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Staying in bounds: Contextual constraints on object-file coherence

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Abstract

Coherent visual perception necessitates the ability to track distinct objects as the same entities over time and motion. Calculations of such object persistence appear to be fairly automatic and constrained by specific rules. We explore the nature of object persistence here within the object-file framework; object files are mid-level visual representations that track entities over time and motion as the same persisting objects and store and update information about the objects. We present three new findings. First, objects files are constrained by the principle of "boundedness"; persisting entities should maintain a single closed contour. Second, object files are constrained by the principle of "containment"; all the parts and properties of a persisting object should reside within, and be connected to, the object itself. Third, object files are sensitive to the context in which an object appears; the very same physical entity that can instantiate object-file formation in one experimental context cannot in another. This contextual influence demonstrates for the first time that object files are sensitive to more than just the physical properties contained within any given visual display.

As we move about the world and as the world moves about us, we readily track objects as being the same entities from one moment to the next. This invaluable skill underlies our ability to interact with our environment without constantly recreating a representation of every entity. In principle, such object tracking could be carried out by continuously comparing a series of individual visual snapshots (Michels, Saxena, & Ng, 2005) or by storing previous exposures to individuals or groups across an entire encounter (Rosencrantz, Gordon, & Thrun, 2003). However, while these are viable computer vision strategies, they would be an overwhelming proposition for the human brain. Rather than using brute force to achieve the perception of persisting objecthood, our visual system uses several heuristics to both optimize and simplify processing. Yet, much remains unknown about what heuristics are used, how they are used, and when they are used.

A powerful framework within which to reason about and test these issues of object persistence is the *object-file theory* (Kahneman, Treisman, & Gibbs, 1992). "Object files" are episodic, visual representations that store and update information about specific objects and track the objects over time and motion via spatiotemporal information. Object files are thought to be a

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critical mid-level of visual representation that can track an entity's persisting identity without relying upon either low-level surface features (e.g., colour, shape) or higher level information (e.g., type or category). For example, take the classic American movie line "It's a bird, it's a plane … It's Superman." Despite changes in low-level information (e.g., a size change as Superman moves closer) and in higher level categorization (e.g., switching from bird to plane), the *it* remains the same—there is never any doubt as to how many objects are present (Kahneman et al., 1992).

The object-file theory has gained empirical support through the *object-reviewing paradigm* wherein specific information presented on a given object is later processed more rapidly when it is presented again on the same object as opposed to on a different object, even if the objects have moved (Kahneman et al., 1992). That is, when the information is initially bound to a specific object, processing of that information at a later time is speeded when the binding is maintained. In a modified version of the object-reviewing paradigm (e.g., Kruschke & Fragassi, 1996; Mitroff & Alvarez, 2007; Mitroff, Scholl, & Noles, 2007; Mitroff, Scholl, & Wynn, 2004, 2005; Noles, Scholl, & Mitroff, 2005; see Figure 1), subjects first view a display containing at least two objects (e.g., two simple frames). Preview information is then briefly presented in each object (e.g., a letter is presented within each frame). After the preview information disappears, the objects move about the display. A final target item (e.g., a letter) is then displayed in one of the objects and subjects are asked to make a speeded response as to whether it is the same as any of the preview items or whether it is novel to that trial. Typically, subjects are quicker to respond when the target item reappears on the same object it was previewed on compared to when it reappears on a different object. This response time benefit has been termed the *object-specific preview benefit* (OSPB). The motion serves to decouple the initial spatial location from object-specific information; thus the OSPB is thought to arise from the preview information being stored in, or bound with, the persisting object-file representation as opposed to a location.

An initial wave of object-file research focused on the nature of an object file's contents (e.g., Kahneman et al., 1992; Gordon & Irwin, 1996, 2000; Henderson, 1994; Henderson & Anes, 1994), establishing that object identity can be maintained in an abstract format. For example, one study found significant OSPBs even if the preview and target items differed in format from words to pictures (Gordon & Irwin, 1996). More recently, object-file research has examined the rules that guide how object files are constructed, maintained, and destroyed (e.g., Mitroff & Alvarez, 2007; Mitroff et al., 2004, 2005; Noles et al., 2005). For example, object files were found to be sensitive to the principle of *cohesion*; to be tracked over time and motion as the same entity, an object should continuously maintain both a single contour and its status as a single unit (Mitroff et al., 2004). When an object split apart into two, the OSPBs for the two resulting objects were significant, but also significantly reduced in magnitude compared to the OSPB from intermixed control trials wherein objects did not undergo a cohesion violation. Thus the cohesion violation of the splitting object played an important role in the object-file maintenance, but perhaps not an "all-or-none" role. An open and important question that remains is to what extent such rules guide object-file processing.

