Journal of Experimental Psychology:
Learning, Memory, and Cognition
2009, Vol. 35, No. 3, 742–756

0278-7393/09/$12.00 DOI: 10.1037/a0015263

Perceive-Decide-Act, Perceive-Decide-Act: How Abstract Is Repetition-Related Decision Learning?

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Recent encounters with a stimulus often facilitate or "prime" future responses to the same or similar stimuli. However, studies are inconclusive as to whether changing the response that is required attenuates priming only for identical stimuli, or also for categorically related items. In 2 object priming experiments, the authors show that priming was eliminated if the initial decision associated with a stimulus changed on a later trial. This disruption of priming extended to perceptually and conceptually similar object exemplars and was found even when the classification tasks were *uncorrelated* with one another, many other items had intervened, and after only 1 prior encounter with a given stimulus. These outcomes are consistent with the rapid and automatic binding of a stimulus with a response into an episodic "instance" or "event file" and demonstrate that repetition-related decision learning is not hyperspecific but generalizes to new stimuli.

Keywords: priming, stimulus specificity, response learning, task switching, automaticity

Researchers have long known that repeated encounters with an object can facilitate, or "prime," one's subsequent ability to perceive and respond to that object, or a similar object (for reviews, see Grill-Spector, Henson, & Martin, 2006; Henson, 2003; Schacter, Dobbins, & Schnyer, 2004). Yet, repetition of an object or word does not invariably lead to facilitation of responding. Although significant *positive transfer*—that is, increased speed and/or accuracy of responding to repeated compared with novel items—is very frequently reported in studies of long-term repetition priming, there are also many circumstances under which repetition does not produce performance benefits (e.g., Franks, Bilbrey, Lien, & McNamara, 2000; Holbrook, Bost, & Cave, 2003; MacLeod, 1989; Oliphant, 1983; Vriezen, Moscovitch, & Bellos, 1995; Wagner, Koutstaal, Maril, Schacter, & Buckner, 2000; Xiong, Franks, & Logan, 2003). In addition, *negative transfer* often has been reported in other prominent cognitive-behavioral paradigms in which the effects of repeated processing of objects and words are explored, such as negative priming (e.g., Neill, 1977; Rothermund, Wentura, & De Houwer, 2005; Tipper, 1985, 2001) and task-switching paradigms (e.g., Waszak, Hommel, & Allport, 2003; see also Neill & Mathis, 1998, for a review).

In an attempt to provide a principled account of the circumstances under which repetition-related positive transfer is observed, researchers have decomposed the apparently simple notion of a "repeated presentation" into multiple components or processes (e.g., Bowers, 2000; Grill-Spector et al., 2006; Roediger, 1990; Schnyer et al., 2007; Vriezen et al., 1995; Xiong et al., 2003). As reviewed later, there is evidence that repetition-related facilitation for objects and words may involve improved efficiency of *perceptual* processes (e.g., relating to object identification), *conceptuall*y mediated processes (e.g., increased accessibility to lexical or semantic feature information), and also benefits at the level of the *response* or *decision* required (e.g., yes–no, animate–inanimate). Each of these factors must be viewed as vital contributors to priming because repetitions across any of the aforementioned dimensions may facilitate responding (Kiesel, Kunde, & Hoffmann, 2007; Schnyer et al., 2007), whereas variations (e.g., a different perceptual format) may attenuate priming.

Several researchers, from different perspectives, also have attempted to provide accounts of how these various components of a particular complex processing episode are *integrated* with one another to influence processing when a given object is again encountered at a later time. Researchers have proposed that the presentation of a stimulus leads to a newly formed episodic representation, such as an "instance representation" (Logan, 1990; cf. Jacoby 1983a), an "integrated S–R episode" (Waszak et al., 2003), or an "event file" (Hommel, 1998, 2004), that not only retains information about an object but also binds together multiple aspects of the context in which it occurred, such as the cognitive processes that were applied and the response or decision that was given. For example, it has been proposed that if the stimulus from an earlier stimulus–response (S–R) episode is reencountered, then the whole S–R episode is automatically retrieved. If the task changes, then such automatic retrieval would render it more difficult to "switch" to a different task or response (Waszak & Hommel, 2007); however, if the task and relevant decision remains constant, then such retrieval might effectively *bypass* the need for an "online" analysis of detailed object knowledge (Dobbins, Schnyer, Verfaellie, & Schacter, 2004). A fundamental question thus concerns the extent to which priming (or more generally many forms of cognition, such as categorization and problem solving), is mediated by such highly specific "episodic" representations or, in

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We thank Kristine Keller and Andrew Mundon for research assistance.

