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Brief article

Chinese and Americans see opposite apparent motions in a Chinese character

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Abstract

The perceived direction of apparent motion can be influenced by both ''top-down'' factors, such as expectation, and by ''bottom-up'' or stimulus-driven factors, such as grouping (Tse, P., Cavanagh, P. & Nakayama, K. (1998). The role of parsing in high-level motion processing. In T. Watanabe, *High-level motion processing – computational, neurobiological and psychophysical perspectives*. Cambridge, MA: MIT Press). Here we report the results of a single experiment that pitted top-down cues against bottom-up cues in an apparent motion sequence over the successive strokes of a Chinese character. Although each stroke was in fact presented all at once, subjects raised in China tended to see apparent motion over a single stroke in the direction it would have taken when drawn by hand, even though bottom-up cues drive a percept of apparent motion in the opposite direction for observers unfamiliar with the Chinese language. There is therefore a learned component to motion perception arising from top-down expectations capable of overriding bottom-up cues to motion. © 2000 Published by Elsevier Science B.V. All rights reserved.

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1. Introduction

When two separated spots of light are flashed in rapid succession, the two flashes appear to comprise a single spot that rapidly shifts its position back and forth. This

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has been termed ''apparent motion'' because motion is perceived in the absence of any real motion in the world (e.g. Kolers, 1972; Ramachandran & Anstis, 1986; von Helmholtz, 1867; Wertheimer, 1912, 1923; Wright & Dawson, 1994). Apparent motion can be influenced by both ''top-down'' factors, such as attention, expectation, or knowledge (e.g. Ramachandran & Anstis, 1986; Ramachandran, Armel, Foster & Stoddard, 1998) and by ''bottom-up'' or stimulus-driven factors, such as spot proximity (e.g. Adelson & Bergen, 1985; Ullman, 1979) or object form (Tse & Cavanagh, 1995; Tse, Nakayama & Cavanagh, 1998). Here we report the results of an experiment that pitted top-down versus bottom-up cues in an apparent motion stimulus. We find that when there is an expectation for motion in a particular direction, that motion is perceived, even when bottom-up cues would predict a percept of motion in the opposite direction.

An instance of top-down influences on perceived apparent motion can be found in the well-known ''quartets'' sequence of apparent motion stimuli. When one fixates the center of an imaginary square and two small spots of light are flashed simultaneously at its diagonally opposite vertices for a brief duration, and then flashed again for the same duration at the other two vertices, apparent motion in either the horizontal or vertical directions is perceived. For naive subjects, horizontal and vertical motions are typically reported with equal probability in a two frame quartets sequence. However, it has been noted that if one expects or ''wills'' to see motion in a particular direction in this bistable apparent motion sequence, then motion in the expected direction is more likely to be perceived (Ramachandran & Anstis, 1986).

Conversely, an example of apparent motion that is driven by stimulus form relationships in a ''bottom-up'' manner is shown in Fig. 1. Here frame 2 consists of a single complex shape. However, when frame 2 is shown immediately after frame 1 such that there is complete overlap between the shapes of the two frames as indicated in frame 3, the three apparent motions depicted with arrows are perceived. Motion is typically perceived to proceed away from the frame 1 shape with which the corresponding portion of the frame 2 figure has been grouped.

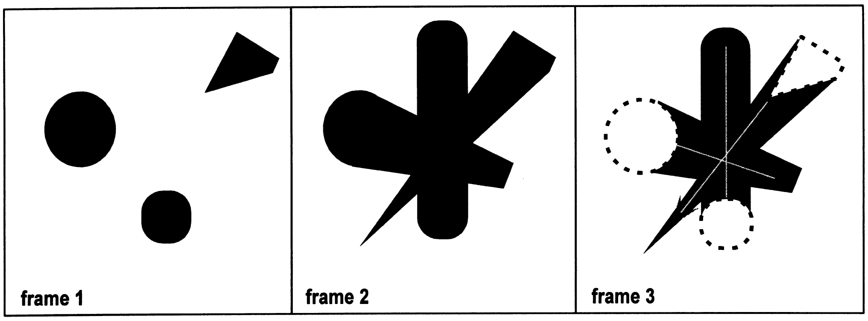

Fig. 1. When frame 2 replaces frame 1, the frame 1 figures undergo smooth motions into their final frame 2 shapes, as shown using dotted figures and arrows in frame 3. When frame 2 appears, the visual system is faced with a parsing problem that must be solved before figures can undergo apparent motion into the corresponding portions of the figures in frame 2.