To date, it has been suggested that object-file processing is influenced by the rule of cohesion (Mitroff et al., 2004) and perhaps the rule of *solidity*, that objects can't pass through other objects (Mitroff et al., 2005). Prior infant cognition research directly inspired these suggestions and raises the possibility that other such principles might guide object files. Developmental work has explored whether specific principles constrain how young infants interact with objects in the world around them (e.g., Cheries, Mitroff, Wynn, & Scholl, 2008; Spelke, 1990; Spelke, Kestenbaum, Simons, & Wein, 1995; Wang, Baillargeon, & Paterson, 2005). For example, using looking time procedures, Spelke et al. (1995) found that young infants expect objects to move along continuous paths—objects cannot move from one location to another without traversing the intermediate region. Such principles have also been linked to the adult object-file literature (e.g., Carey & Xu, 2001; Feigenson, Carey, & Hauser, 2002; Richardson & Kirkham, 2004; Scholl & Leslie, 1999). As such, exploring additional developmentally inspired rules in adult mid-level vision provides a natural continuation of this research enterprise.

CURRENT STUDY

In the current paper, we address two previously unexplored rules in the adult object-file literature: *Boundedness*—that an object must have a single continuous boundary, and *containment*—that the properties of the object must be located within the boundaries of the object itself. By exploring these two potential object-based constraints we aim to further establish the rules of how information is bound into object-file representations. As will be addressed in the General Discussion, our investigation into boundedness and containment has also given rise to an intriguing effect—the results suggest that the *context* in which an object is encountered influences the "goodness" of the object for object files; the very same physical entity that can instantiate object-file formation in one experimental context cannot in another context. We explore the contribution of context by assessing boundedness and containment in two different experimental procedures. In the intermixed condition, trials containing bounded objects (see Figure 2) are randomly interleaved with trials containing unbounded objects (likewise for containment in Experiment 2). In the pure condition, only trials with unbounded objects are presented (again, likewise for containment in Experiment 2). If the general context within which a stimulus is presented affects object-file processing, we should see a difference between the intermixed and pure conditions. This is exactly what we found and it represents a sharp deviation from existing lines of research that have focused specifically on the role of visual characteristics for object files.

EXPERIMENT 1: THE ROLE OF BOUNDEDNESS

Previous investigations have found that the principle of cohesion influences what the adult mid-level visual system will consider the same object over time and motion (Mitroff et al., 2004). Yet, why exactly such cohesion violations disrupt object files remains an open question. On one hand, the deleterious effects of a cohesion violation could stem from the breaking of an already established boundary or the instantiation of a new object. On the other hand, the mere presence of an ambiguous boundary at any point during the object tracking process could result in such disruptions. Here we address this open question by exploring the principle of boundedness—that an entity must have and maintain a single continuous boundary. Must an object be "bounded" to be represented as a true object and to be tracked over time and motion as the same? This is an intriguing topic of enquiry since both prior infant (e.g., Xu, 1997) and adult (e.g., Marino & Scholl, 2005) research has suggested that boundedness can influence object perception. However, it remains unclear how this specific constraint influences object-file calculations and object tracking.

To address the role of boundedness for object files, we use an especially apt visual stimulus—objects constructed with illusory contours (e.g., Kanizsa, 1955/1987; see Figure 2). Objects defined by illusory contours behave much like objects defined by physical contours, and evidence suggests they are completed early and automatically in visual processing (e.g., Davis & Driver, 1994; Smith & Over, 1977; von der Heydt, Peterhans, & Baumgartner, 1984). Since illusory-defined objects do not have a single, continuous boundary, they provide an ideal stimulus for exploring the role of boundedness in object persistence, allowing us to compare the viability of object-file processing for "objects" with and without physical boundaries.

Methods

Participants—Forty members of the Duke University community participated for either payment or course credit (20 in each of the intermixed and pure conditions).

Apparatus and stimuli—The experiment was presented on a Macintosh G4 computer with a 19-inch monitor, programmed with customized software utilizing the VisionShell Graphics Library (Comtois, 2006). Subjects sat approximately 55 cm from the monitor without head restraint. The objects in the "illusory-defined" trials consisted of four equally spaced black notched discs (0.86 deg in diameter) that were aligned inwards creating a Kanizsa-like illusory square that subtended 3.44 deg^2 (see Figure 2). The objects in the "physically defined" trials were identical with the addition of a thin black line (0.17 deg) connecting the discs, creating a physically connected square. Letters were drawn in a black monospaced font subtending 1.72 deg and were centrally presented within an object. Unique preview letters were assigned randomly on each trial from the set [F,H,M,Q,U,X] and the target letter was either one of the preview letters or a novel letter from the same set.