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addition, is mediated by abstract representations (e.g., Bowers, 2000; Tenpenny, 1995).

In the present research, we focused on the interrelations of three types of specificity in determining whether facilitation is observed during repetition priming: *perceptual specificity*, *task specificity*, and *response specificity*. Although each of these forms of specificity has been examined individually or in pairs, the relation between all three has been seldom explored and has yielded contradictory outcomes. Two research reports—one using the paradigm of task switching and the other using long-term repetition priming—reached entirely different conclusions regarding the extent to which response or decision learning is stimulus specific, or can generalize to related but new (not previously presented) objects. On the basis of findings in which object exemplar pairs and a size classification judgment task that reversed across blocks were used, Schnyer et al. (2007) argued that response learning was hyperspecific because they found no evidence of transfer to different object exemplars, even when the exemplars were judged to be highly visually similar. In contrast, using a response-switching paradigm, Waszak, Hommel, and Allport (2004) argued that response learning generalizes across semantically related stimuli.

Adjudicating between these two contrary conclusions has important implications. If the binding of a stimulus with a task-related code or decision is highly specific, then later encountering a somewhat modified (similar but not identical) stimulus will not automatically elicit a response. However, if the binding generalizes, then task-switch costs (and also benefits) might be expected even when a given stimulus has never been encountered before. Therefore, this has strong implications for the "flexibility of implicit memory" (Lazzara, Yonelinas, & Ober, 2002, p. 145) and the extent to which priming is an "adaptive and flexible mechanism for modification of perceptual processing" (Holbrook et al., 2003, p. 380).

We report two experiments in which we examined the relation between response, task, and stimulus specificity. The experiments differed in the task or contextual changes we used (explained more fully in the *Experimental design* section for each experiment), but both involved long-term repetition priming of multiple object exemplars and included our examination of the effects of changes in task, and of constant versus switched responses (yes–no decisions regarding varied semantic classification questions) across multiple repetitions. However, before further characterizing these experiments, we provide a more detailed description of the two previous studies that yielded contrasting conclusions regarding the stimulus specificity of decision- or response learning.

Stimulus Specificity and Decision or Response Learning

Using a task-switching paradigm, Waszak et al. (2004) required participants to alternate between a picture-naming and a word-reading task. Both tasks were performed on "Strooplike" stimuli that contained words superimposed on line drawings (e.g., the word *throat* superimposed on a line drawing of a foot, or the word *steamship* superimposed on a line drawing of an airplane). The stimuli were taken from a total of six semantic categories such as clothing, animals, and furniture, with between 6 and 24 items per category. Waszak et al. (2004) compared performance with three sets of items: picture–word stimuli that had been presented previously in the competing picture-naming task, in which switch costs were expected to be high (what we term the *identity-primed competing task condition*), picture–word stimuli that were only presented in the word-reading task, in which switch costs were expected to be low (*comparison task condition*), and picture–word stimuli that were only presented in the word-reading task but that were semantically related to items already presented in the picture-naming task (*semantically related competing task condition*). The experiment began with a picture-naming block, in which the identity-primed competing task condition stimuli were presented twice, after which there were alternating mini blocks of two trials each requiring either word reading or picture naming (e.g., PP-WW-PP-WW-PP). This entire cycle was repeated four times.

The results showed, as expected, that response times were significantly longer when there was a task switch than when there was not a task switch, and this was true for all of the conditions. More important, this effect was also moderated by condition, such that task-switch costs were the greatest for the identity-primed competing task condition, intermediate for the semantically related competing task condition, and least apparent for the comparison task condition.

Waszak et al. (2004) noted that the semantically related stimuli within a category likely shared perceptual features and that, in general, the magnitude of the task-switch cost perhaps "increases with the degree of feature overlap between the current stimulus and the stimuli that [have] already appeared in a competing task" (p. 1031). Developing this idea further, Waszak et al. noted that even the items presented in the comparison task condition shared some similarity with items that had been presented in the competing task condition.

