SURFACE FEATURES DO NOT GUIDE OBJECT CONTINUITY EVEN WHEN SPATIOTEMPORAL INFORMATION IS AMBIGUOUS

Yosef Pirkner and Ruth Kimchi
Department of Psychology and Institute of Information Processing and Decision Making
University of Haifa, Israel
ypirkner@campus.haifa.ac.il; rkimchi@research.haifa.ac.il

Abstract

Perception of object continuity depends on establishing correspondence between objects viewed across disruptions in visual information. Several researchers have claimed that object correspondence is based only on spatiotemporal information (Kahneman et al., 1992); other studies suggest that surface features may also play a role in guiding object continuity (e.g., Hollingworth & Franconeri, 2009). This study examined whether surface features can be used to establish object correspondence when spatiotemporal information is ambiguous, using the object-reviewing paradigm. We manipulated spatiotemporal congruency (Experiment 1) and color congruency under conditions of spatiotemporal ambiguity and spatiotemporal discontinuity (Experiments 2-3). Object-specific preview benefit was observed only for unambiguous spatiotemporal information (consistent trajectory under occlusion; Experiment 1), but not for spatiotemporal ambiguity (unpredictable trajectory under occlusion; Experiment 2) and spatiotemporal discontinuity (Experiment 3). These results suggest that surface features cannot be used to establish object correspondence even when spatiotemporal information is ambiguous, thus supporting the view that object correspondence is based only on spatiotemporal information.

The world we perceive is stable and continuous despite changes and disruptions in the visual information resulting from movements of the observer, movements of objects, saccades or brief occlusion. To achieve perception of object continuity the visual system must be able to establish correspondence between objects viewed across disruptions.

A dominant view concerning object continuity claims that object correspondence across brief disruptions is based only on the spatiotemporal properties of an object (Kahneman, Treisman, & Gibbs, 1992). This claim has been driven by theory and by empirical evidence. Theoretically, it follows directly from the object file framework presented by Kahneman et al. (1992). Object files are temporary, episodic visual representations that store and update information about specific objects and use spatiotemporal information to track the objects over time and space. Thus, object files allow an object's identity to persist even as its properties change, as long as there is spatiotemporal continuity between its successive states.

Empirical evidence that object correspondence is based only on spatiotemporal information comes from several studies using the object-reviewing paradigm (Kahneman et al., 1992). In this paradigm, observers view a preview display, which contains two objects (e.g., squares) with a different letter presented in each for a short time. After the letters disappear, the objects move to new locations. Then a target letter appears in one of the objects and the participants have to name it aloud. Typically, responses are faster when the target letter is the same as the preview letter than a new letter (general priming). Critically, responses are faster when the target letter matches the preview letter that appeared on that same object (congruent condition) than on a different object (incongruent condition). This

congruency effect is referred to as object-specific preview benefit (OSPB), and it provides an index of object continuity.

OSPB effects were consistently observed when spatiotemporal information was available to establish object correspondence, but no OSPB effects were observed when surface features were the only cue for object correspondence (Kahneman et al., 1992; Mitroff & Alvarez, 2007). For example, using a slight modification of the object-reviewing paradigm, Mitroff and Alvarez (2007) found OSPB when the objects moved to their final locations (spatiotemporal condition). However, when the objects disappeared and reappeared in new locations and surface feature congruency was manipulated (feature condition), no OSPB was observed, regardless of the salience and number of features. Further evidence for the critical role of spatiotemporal information for the perception of object continuity comes from studies of apparent motion, the tunnel effect, and multiple object tracking (see Flombaum, Scholl, & Santos, 2009, for a review).

Other findings, however, seem to suggest that surface features may also play a role in guiding object continuity (e.g., Hollingworth & Franconeri, 2009; Moore & Enns, 2004; Moor, Mordkoff, & Enns 2007; Moore, Stephens, & Hein, 2010; Richard, Luck, & Hollingworth, 2008). For example, Moore and Enns (2004) found that an abrupt change in the size or color of a moving object disrupts its perception as a single object, resulting in a perception of two objects, the original unchanged object and the changed object.

The present study attempted to examine whether surface features can be used to establish object correspondence when spatiotemporal information is ambiguous. This hypothesis was recently tested by Hollingworth and Franconeri (2009), using a modified version of the object-reviewing paradigm. They showed participants two disks in different colors with a different novel shape presented in each disk for a short time. Then the disks moved towards the center and disappeared behind occluder at the same vertical position. The occluder was then removed, revealing the two disks separated vertically, with a test shape in each disk. Target shapes that matched the preview shapes could appear in the same color disk as the preview shape or in a different color disk. Subjects had to decide whether the two shapes were the same as the preview shapes or not. Their results showed an OSPB effect, which could be based only on color congruency, suggesting that under spatiotemporal ambiguity object correspondence was established on the basis of a surface feature (color).