Procedures

Each trial began when subjects pressed the spacebar with their left hand. A "preview" display would appear with two objects horizontally aligned, 4.25 deg to the left and right of centre. A single preview letter appeared in each object for 500 ms. The letters were then removed and the objects traversed a circular path (50% clockwise) for 1000 ms such that they stopped 4.25 deg above and below centre. A single target letter was then presented within one of the two objects (50% of the time in the top object) and subjects were to make a speeded response as to whether it was the same as *either* of the two previously displayed letters (pressing "1" for match and "2" for no match). The target display remained until the response. On 50% of the trials the target letter did not match either of the two preview letters (no-match trials). Of the remaining match trials, 50% of the time the target letter reappeared in the same object in which it was initially displayed (congruent match trials) and 50% of the time it reappeared in the object which initially contained the other preview letter (incongruent match trials).

Subjects participated in one of two experimental conditions. The intermixed condition contained 144 illusory-defined trials and 144 physically defined trials, with trials randomly intermixed. A given trial always contained either two illusory-defined objects or two physically defined objects throughout. That is, there was never a mix of object types within a single trial. The pure condition contained 144 illusory-defined trials. Prior to the experiment, subjects completed 20 practice trials that mirrored their experimental condition.

Results

The subjects were highly accurate on the match/no-match task for both the intermixed (*M*=96.46%, *SD*=2.54%) and pure conditions (*M*=96.44%, *SD*=2.26%; see Table 1). Trials with a response time greater than 2000 ms were removed from analyses (0.10% and 0.73% trials removed for intermixed and pure, respectively). All further analyses were conducted only on trials with a response time within 2 *SD*s of each individual subject's global mean (removal of 4.11% and 4.32% of the trials for intermixed and pure) and with a correct response.

The primary measure of interest was the difference in response time between the congruent match trials (when the target letter reappeared in the same object in which it was originally previewed in) and incongruent match trials (when the target letter reappeared in the object it was *not* previewed in). This response time difference represents the object-specific preview benefit (OSPB)—a processing advantage beyond general display-wide priming for information that had previously been associated with a specific object file (Kahneman et al., 1992). The OSPB serves as an operational definition of object persistence such that finding a significant

OSPB demonstrates that the object was perceived as the same persisting entity across the trial. As shown in Figure 2, the intermixed condition revealed a significant OSPB of 19.21 ms for the physically defined trials, $t(19)=3.26$, $p=.004$, yet no significant OSPB (5.45 ms) for the illusory-defined trials, $t(19)=0.88$, $p=.384$. The pure condition, which consisted solely of illusory-defined trials, did however reveal a significant OSPB of 20.76 ms, $t(19)=3.23$, $p=.004$; see Yang, 2006, for similar results with "pure" trials). The OSPB for the illusory-defined trials from the pure condition was marginally significantly different from that of the intermixed condition, $t(18)=1.78$, $p=.091$. The illusory-defined trials produced a significant OSPB when presented in isolation (pure condition) but not when presented in the context of physically defined trials (intermixed condition).

How bounded are unbounded illusory contours?

The differences between the intermixed and pure conditions suggest that illusory-defined objects do not underlie object-file processing as well as physically defined objects. However, an important question is whether illusory-defined, modally completed entities should even be considered "objects". We address this before discussing the implications of this study via an additional experiment. Here we pit illusory-defined objects against entities constructed of the same elements that do not give rise to a subjective object. Twenty new subjects participated in an experiment identical to the intermixed condition described above where half the trials were the illusory-defined trials previously described with pac-men facing each other to create an illusory square and the other half of the trials had the same pac-men rotated 180 deg so each was facing away from the centre. Subjects reported seeing an illusory square when the pac-men faced inwards but not when they faced outwards. The inwards facing, illusory-defined, trials revealed an OSPB of 11.98 ms (congruent and incongruent match mean RTs=595.19 ms and 607.17 ms, respectively), $t(19)=2.06$, $p=.053$. However, the outwards facing, nonillusory-defined, trials did not produce a significant OSPB (1.83 ms; congruent and incongruent match mean RTs=609.44 ms and 611.27 ms, respectively), $t(19)=0.16$, $p=.867$. Any concern over the relative visibility of the preview and target letters between the inwards and outwards facing trials due to physical differences is alleviated by identical performance in accuracy (M=96.91% and 96.28%, respectively) and in no-match trial RT (612.54 ms and 613.89 ms, respectively). The results suggest that the illusory-defined trials in Experiment 1 do represent object-based processing—the mere grouping of inducing elements into a coherent entity is not as sufficient as an "object" in producing object-specific preview effects.