> Both types of items were picture-word compounds of a particular size and drawing style, both appeared at the same location on the screen, both required a vocal response, and so forth. If we can assume that perceptual, semantic, and contextual features of a given stimulus–response episode are encoded into a coherent event representation [. . .] then even [the comparison task condition] items must have been primed to at least some degree—in the sense that some of their features were already associated with the competing naming task. (Waszak et al., 2004, p. 1031)

In contrast, using an object-priming paradigm, Schnyer et al. (2007) presented pictures of individual common objects (e.g., bear, apple, television) one or three times during a study phase; the participant's task was to decide whether each object was bigger than a shoe box (yes–no). In the test phase, which included only items that had been presented three times previously, they examined the effects of performing either the same task judgment as at study (that is, deciding whether the object was bigger than a shoe box) or the *reversed* judgment (deciding whether the object was *smaller* than a shoe box). In addition, whereas one half of the objects that were presented at test were the same object exemplar as had been presented at study, the remaining items were a different exemplar (e.g., a different television from that shown during the study phase).

Consistent with earlier studies on perceptual specificity (e.g., Cave & Squire, 1992; Koutstaal, 2003; Marsolek, 1999), the overall level of priming was greater for same exemplars than for different exemplars; however, most importantly, there was a priming "cost" (decrement in facilitation) as a function of the change in the decision cue (same decision cue vs. inverted decision cue) *only* *for the same exemplars. The different exemplars showed equivalent priming for the original task and for the reversed decision.* Therefore, in marked contrast to the conclusions reached by Waszak and colleagues (2004) on the basis of their task-switching paradigm results, Schnyer et al. (2007) concluded that there was "no evidence that the portion of priming sensitive to decision cue inversion (and indicative of response learning) transfers across different visual exemplars of a studied item" (p. 1477) and that "response learning in an object classification task is perceptually highly specific and is not preserved across visually similar exemplars" (p. 1478).

The Present Experiments and Stimulus, Task, and Response Specificity

We used a visual object-priming paradigm in which we varied the perceptual form of the objects that were presented (exemplar type), the task or semantic classification judgment that was performed while viewing the objects, and the particular response or decision to the tasks. To manipulate priming specificity at the *stimulus level* (i.e., the perceptual identity of the stimuli), our participants provided a series of task-relevant responses to images of common objects that were repeated in either the same form or as one of up to four different variants of that exemplar category (i.e., different instances of cows, guitars, or airplanes). We manipulated specificity at the *task and/or context level* (involving the semantic or conceptual features accessed by the participants) by examining performance across different classification task conditions (e.g., making judgments of the size of the objects compared with a given referent size, or whether the object contained metal). For instance, participants who invoked the task-relevant semantic associations for an airplane may see this same airplane (or a different airplane) repeated in a subsequent block of trials, but under a different and uncorrelated task context. Finally, and perhaps most centrally, we examined priming at the *response or decision level* by examining the effects of repetition when the yes–no decisions that were provided by participants to a particular object or object category across the classification decision tasks were either the same or varied ("switched") across repetitions and/or tasks.

Several previous studies have shown that behavioral priming extends across object exemplars within a category, although greater priming typically is obtained for same than for different exemplars (Cave & Squire, 1992; Koutstaal, 2003; Koutstaal et al., 2001; Marsolek, 1999; Simons, Koutstaal, Prince, Wagner, & Schacter, 2003). The vast majority of these studies, however, used only two exemplars per object category (though see Bartram, 1974, for an early exception). Here, we included five different exemplars in each object category. This allowed us to examine possible interactions between exemplar type (i.e., repeated in the same or different form) and task requirements (i.e., consistent or varied classification tasks across all trials) across multiple object exemplars and provided a highly sensitive test of the extent to which response learning is extremely stimulus specific (as suggested by the outcomes of Schnyer et al., 2007) or generalizes across perceptually and conceptually related items (as suggested by the results of Waszak et al., 2004, albeit in a task-switching rather than long-term repetition priming paradigm).

