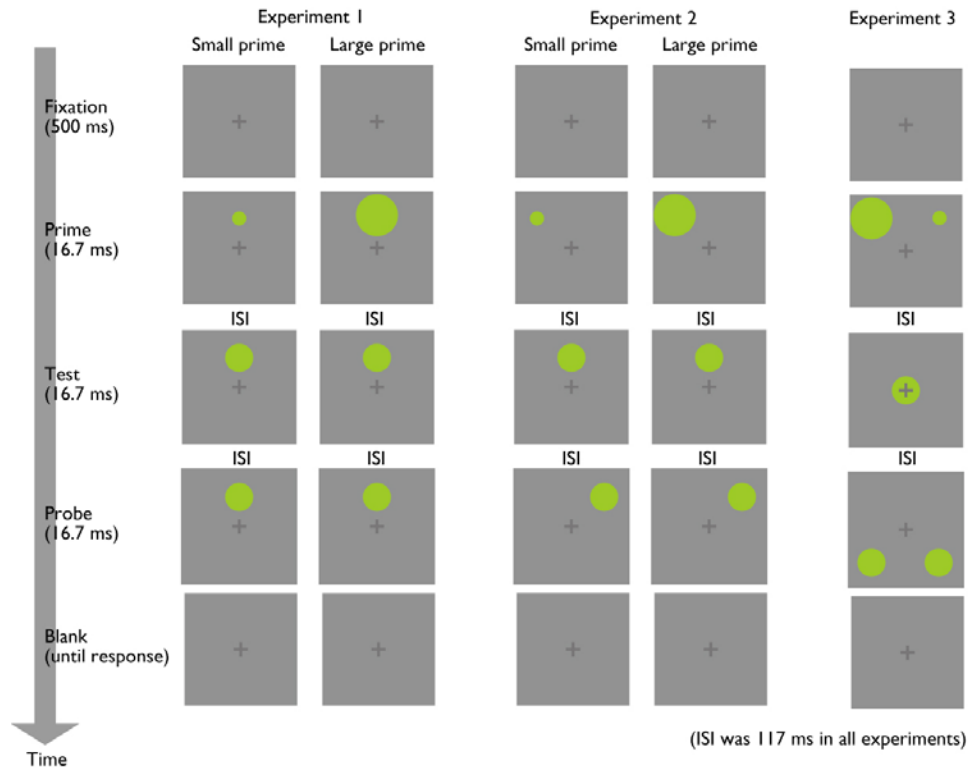


Fig.1 Schematic diagrams of the stimulus presentation in each experiment.

Thus, the direction of apparent motion (leftward or rightward) as well as vertical position (above or below of the fixation cross) was randomly determined from trial to trial. In Experiment 3, initially, two prime disks with large or small radii were presented 2.8 deg left and right of and 5.6 deg above the fixation cross. When the size of the prime disk at one side was 0.95 deg, the size of the disk at the other side was 2.84 deg. Second, a test disk with a radius of 1.43, 1.9 or 2.37 deg was presented behind the fixation cross. Third, probe disks with radii of 1.9 deg were presented 2.8 deg left and right of and 5.6 deg below the fixation cross. Thus, a stimulus movie had two streams of apparent motion, in right-diagonal and left-diagonal directions.

Procedure

Observers initiated each trial by pressing the spacebar on a keyboard externally connected to a MacBook. After the keypress, a stimulus movie was presented. During the presentation of the movie, observers maintained their gaze on the fixation cross. After the observation, they reported whether the probe disk was smaller or larger than the test disk using assigned keys. They were urged to respond accurately. In Experiments 1 and 2, each observer received 280 trials consisting of 2 primer radii x 7 test radii and 20 replications. In Experiment 3, They received 120 trials. 3 radii of test disks x 2 attended apparent motion paths (left and right diagonal) x 20 replications. The order of trials was randomized across observers.

Results and Discussion

Experiment 1

A psychometric function was fitted to the data for each observer to estimate the point of subjective equality (PSE) for visual size between test and probe disks. The data for the author was not different from that for the other observers; thus, all PSEs in each prime condition were averaged across observers. Fig. 2a and Fig. 2b shows the averaged proportions of trials in which the probe was judged to be larger than the test and the individual and averaged PSEs, respectively. A two-tailed t-test showed that there was a significant difference in PSE between the test and prime disks ($t_4 = 5.97, p < .005$).