Discussion

Objects constructed of illusory contours do not always underlie the formation and/or maintenance of object files. This is quite surprising given that illusory contours are processed early in visual perception and that the stimuli in this experiment adhered to several strong grouping cues that have previously been shown to underlie object tracking (e.g., vanMarle & Scholl, 2003; Yang, 2006). Since the only difference between the illusory- and physically defined objects was the lack of a physical boundary, these results suggest that the developmentally inspired rule of *boundedness* may in fact influence adult computations of object persistence. Importantly, it is not the case that the illusory-defined objects can never support object files—they did produce a significant OSPB when presented in isolation with no physically defined objects presented in the experiment. Thus boundedness may be an important rule for forming and/or maintaining object persistence, but not always a necessary rule. An intriguing outcome of this study is that the *context* in which illusory-defined objects are presented (in isolation vs. intermixed with physically defined objects) can impact whether or not object-file representations are instantiated. We return to this issue of context in the General Discussion after first exploring the principle of containment in Experiment 2.

EXPERIMENT 2: THE ROLE OF CONTAINMENT

Experiment 1 provided two findings—object files are sensitive to the principle of boundedness and this sensitivity can be modulated by contextual information. Here we look to further explore the role of context by investigating the independently important question of whether or not object files are sensitive to the principle of *containment*—that an object's features must be located within the boundaries of the object itself for it to be tracked over time and motion as a single persisting entity. Containment has been explored in the developmental literature (e.g., Hespos & Baillargeon, 2001; Wang et al., 2005) but has yet to be explored in the adult object persistence literature. As well, we also hope to provide converging evidence for Experiment 1's intriguing implication that the object-file system is sensitive to contextual information.

Methods

Participants—Forty members of the Duke University community participated for either payment or course credit (20 in each of the intermixed and pure conditions).

Apparatus, stimuli, and procedures—The experimental paradigm was identical to Experiment 1 except for the following. The objects in the "inside" trials were outlined squares (2.87 deg^2, 0.17 deg frame thickness) and had the preview and target letters drawn at their centre. The "outside" trials were identical to the inside trials except the letters were drawn 2.87 deg to the left of each object's centre (see Figure 3). Subjects in the intermixed condition completed 144 inside trials randomly intermixed with 144 outside trials. Subjects in the pure condition completed 144 outside trials.

Results and discussion

As for Experiment 1, the subjects were highly accurate on the match/no-match task for both the intermixed (M=98.61%, SD=2.25%) and pure conditions (M=97.27%, SD=3.02%; see Table 1). Outlying data were removed using the criteria described in Experiment 1: Trials were removed with a response time over 2000 ms (0.38% and 0.43% for intermixed and pure, respectively) and for a response time over 2 *SD*s from the individual subject's mean (4.46% and 4.43% removed for intermixed and pure, respectively). As depicted in Figure 3, the intermixed condition revealed a significant OSPB of 23.94 ms for the inside trials, $t(19)=3.38$, $p=.003$, yet no significant OSPB (3.85 ms) for the outside trials, $t(19)=0.46$, $p=.651$. However, in the pure condition, there was a significant OSPB of 12.80 ms for the outside trials, $t(19)=2.62$, $p=.017$.

The intermixed condition of Experiment 2 provides the first evidence that the principle of *containment* can affect object-file calculations. When the preview and target letters were simply moved outside the objects, the corresponding object files were attenuated such that they failed to produce a significant OSPB. This offers a surprisingly specific adherence to the principle of containment since an OSPB was found when all other aspects of the display were identical except that the letters appeared inside the objects. This finding also highlights the fact that object files are not driven solely by a simple association between the preview information and the objects in the displays; such an association would predict no difference between the inside and outside trials.

However, the object file adherence to containment appears to be contingent upon the nature of the objects present in the experiment since the outside trials did produce a significant OSPB in the pure condition. Beyond the theoretical implications that will be discussed in the General Discussion, the pure condition also serves to alleviate concerns that simple, atheoretical differences between the inside and outside displays may be driving the intermixed trial results.

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It is not that the outside trials (those violating containment) can never underlie object files, it is that they do not successfully do so in the context of more canonical object relationships.