To examine the behavioral facilitation attributable to repeatedly accessing the same semantic or conceptual features, researchers have traditionally relied on cross-task experimental designs (e.g., Bruce, Carson, Burton, & Ellis, 2000; O'Kane, Insler, & Wagner, 2005; Thompson-Schill & Gabrieli, 1999; Vriezen et al., 1995; Xiong et al., 2003). These approaches allow for a comparison between performance on an initial study task (e.g., pleasantness–unpleasantness) and on a later test task (e.g., relative size) when the stimulus is held constant but the classification task differs. Task changes have been known to lead to impaired processing of repeated objects for some time (Jersild, 1927; Spector & Biederman, 1976). Because the same stimuli are used in most cross-task designs in both experimental phases, some researchers have suggested that the features that were once relevant in an old task interfere with the ability to select features relevant to the current task-related goal (Rubin & Koch, 2006).

There remains a good deal of debate over the component processes and contextual markers that become associated with performing a given task. Merely encountering stimuli in the absence of any clear task demands does not necessarily lead to priming effects. In an influential early demonstration of the context dependency of repetition priming, Oliphant (1983) reported that an initial, incidental exposure to a particular stimulus (in this case, *high*-frequency words) was insufficient to invoke later processing gains—only when the stimulus was reencountered under the guise of the same task did Oliphant observe robust behavioral facilitation (see also Holbrook et al., 2003). More recently, Bowers and Turner (2003) examined repetition priming for *low*-frequency words and observed significant cross-task priming that was, however, apparently not orthographically mediated (priming was equivalent for written-to-written and spoken-to-written tasks) but appeared to predominantly involve phonological facilitation. In general, consistent with a "transfer appropriate processing" approach (Roediger, Weldon, & Challis, 1989), the majority of findings point to the importance of the degree of congruency or similarity between the lexical, semantic, or conceptual components activated during initial exposure, and those reactivated on later encounters, with greater repetition-related facilitation found with same than with unrelated classifications and increasing transfer with increasing congruency or similarity across different classification tasks (e.g., Thompson-Schill & Gabrieli, 1999; Vriezen et al., 1995; Xiong et al., 2003).

The final dimension of specificity that we considered was that of the participant's response to the object or to categorically related exemplars. For example, in an early study on the effects of task and response specificity, Vriezen and colleagues (1995, Experiment 6) reported significant priming only for consistent responses across two different size classification tasks (i.e., "yes" or "no" responses for both tasks) and not for inconsistent responses (i.e., "yes → no," or "no → yes" responses). Although such response specificity of priming may, in part, reflect alterations at the level of the motor response mapping itself (i.e., consistent right- or left-hand key presses in response to changing tasks, cf. Horner & Henson, 2009), a number of studies have provided evidence that the motor response, per se, plays little to no role in behavioral priming indices (Dennis & Schmidt, 2003; Logan, 1990; Schnyer et al., 2007). Findings suggest that the relevant associations are between a stimulus and a "stimulus interpretation" (Logan, 1990) or more abstract (e.g., affirmative vs. negative) decision (Horner &

Henson, 2008; Schnyer et al., 2007; Waszak et al., 2003) rather than a lower level motor response. For example, Rothermund and colleagues (2005, Experiment 2) found facilitation for repeated responses but impairment for switched responses—even when the response mode changed from verbal to manual between the prime and the probe. This finding led them to conclude that "priming effects are mediated by an automatic retrieval of responses that is located at an abstract or categorical level rather than at the level of specific motor responses" (p. 487).

Using an object-priming paradigm, Dobbins and colleagues (Dobbins et al., 2004; Schnyer et al., 2007; Schnyer, Dobbins, Nicholls, Schacter, & Verfaellie, 2006) have provided evidence of "instance-based" response- or decision-learning mechanisms that may substantially contribute to priming. These studies demonstrated significant attenuation of priming when decisions were reversed between the initial presentations and the subsequent test trial. Of importance is that this marked reduction in priming occurred even (a) when an identical object was shown and (b) when the classification decision on both the initial and switched trials concerned similar object property information (judging the object's relative size). Notably, however, these studies also involved *reversal* of the required classification decision. Participants were initially asked to make "larger than" judgments and then to make "smaller than" judgments. This requirement to perform the *opposite judgment* task on "switch" trials may have generated interference that undermined or masked conceptually or perceptually based priming. Thus, it is essential to evaluate whether behavioral priming is similarly reduced by decision changes that do not require reversal of the classification decision.