However, Hollingworth and Franconeri (2009) obtained a similar color congruency effect even under spatiotemporal discontinuity, in clear contrast with the finding of Mitroff and Alvarez (2007). Since Hollingworth and Franconeri's task involved unfamiliar shapes and required matching two shapes to the preview ones, whereas Mitroff and Alvarez's task involved familiar letters and required matching only one target letter to the preview letters, it is possible that the color congruency effects observed by Hollingworth and Franconeri (2009) emerged from memory and other non-perceptual task demands, reflecting strategic organization of information useful for completing the task at hand, as suggested by Moore et al. (2010). Thus, the question whether or not surface features can be used to establish object correspondence under spatiotemporal ambiguity remains to be resolved.

This study examined the influence of surface features on object correspondence under conditions of spatiotemporal ambiguity, using the object-reviewing paradigm with stimuli and task similar to those of Mitroff and Alvarez (2007), which minimize memory load and other non-perceptual task demands. We conducted three experiments. In Experiment 1 there was no spatiotemporal ambiguity. The objects moved from their initial locations, briefly disappearing behind an occluder, and continued to move to their final locations, following the same trajectory (Figure 1A). Actually, this experiment replicated the spatiotemporal condition of Mitroff and Alvarez's (2007), with the exception of the presence of an occluder. The critical experiment was Experiment 2, in which we induced spatiotemporal ambiguity by an

unpredictable change in the object trajectory when the object disappeared behind the occluder, and manipulated the object's color congruency (Figure 1B). Color congruency was also manipulated in Experiments 3, which employed spatiotemporal discontinuity (Figure 1C).

If object correspondence is based on the available information, be it spatiotemporal or surface features, then OPSB is expected to be observed in all three experiments, based on spatiotemporal congruency in Experiment 1 and by color congruency in Experiments 2 and 3. If, however, spatiotemporal properties are the only information that can be used to establish object correspondence, then we will expect to observe OSPB only in Experiment 1. If surface features can be used to establish object correspondence only when the spatiotemporal information is ambiguous, then we will expect to observe OSPB effects also in Experiment 2.

Method

The three experiments used the same method, except as noted below.

Participants

All participants, 12 in each experiment, were students from the University of Haifa community; each participated in only one experiment. Course credit or payment was given for participation. All participants had normal or corrected-to-normal vision.

Stimuli and apparatus

The stimuli include black outlined squares (Experiment 1) or red and blue solid squares (Experiments 2-3), each of which subtended 1.9° x 1.9°, presented on a white background. Preview and target letters were drawn randomly from the following set of black Arial Narrow letters: K,M,P,S,T,V,X,H,F,R. Each letter subtended 1.3° x 1°. The squares appeared 6.14° to the left and right of center in the preview display, and 6.14° above and below the center in the target display. A gray X shaped occluder (3° width) was presented in the center of the screen, subtending 14.24° x 14.24°. All distances are calculated from center of the stimuli.

Stimuli were presented on a 17" CRT monitor with 85 Hz refresh rate. The experiment was controlled by a computer running E-Prime software. Viewing distance was fixed at 57 cm, and a chinrest was used. Responses were made by pressing response box's keys.

Design and Procedure

Each trial in all experiments began when the participant pressed a key causing the preview display to appear. Two squares to the left and right of center along with a central gray X appeared for 500 ms. Then two preview letters, one letter centered within each square, were presented for 1200 ms. After the preview letters disappeared, the squares stayed in place for additional 500 ms. Trials in all three experiments ended with two squares above and below the center. A target letter appeared in one of the squares, until response. The participants were required to indicate as quickly as possible whether the letter was the same as either of the preview letters by pressing one of two keys. The linking phase between the preview and target display varied across experiments. In Experiment 1 (Figure 1A), the two black outlined squares moved smoothly from their initial locations to their final locations on a diagonal path for 1500 ms, briefly occluded for 55 ms by the X on their way. There was no spatiotemporal ambiguity in this experiment because the squares followed a consistent trajectory from their initial to final locations. In Experiment 2 (Figure 1B) the two colored squares moved initially

horizontally for 615 ms, disappeared behind the occluder at the same vertical position for 270 ms of full occlusion, and reappeared again, moving up or down to their final location for additional 615 ms. In this experiment, spatiotemporal information was ambiguous because the squares' trajectory was unpredictable. In Experiment 3 (Figure 1C) there was spatiotemporal discontinuity – the two colored squares disappeared for 1500 ms and then reappeared at the final position.