The results showed that a leading object's size strongly modulated the perception of a trailing object's size. This indicates that a retinotopic feature attribution occurs for visual size.

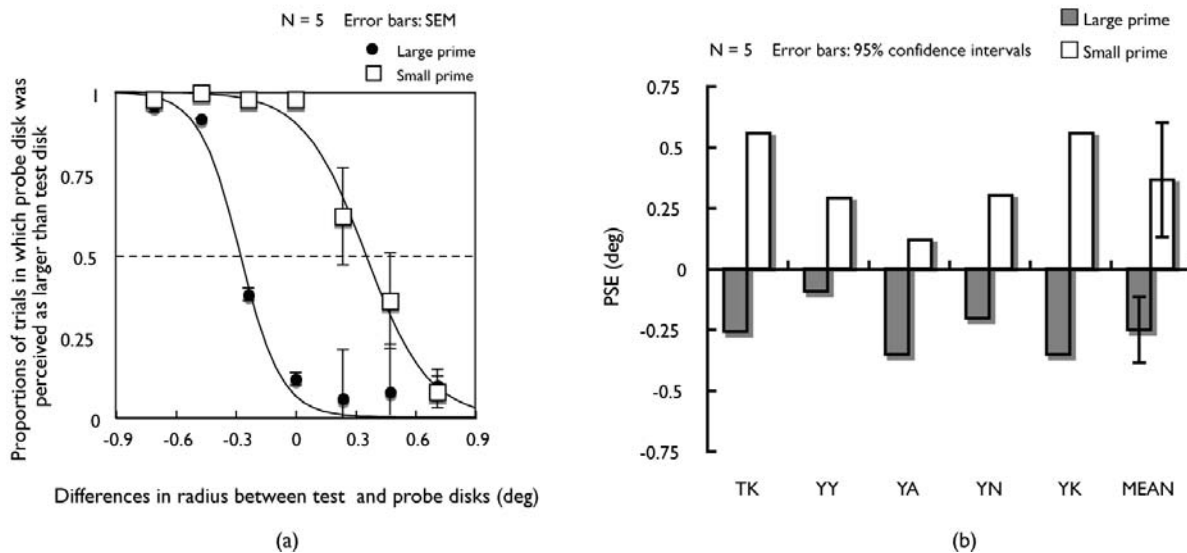


Fig. 2. The results of Experiment 1. (a) Proportions of trials in which the probe was perceived to be larger than the test disk. Error bars denote standard errors of the means. (b) Individual and averaged PSEs for the test disk. Error bars denote 95% confidence intervals.

Experiment 2

As in Experiment 1, we estimated the PSEs for visual size between the test and probe disks. The data for the author was not different from that for other observers; thus, all of the PSEs in each prime condition were averaged across observers. Fig. 3a and Fig. 3b show the averaged proportions of trials in which the probe was judged as larger than the test and the individual and averaged PSEs, respectively. A two-tailed t-test showed that there was a significant difference in PSE between the large and small prime disks [$t(3) = 3.28, p < .05$].

The results showed a robust non-retinotopic feature attribution: the size of a leading disk altered the perceived size of a trailing disk, even when they were presented at different places. Thus, the results indicate that non-retinotopic feature attribution is not confined to the vernier offset, but is extendable to visual size.