Central to our approach is the way in which our task judgments address task switching and response mapping. Whereas Dobbins et al. (2004) and Schnyer et al. (2007) merely reversed the direction of their question with regard to a static size referent (larger than/smaller than a shoebox), we adopted a novel task design in Experiment 1 of the present article in which the classification task remained constant, whereas a *changing referent* allowed for both maintained and switched responses to the classification (cf. MacDonald, Joordens, & Seergobin, 1999; Schneider & Logan, 2007). Participants made either "larger than" or "smaller than" judgments to pictures of common objects (e.g., airplanes, cookies, chairs) across a series of five experimental blocks. Depending on their experimental condition, some participants were charged with making these judgments with regard to a variable size referent. For example, although a chair may be larger than a $1' \times 1' \times 1'$ size referent in one block, it may not be larger than the $5' \times 5' \times 5'$ referent on a subsequent block. Therefore, the correct response for a particular item may vary depending on the current size referent assigned to that block, but the higher order construal of the task requirements is held constant throughout. We also examined in Experiment 1 the specificity of the stimulus representations that contribute to decision-change disruption of priming by testing whether such disruption transfers to perceptually and conceptually similar exemplars of previously presented objects. As noted, unlike earlier investigations of stimulus specificity in repetition priming (e.g., Koutstaal et al., 2001; Marsolek, 1999), we examined responses for up to five different exemplars of an object category. This enabled the assessment of repetition-induced facilitation, and any decision-change-related disruption, when the presentation of different exemplars encouraged the abstraction of commonalities shared between multiple objects within a category, as well as when the extraction of item-specific details was promoted by presenting the same object exemplar repeatedly. In contrast, in Experiment 2, as detailed later, we used five different semantic classification tasks.

To briefly anticipate our key findings: In both experiments, we found that there were significant effects of response specificity and that these effects *generalized across exemplars*, indicating at least some degree of perceptual and/or conceptual abstraction in the episodic representations that mediate stimulus-to-decision responses. Stated differently, in both experiments, a switch in the provided classification response from an initially provided response (*yes* to *no*, or vice versa) eliminated priming both for the same object and for perceptually/conceptually similar exemplars of the object; furthermore, this disruption of priming was observed even though the nature of the classification decisions themselves differed across the repetitions.

Experiment 1

Method

Experimental design. The experimental design included one between-subject factor: task condition (constant size referent vs. varied size referent). There were three within-subject factors: object exemplar type (same exemplar, different exemplar), repetition number (from Rep-1 [novel] to Rep-5), and response type (determined according to participants' classification responses during testing, as described in the *Switch analyses* section). In the constant referent condition, participants evaluated the size of presented objects with reference to a $3' \times 3' \times 3'$ box throughout all blocks. In the varied condition, the size of the reference box changed in a nonlinear way across successive blocks, either in the order of 4′, 2′, 5′, 1′, and 3′ or its reverse. In addition, one half of all participants in all conditions made "smaller than" judgments throughout the entire experiment, whereas the other half of the participants made "larger than" judgments throughout the entire experiment. Given that the same pattern of results was found for both of these judgments, here we present analyses combined across these groups.

Participants. Eighty-four young adults (mean age = 20.8, SD = 2.9; mean years formal education = 14.9, SD = 1.8) took part in Experiment 1. No participants had contributed to the previous normative studies (described in the *Stimulus materials* section), and all reported normal or corrected-to-normal vision and color vision and were native speakers of English. Participants took part for course credit or for a small monetary compensation.

Stimulus materials. The stimulus set consisted of detailed color photographs or drawings of 630 common objects, displayed against a white background (see Figure 1). This set included five different exemplars of 126 different object categories (e.g., airplanes, cows, trees). These stimuli were selected on the basis of a preexperimental normative study (N = 25, mean age = 19.0, SD = 1.8) in which participants viewed the entire set of objects and provided names and typicality ratings for each item. Participants were asked to name each object and to evaluate how typical the object was of that type or category of object. The objects within each category elicited highly consistent naming responses (mean within-category name agreement = 98.6%, SD = .04), and par-