A 2(match, no match) x 2(congruent, incongruent) within-subjects design was used in all experiments (congruency was meaningful only for the match condition). The target letter was one of the letters in the preview display on 50% of the trials (match trials), and it was neither of the preview letters on the other 50% of the trials (no-match trials). On 50% of the match trials the target letter was the same as the preview letter that appeared on that square (congruent trials), and on the other 50% of the match trials the target letter was the same as the preview letter that appeared on the other square (incongruent trial). Congruency was defined by spatiotemporal history (the square's trajectory) in Experiment 1, and by the square's color in Experiments 2-3. All variables – target location (top/bottom), motion direction (clockwise/counterclockwise, Experiment 1), and square location (right/left and top/down, Experiments 2-3) – were counterbalanced. Each experiment included 384 experimental trials, randomly presented, and preceded by 12 practice trials.

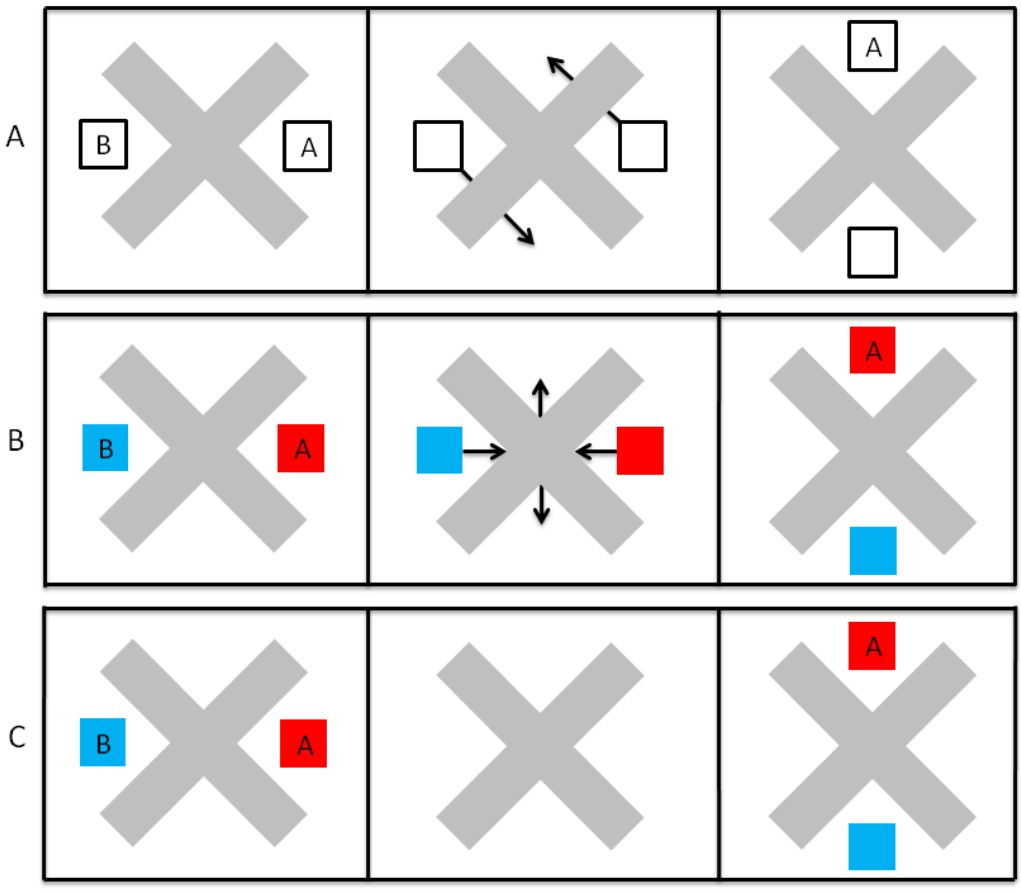

Figure 1. Illustrations of the conditions of the three experiments. (A) Experiment 1: Spatiotemporal continuity. (B) Experiment 2: Spatiotemporal ambiguity. (C) Experiment 3: Spatiotemporal discontinuity.

Results and Discussion

Mean accuracy and correct RT data for Experiments 1-3 are presented in Table 1. For all Experiments analyses were conducted over match trials, for which congruency conditions are meaningful. RT analyses were limited to correct responses. Responses longer than 2500 ms or shorter than 150 ms were omitted from the analyses (less than 1% of the data in any experiment).