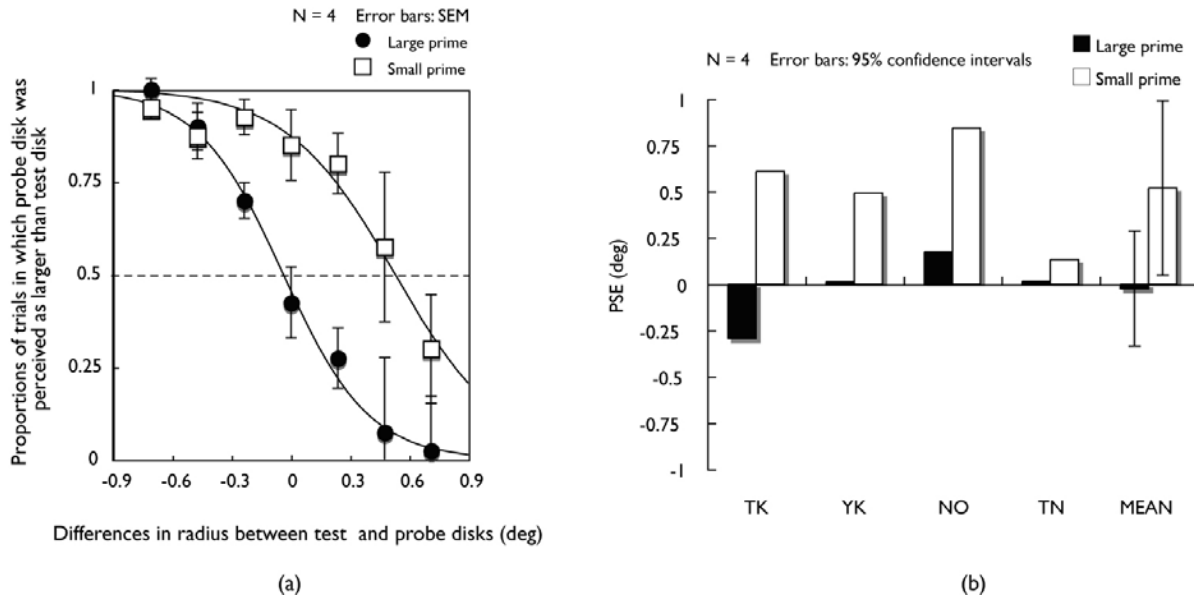


Fig. 3 The results of Experiment 2. (a) Proportions of trials in which the probe was perceived to be larger than the test disks. Error bars denote standard errors of the means. (b) Individual and averaged PSEs for the test disk. Error bars denote 95% confidence intervals.

Experiment 3

Fig. 4 shows the averaged proportions of trials in which the probe was perceived to be larger than the test. Small graphs on the right side of Fig. 4 show individual data. The individual data had a similar tendency to each other. Thus, using the group data, we conducted a two-way ANOVA with the radii of the prime and the radii of the test as factors. The main effect of the radii of the prime was marginally significant, $F(1, 2) = 8.88, p < .1$. The main effect of the radii of test was significant, $F(2, 4) = 11.307, p < .03$. Interactions between these two factors were also significant $F(2, 4) = 7.969, p < .05$. The simple main effect of the prime was significant when the radius of the test was 1.9 or 2.37 deg, $F_s(1, 6) = 9.811$ and 14.777 , respectively, $p < .03$.

General Discussion

In three experiments, I showed that a fundamental visual feature, size, was attributed to spatiotemporally corresponding objects, and suggested that feature attribution may be a phenomenon which is extendable to visual feature other than vernier offset.

Several studies have indicated that visual features are integrated along the path of movements. Recently, Nishida, Watanabe, Kuriki, & Tokimoto (2007) showed that color information, for example, red and green, is integrated into a unitary color (yellowish), along a motion trajectory. Moreover, Cavanagh & Holcombe (2005) demonstrated that an attention-based motion could resolve spatial orientation-color binding. As described in the Introduction, a vernier

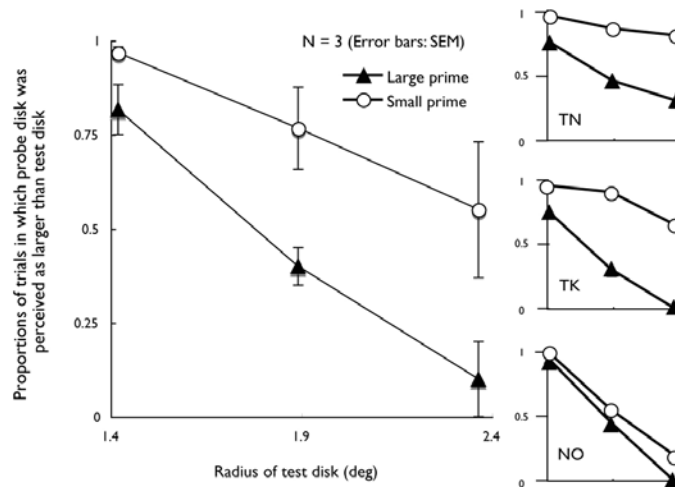


Fig. 4 The results of Experiment 3. Error bars denote standard errors of the means. Small graphs show individual data.

offset is also integrated across objects in an ambiguous apparent motion (Ögmen et al., 2006). In this way, feature integration along a motion trajectory is observed in various types of features, and this fact leads us to suggest that integrating visual features across space and time may function to disambiguate and extract objects from complex and noisy dynamic signals.

Acknowledgements

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