Grouping takes place on the basis of many of the familiar Gestalt grouping principles (Koffka, 1935), such as good contour continuation, contiguity and similarity of color and texture cues (Tse & Cavanagh, 1995; Tse et al., 1998). Perhaps the strongest cue is spatiotemporal figural overlap. For example, the shapes in frame 1 of Fig. 1 are replaced by other figures that overlap them in frame 2, as depicted in frame 3. This is evidence that certain scenes are grouped or segmented into overlapping objects before a set of motions guided by that form analysis is perceived.

We set the top-down factor of expectation against the bottom-up or stimulus-driven factor of grouping using the Chinese character shown in Fig. 2. Subjects raised in China should expect the six strokes to be drawn in the particular order and set of directions indicated, whereas American subjects who have not studied Chinese should not have such expectations. We tested the prediction that Chinese subjects would see ambiguous apparent motions differently than American subjects because of their different expectations with respect to this stimulus sequence.

2. Method

2.1. Participants

Ten Chinese subjects in their 20s, 30s and 40s who had come to study in the United States no more than 10 years prior to the experiment, and who were at least 18 when they arrived in the United States, comprised half the subject pool. Their mother language was Mandarin ($n = 7$) or Cantonese ($n = 3$). The other half consisted of 10 American students of comparable age with no knowledge of the Chinese language whose mother language was English. Four of the Chinese subjects and five of the Americans were psychophysicists unfamiliar with the aims of the experiment.

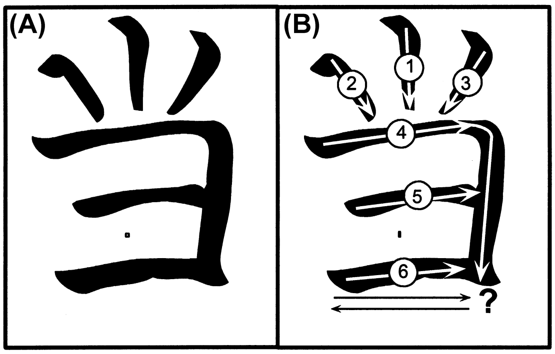

Fig. 2. The six strokes of the character shown in (A) are written in the order shown with the directions indicated by the white arrows in (B). Subjects had to report the motion that they perceived upon appearance of the sixth stroke. The small square indicates the fixation point.

2.2. Apparatus

Stimuli were presented using an Apple Power Macintosh computer on an Apple 13-inch color monitor with a refresh cycle of 15 ms.

2.3. Stimuli

The six stroke Chinese character shown in Fig. 2 was presented stroke by stroke by presenting six static images sequentially. The character was approximately 4×6 degrees of visual angle. The character was crimson on a black background and the fixation point positioned midway between the fifth and sixth strokes was white. Subjects viewed the stimulus from a distance of 57 cm. The first stroke was presented all at once in isolation, except for the fixation point, and was the stroke that would in fact be drawn first if the character were written by hand. When the second stroke appeared all at once, the first stroke remained on the screen. Similarly, when the sixth stroke appeared, the previous five strokes remained on the screen. There was no real motion or animation in the stimulus.

2.4. Design

The complete character was on the screen when subjects were asked to sit down. This was done to implicitly invoke any expectations that the subject might have about this character. Subjects were told that they would see this character disappear and then reappear on the screen stroke by stroke and that their task was twofold. First, they had to maintain fixation, and second, they had to judge whether the direction of motion of the last stroke was left-to-right, right-to-left, or no motion at all. They were told that they should report which of the three alternatives best characterized their motion percept. While eye movements were not monitored, four of the Chinese subjects and five of the American subjects were psychophysicists adept at maintaining eye fixation. Subjects fixated the fixation spot between the fifth and sixth strokes of the complete character. When a subject pressed a key indicating that he or she was ready, the entire character disappeared, leaving only the fixation point on the black screen. After 1050 ms of this blank interval, the strokes appeared one at a time in correct sequence. Each stroke in fact appeared all at once and remained on the screen once drawn. There was a 450 ms stimulus onset asynchrony between the onset of successive strokes in order to mimic the speed with which a person might actually write this character. There was no interstimulus interval between successive strokes.