GENERAL DISCUSSION

Three novel findings are presented here. First, object files, episodic mid-level visual representations that bind identity information to visual objects, are sensitive to the principle of boundedness—objects without complete closure do not support object files as well as objects with complete closure. Second, object files are influenced by the principle of containment—objects without all of their identifying information residing within their physical boundaries do not support object files as well as objects that do contain all their parts. Third, the global context created by the types of objects presented across an experiment can modulate the influence of these two principles. We discuss the broader impact of these issues in turn.

Object file rules

The current findings combine with past work to suggest that distinct principles can guide the formation and maintenance of object files. The influence of these principles on object-file processing mirrors infant cognition research; when entities violate certain principles of persisting objecthood, infants do not treat those entities as “real” objects (e.g., Chiang & Wynn, 2000; Huntley-Fenner, Carey, & Solimando, 2002). For example, young infants have specific expectations about the qualitative and quantitative properties of objects hidden behind occluding surfaces: Wynn (1992) found that when infants are shown two objects placed behind a screen, they expect there to be two items when the screen is removed. However, Huntley-Fenner et al. (2002) found no such expectations with piles of noncohesive sand.

Each principle tested within the object-file framework to date (cohesion, boundedness, containment, and solidity) has been explored with young infants and has been found to directly guide how infants reason about persisting objecthood. As such, it will be highly beneficial for both fields to explore other developmentally inspired principles in adult mid-level vision (e.g., object support; Needham & Baillargeon, 1993) and to re-explore these principles with infants. For example, based upon the findings of Mitroff et al. (2004), Cheries et al. (2008) returned to the principle of cohesion in infants and found that even very simple cohesion violations could disrupt infants’ ability to track objects through occlusion.

The contingency of object file rules

An important aspect of both of the current experiments is that they suggest a contingency to how object files obey specific rules—violations of bounded-ness and containment adversely affect object files, but not in every situation. The illusory-defined and outside trials produced significant OSPBs when presented in isolation but not when intermixed with the physically defined and inside trials. It remains an open question whether this contingency takes a graded form or an all-or-none form; object files might be formed for the illusory-defined and outside objects but formed to a lesser degree, or not at all, for the violation trials in the intermixed conditions. Previous findings suggest adherence to the cohesion rule is graded—when objects split into two, the resulting objects produced significant but attenuated OSPBs (Mitroff et al., 2004). Work outside the object-file literature has also demonstrated a graded aspect to object-based effects. For example, visual attention can spread through a single object more efficiently when the object obeys the boundedness principle; object-based attention effects can be found for entities lacking closure (Avrahami, 1999), but the effects are enhanced for bounded objects (Marino & Scholl, 2005). The current findings cannot distinguish the exact nature of this contingency, but they do raise several important issues about contextual influences on object files.

Context affects object files

The context within which an object is presented influences the degree to which its object-file representation adheres to specific rules. For example, the rule of boundedness had no clear influence when unbounded objects were presented in isolation but a strong effect when those same unbounded objects were seen in the context of bounded objects. Few object files are maintained at any given moment (Kahneman et al., 1992) so perhaps when less-than-ideal entities are seen in the context of canonical objects, resources are withheld so they can be reserved for the more legitimate objects. This would suggest that object files are not restricted to the “here-and-now” of any given situation since they can be affected by prior information. Note also that the contextual effects operated temporally over the experiment— objects that violated the boundedness or containment principles were never presented in the same visual array as objects that did not violate these principles.

Does context affect perception, attention, or memory?—The present finding that object files are sensitive to the nature of the objects seen before them mirrors previous object-based attention research (e.g., Chen & Cave, 2006; Zemel, Behrmann, Mozer, & Bavelier, 2002). Zemel et al. (2002) were able to reverse what subjects perceived as an object or nonobject in an ambiguous display by exposing them to specific visual stimuli. That is, how subjects process objecthood for a single trial can be directly affected by what they have seen before. Previous research has thus revealed experience effects on the ability to parse and distribute attention through static displays, and the present work is the first to demonstrate similar experience effects for object-file representations. However, it remains an important goal to establish when along the process these contextual effects administer their influences. On the one hand, as mostly discussed here, the effects can be at the representational stage, wherein noncanonical entities are not represented as persisting objects in the presence of better objects. On the other hand, the influence could also occur at the perceptual stage, such that the presence of better objects leads to the parts of the noncanonical objects not being perceived as bounded together into a single object. Future work can help to distinguish between these two theoretical possibilities.