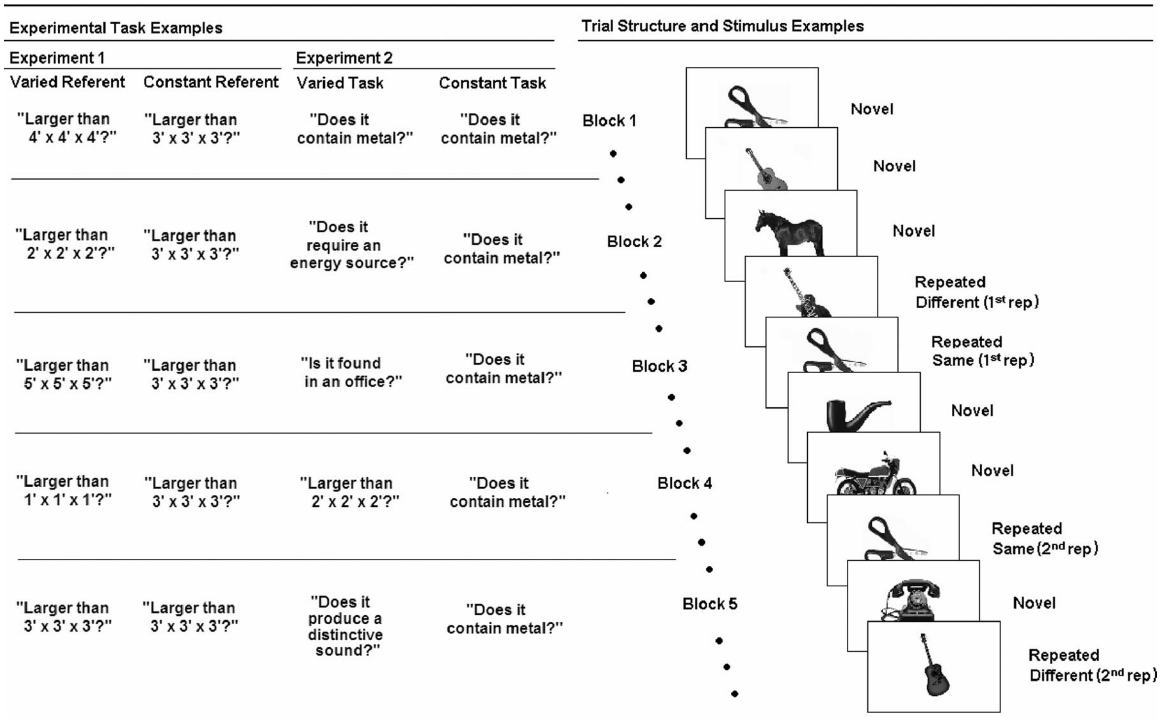

Figure 1. Experimental design for Experiments 1 and 2. Shown are example task orders across the five experimental blocks and stimulus examples for items presented for the first time (novel), repeated in the same form (same exemplar), or repeated in a different form (different exemplar). A total of 360 items were presented, and no items were repeated within the same experimental block, yielding an average lag of more than 25 items between repetitions of the same or different exemplar. rep = repetition.

ticipants rated all stimuli as typical of their category (mean within-category prototypicality rating = 4.0, *SD* = 0.5; ratings on a 5-point Likert-type scale, where 1 indicated the object was *not at all* and 5 indicated that it was *exactly* as one would expect of an object of its class).

To ensure that the stimulus set contained roughly equivalent numbers of various object sizes, an additional normative study ($N = 10$, mean age = 24.0, $SD = 2.3$) was undertaken to establish the perceived size of each stimulus as it exists in the real world. Participants gave either *larger than* or *smaller than* judgments for all 630 items across all five reference-box sizes. By averaging the block numbers in which the response changed, a mean "switch point" for each object category was established. For instance, if most participants making a smaller than judgment stated that the clothes hanger was smaller than a 2-foot (.6096-m) box but then larger than a 1-foot (.3048-m) box, then the switch point for that item was defined as the block in which the majority of responses changed (here, the 1-foot box). These expected switch points were also used later as an index of participants' accuracy in completing the experimental task, described in the *Outlier screening* section.