The critical measure is the object-specific preview benefit (OSPB) – calculated as the difference in response time between incongruent and congruent conditions. OSPB was observed only for Experiment 1. Responses in the congruent condition were faster than responses in the incongruent condition by 28 ms, $t(11) = 2.24$, $p < .05$, indicating object correspondence based on spatiotemporal congruity. This finding is consistent with previous results from the object-reviewing paradigm (e.g., Hollingworth & Franconeri, 2009; Kahneman et al., 1992; Mitroff & Alvarez, 2007), and with the "tunnel effect" (Burke, 1952; Flombaume and Scholl, 2006). Object continuity is not disrupted by occlusion as long as the object follows consistent trajectory when emerging from the occluder.

No OSPB effect was observed in Experiment 2, $t(11) = 1.19$, $p > .25$, suggesting that no object correspondence was established. In this experiment, spatiotemporal information was not useful for establishing object correspondence because it was ambiguous; the only cue for correspondence was the object's color. The results clearly suggest that color was not used to establish object correspondence under this condition of spatiotemporal ambiguity.

The results of Experiment 3 also showed no OSPB, $t(11) = -0.01$, $p > .99$, indicating that no object correspondence was established under the condition of spatiotemporal discontinuity. This finding is consistent with the finding in the feature condition in Mitroff and Alvarez' (2007) study, demonstrating that surface features are not used to establish object correspondence.

The results of Experiments 2 and 3 are in clear contrast with the results of Hollingworth and Franconeri (2009, Experiments 2 and 5). Note that in our spatiotemporal ambiguity condition, unlike in Hollingworth and Franconeri's, the movement of the objects to their final locations (after emerging from the occluder) was visible, and nevertheless no color congruency effect was observed. In addition, our Experiment 3 replicated the results of Mitroff and Alvarez (2007). Given the simpler task and stimuli used in our experiments, our results are seen to support the conjecture that the color congruency effects observed by Hollingworth and Franconeri (2009) under spatiotemporal ambiguity and spatiotemporal discontinuity were "illusory OSPB" (Moore et al., 2010; Gao and Scholl, 2010), caused by non-perceptual task demands.

	Congruent Match	Incongruent Match	No Match
Exp. 1: Spatiotemporal congruency			
Correct RT	728	756	803
Accuracy	97.3	97.3	97.7
Exp. 2: Color congruency			
Correct RT	741	747	811
Accuracy	96.2	96.2	97.7
Exp. 3: Color congruency			
Correct RT	722	722	768
Accuracy	96.9	96.1	97.9

Table 1. Mean accuracy (%) and correct RT (ms) for Experiments 1-3.

Taken together, our results suggest that surface features cannot be used to establish object correspondence even when spatiotemporal information is ambiguous, thus supporting

the view that object correspondence in dynamic perception is based only on spatiotemporal information.

References

Burke, L. (1952). On the tunnel effect. *Quarterly Journal of Experimental Psychology, 4*, 121–138.

Flombaum, J. I., & Scholl, B. J. (2006). A temporal same-object advantage in the tunnel effect: Facilitated change detection for persisting objects. *Journal of Experimental Psychology-Human Perception and Performance, 32*, 840-853.

Flombaum, J. I, Scholl, B. J, & Santos, L. R (2009). Spatiotemporal priority as a fundamental principle of object persistence. In B. Hood & L. Santos (Eds.), *The origins of object knowledge* (pp. 135–164). Oxford University Press.

Gao, T., & Scholl, B. J. (2010). Are objects required for object-files? Roles of segmentation and spatiotemporal continuity in computing object persistence. *Visual Cognition, 18*, 82-109.

Hollingworth, A., & Franconeri, S. L. (2009). Object correspondence across brief occlusion is established on the basis of both spatiotemporal and surface feature cues. *Cognition, 113*, 150-166.

Kahneman, D., Treisman, A., & Gibbs, B. J. (1992). The Reviewing of Object Files - Object-Specific Integration of Information. *Cognitive Psychology, 24*, 175-219.

Mitroff, S. R., & Alvarez, G. A. (2007). Space and time, not surface features, guide object persistence. *Psychonomic Bulletin & Review, 14*, 1199-1204.

Moore, C. M., & Enns, J. T. (2004). Object updating and the flash-lag effect. *Psychological Science, 15*, 866-871.

Moore, C. M., Mordkoff, J. T., & Enns, J. T. (2007). The path of least persistence: Object status mediates visual updating. *Vision Research, 47*, 1624-1630.

Moore, C. M., Stephens, T., & Hein, E. (2010). Features, as well as space and time, guide object persistence. *Psychonomic Bulletin & Review, 17*, 731-736.

Richard, A. M., Luck, S. J., & Hollingworth, A. (2008). Establishing object correspondence across eye movements: Flexible use of spatiotemporal and surface feature information. *Cognition, 109*, 66-88.