Limits of the contextual effects—The effects of context do not seem to be universally administered. We have recently found that object-file tracking relies heavily upon spatiotemporal parameters; in the absence of spatiotem-poral continuity, surface feature information (e.g., an object’s colour or shape) does not support object-file maintenance (Mitroff & Alvarez, 2007). Analogous to the experimental conditions of the current paper, both “intermixed” and “pure” conditions were tested—feature-defined trials were either intermixed with spatiotemporally defined trials or presented alone. In contrast to the clear differences between the intermixed and pure conditions of Experiments 1 and 2, surface features failed to underlie object-file processing in both conditions (Mitroff & Alvarez, 2007). Whereas spatiotemporal continuity is a necessary condition for object files, the principles studied here appear to operate in a more contingent fashion.

CONCLUSIONS

The current experiments began with the primary goal of exploring the effects of violating the boundedness and containment principles on object files. However, not only did these studies demonstrate novel, nuanced effects of boundedness and containment violations, they also revealed an exciting contextual influence on object files. Whereas object files have been examined and discussed as “here-and-now” representations of a given visual environment, the contextual effects suggest a much broader scope. Combined with prior research there now exist three cases in which context can affect object files (with violations of cohesion, boundedness, and containment) and one case in which object files are immune to context (spatiotemporal violations). These contextual effects speak to the nature of feature binding in visual working memory, highlighting perhaps a special role for spatiotemporal factors where tracking an object relies relatively little on an object's features. Conversely, the effective binding of episodic information (e.g., the presentation of a letter) to a specific object can be influenced by the "goodness" of the object itself. Clearly these results just scratch the surface of this important issue and in so doing they raise several questions. For example, what other aspects of object persistence are context-dependent and context-independent? How malleable are these context effects? Are the context effects interactive (e.g., what would happen when intermixing the illusory-defined trials of Experiment 1 with the outside trials of Experiment 2)? With these and other such questions still unanswered, we have much to learn about object files. Nevertheless, the current findings serve an important role by elucidating the complex nature of object-file processing. To facilitate object persistence, object files both adhere to specific rules and incorporate prior knowledge.

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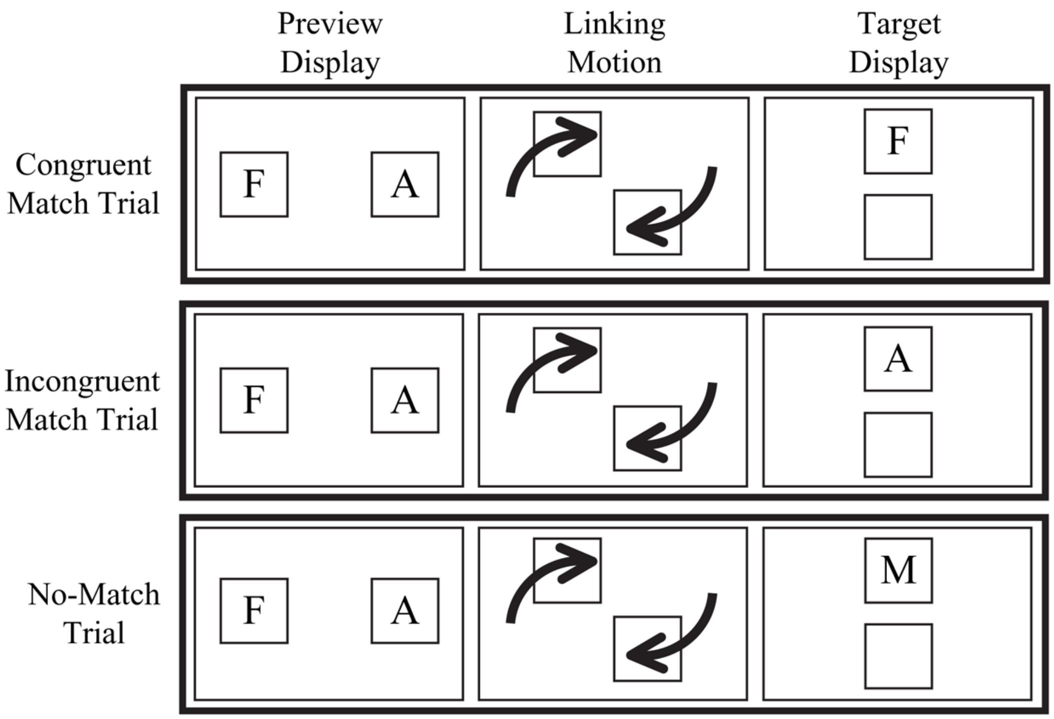

Figure 1.
Depiction of the congruent match, incongruent match, and no-match conditions of the object-reviewing paradigm. Faster response times are typically found on congruent than on incongruent match trials and this difference represents the object-specific preview benefit (OSPB). Figures are not drawn to scale and only depict one motion direction and one target letter location.