Our hypothesis was the following. Since Chinese subjects have an expectation about how the final stroke is drawn, they might perceive the motion of the final stroke to proceed from left to right even though it in fact appears all at once. Grouping processes that we have described elsewhere (Tse et al., 1998), however, would group the sixth stroke with the vertical fourth stroke since there is nothing to group it with on its left side. Grouping processes would therefore tend to drive perceived motion from right to left. Chinese subjects might tend to see left-to-right motion, whereas Americans unfamiliar with the Chinese language should tend to see a right-to-left motion in the final stroke of the character.

3. Results

Whereas all American subjects reported right-to-left motion, consistent with grouping cues, seven of the ten Chinese subjects tested reported having seen left-to-right motion. All four Chinese subjects who were psychophysicists reported seeing left-to-right motion. Of the three Chinese subjects who did not report left-to-right motion, one reported a ''no motion'' percept and the other two reported right-to-left motion. Assigning a response of right-to-left a dummy value of positive one, a response of ''no motion'' a value of zero and a response of left-to-right motion a value of negative one, the responses of the Chinese and non-Chinese subjects were found to differ significantly using Student's *t*-test for two samples ($t = 5.582$, d.f. $= 18$, $P < 0.0001$).

Despite countervailing grouping cues, most Chinese subjects perceived the motion that they expected to perceive given their years of experience writing this common character. Note that these results are the outcome of a single trial per subject. During debriefing, when the stimulus was shown to the subject again as many times as the subject wished, most Chinese and American subjects said that they were unable to see the motion appear all at once even when told that this was in fact how it appeared on the screen. All Americans continued to report seeing right-to-left motion even when told that the final stroke in fact appeared all at once. Of the seven Chinese subjects who saw left-to-right motion in the first trial, five reported that they continued to see motion proceed from left to right, even after multiple presentations and encouragement by the experimenter to try to see the opposite motion.

4. Discussion

We pitted the top-down factor of expectation against the bottom-up factor of grouping using the common Chinese character shown in Fig. 2. Subjects raised in China should expect the six strokes to be drawn in the ''correct'' order and set of directions indicated in Fig. 2, whereas American subjects who have not studied Chinese should not have such expectations. Independently of expectations, the right end of this final stroke is in contact with the bottom of the preceding vertical stroke. Grouping processes should group this new stroke with the previous one and drive perceived motion from right to left as the new stroke, in effect, is inferred to grow out from the existing shape (Tse et al., 1998). Although each stroke was in fact presented all at once, subjects raised in China tended to see apparent motion over a single stroke in the direction it would have had if it were drawn by hand, even though bottom-up grouping cues drive a percept of apparent motion in the opposite direction for observers unfamiliar with the Chinese language. There therefore appears to be a ''cultural'' or learned component to motion perception arising from top-down expectations capable of overriding bottom-up cues to motion.

The expectations of Chinese observers presumably arise from their years of experience writing this character in the standard stroke order. Because expectations are not limited to the domains of reading or writing, it is likely that expectations in other domains can influence how ambiguous stimuli are perceived. Indeed, expectations about how human bodies move can affect how observers see apparent motion over sequences of images of human bodies (e.g. Chatterjee, Freyd & Shiffrar, 1996; Ramachandran et al., 1998). However, how expectations exert their influence on perception is not clear. The ''standard'' view of top-down processing is that later visual areas influence earlier areas via feedback connections. There are other possibilities, however. Expectation and knowledge could in principle alter the circuitry involved in grouping, in which case a top-down influence would be exerted in a bottom-up manner (cf. Wright & Dawson, 1994). Thus, the distinction between top-down and bottom-up processing is a heuristic rather than anatomical one, and the issue of how top-down influences on perception are neuronally realized remains an open problem.

In conclusion, apparent motion can be influenced by both top-down factors such as expectation or attention and by bottom-up factors such as grouping or proximity. When these factors are placed into conflict, one or the other factor may predominate. Which predominates may depend on the weights attached to the various conflicting factors. Here we have reported an example where the motion percept is dominated by expectation more than it is by grouping.

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