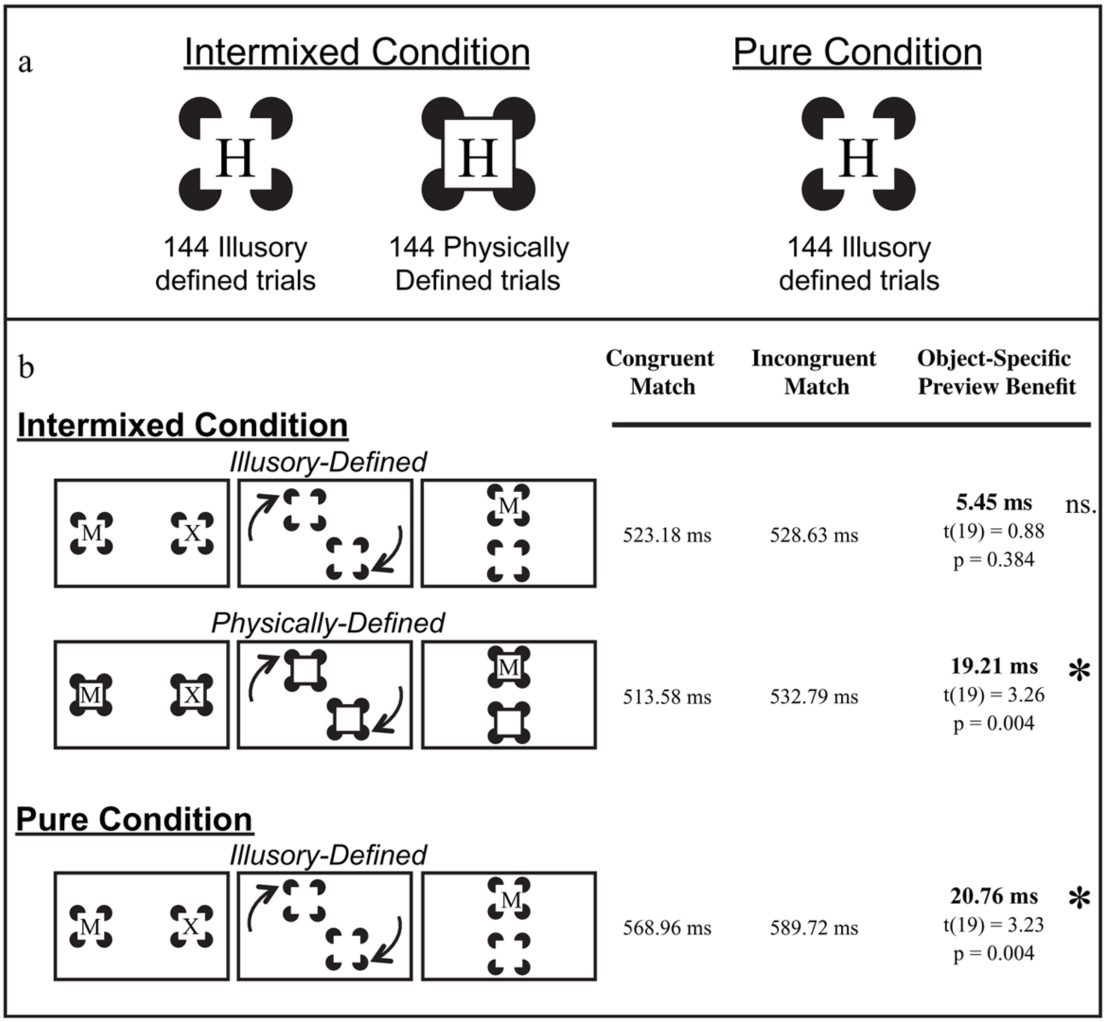

Figure 2.
The (a) stimuli and (b) response times of Experiment 1.

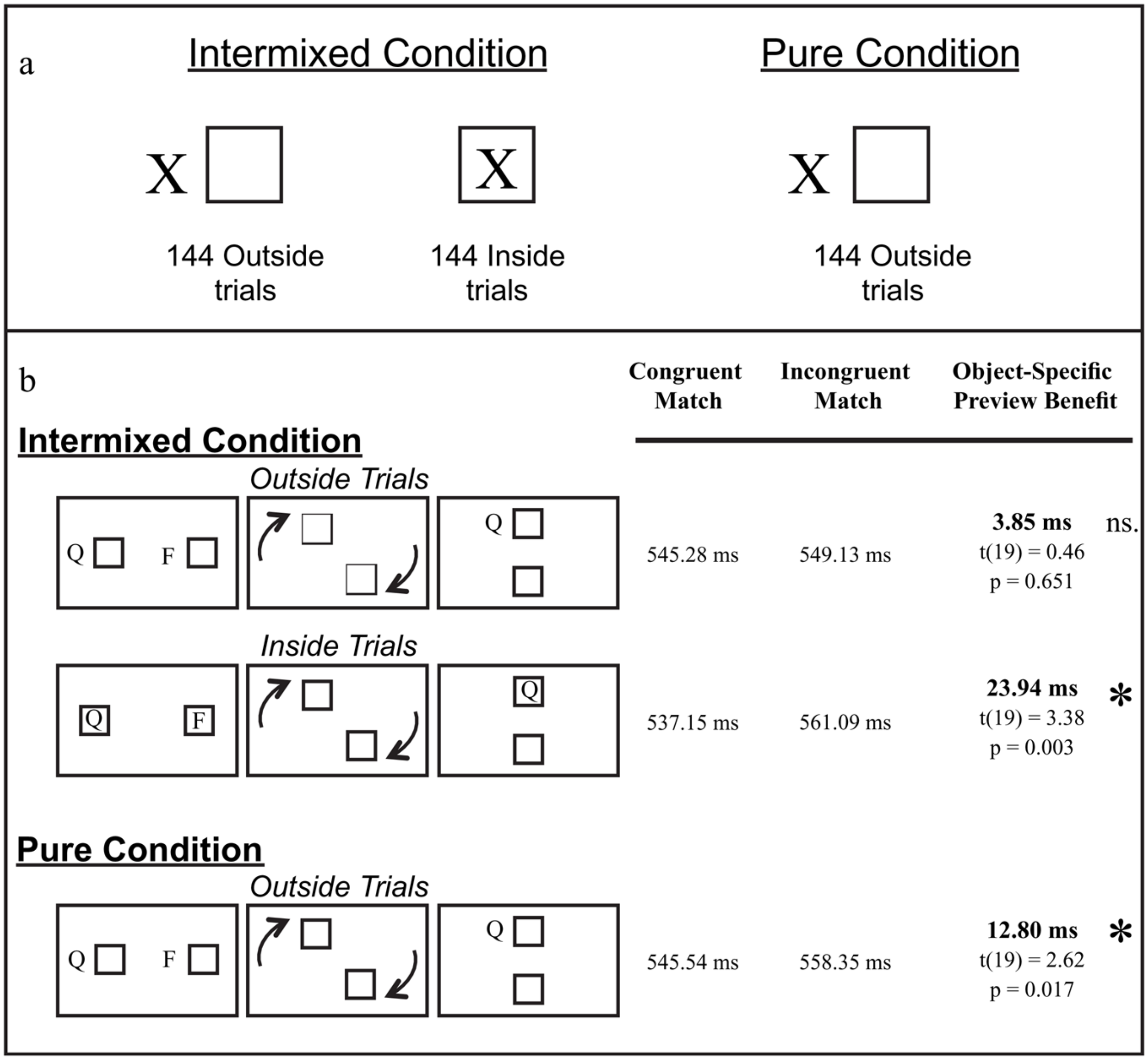

Figure 3.
The (a) stimuli and (b) response times of Experiment 2.

TABLE 1

Accuracy and response times (with standard errors) for Experiments 1 and 2 by condition and trial type

		Experiment 1: Boundedness			Experiment 2: Containment		
		Intermixed		Pure	Intermixed		Pure
		Illusory defined	**Physically defined**	**Illusory defined**	**Outside trials**	**Inside trials**	**Outside trials**
Accuracy	Congruent match	97.08%	95.42%	95.56%	95.14%	95.83%	96.53%
	Incongruent match	95.42%	92.50%	94.58%	94.58%	94.58%	95.69%
	No match	97.57%	98.06%	97.36%	97.78%	97.92%	98.61%
Response time	Congruent match	523.18 ms (18.15 ms)	513.58 ms (18.95 ms)	568.96 ms (21.50 ms)	545.28 ms (17.14 ms)	537.15 ms (14.89 ms)	545.54 ms (23.59 ms)
	Incongruent match	528.63 ms (17.09 ms)	532.79 ms (16.73 ms)	589.72 ms (21.81 ms)	549.13 ms (13.82 ms)	561.09 ms (18.77 ms)	558.35 ms (25.10 ms)
	No match	536.70 ms (19.96 ms)	531.41 ms (18.79 ms)	581.94 ms (24.20 ms)	538.89 ms (15.94 ms)	553.35 ms (16.63 ms)	571.77 ms (26.24 ms)