Counterbalancing of the stimuli for the experiments was achieved by first dividing the 126 object categories into major semantic groupings (e.g., animate objects, clothing, food). Moreover, the mean switch points obtained from the prior normative study were used to ensure that each counterbalancing set included items that were likely to elicit approximately equivalent numbers of "switched responses." Seven counterbalancing sets were created (Sets A–G), each approximately equated across semantic groupings and expected switch point. These sets were rotated across blocks and repetition conditions within the experimental session (see Figure 2 for one counterbalancing example). Additionally, two variants were generated for each of the seven counterbalancing lists by assigning one half of the items in a set to the same-exemplar condition and the other half to the different-exemplar condition, and vice versa. Alternative orderings of these 14 lists were then created by randomizing the presentation order of the individual stimuli within each, providing a unique counterbalanced list for each participant. Each object appeared a maximum of five times throughout the course of the experiment, and could only appear once during each particular block. To reduce the correlation between the number of times an object/object category was presented and time of occurrence within the session, some item sets introduced earlier in the experimental session were not repeated on all blocks but "skipped" a block (see Figure 2). For example, one set of items first introduced (as novel items) in Block 2 did not repeat again until Block 4.

The mean lag between repeated presentations for same exemplars or different exemplars within a given category varied, depending on the total number of presentations of that stimulus (ranging from 1 to 5), and whether the given item set repeated on all blocks once it was introduced (e.g., Set A in the counterbalancing shown in Figure 2) or "skipped" a block (e.g., Set C in the counterbalancing shown in Figure 2). As shown in Figure 2, the blocks with primed trials included between 54 and 108 items, with

	Block 1		Block 2		Block 3		Block 4		Block 5	
	N items	*Set*	*N items*	*Set*	*N items*	*Set*	*N items*	*Set*	*N items*	*Set*
Rep 1 (Novel)	54	A, B, C	18	D	18	E	18	F	18	G
Rep 2	none		36	A, B	18	C	18	D	18	E
Rep 3	none		none		18	A	36	B, C	18	D
Rep 4	none		none		none		18	A	36	B, C
Rep 5	none		none		none		none		18	A
Trials / block	**54**		**54**		**54**		**90**		**108**	

Figure 2. Example of the counterbalancing schema used for Experiments 1 and 2. Shown are the five experimental blocks in which each of the seven item sets (A – G) were first introduced (Novel or Rep 1) and the points at which later repetitions of the item sets occurred (Rep 2–Rep 5). Each item set was further divided into two subsets, such that for one subset the same exemplar repeated each time, and for the other, a different exemplar was presented on each occasion (and vice versa for other participants). Across participants, all item sets appeared in each of the possible positions shown. Rep = Repetition.

no repetitions within a block, yielding an average lag of more than 25 items between repetitions of the same or different exemplar.

Procedure. All participants were tested individually, in a single experimental session, lasting approximately 1 hr. Participants first gave informed consent and then were instructed in the experimental procedure. Participants were asked to make their judgments with regard to the real-world referent of the pictured object (rather than the picture itself) and were asked not to perform any mental manipulation of the object, such as folding (which could impact judgments of relative size). The importance of both accuracy and speed were stressed. Five practice trials, appropriate to the participant's condition, were administered after the instructions. Participants indicated their yes–no decisions via designated keys (keys *b* and *n*) on the computer keyboard, using the index and middle fingers of their dominant hand. The same yes–no response mapping was maintained throughout the experiment.

Stimuli were presented on a 19-in. (48-cm) color monitor, centered, using E-prime (Psychology Software Tools, Inc., 2002, Pittsburgh, PA).[1] Objects were presented for 1 s, interspersed by visual fixation trials of approximately 1.5 s. There were a total of 360 stimulus presentations over five experimental blocks. An instruction screen before each block informed participants of the required judgment (referent size) for the following trials; following the instruction screen, a photograph depicting the relevant referent-box size was shown. After completing all trials, participants were debriefed.

Switch analyses. Each participant's responses were classified into several response categories on the basis of how they had responded, across repetitions, to the same items (same exemplar) or to other items within the same object category (different exemplar). Trials in which item responses were invariant over repetitions were considered *nonswitch* trials. These included the first size judgment made about a particular object, which served as a baseline response, as well as subsequent trials in which the initial judgment for that object/object class was continuously maintained. Trials in which the response for the current object class differed from that given for its prior presentation were considered *switch* trials (e.g., when the response given for the first presentation of an object was yes and the response provided on the second trial was no). Future trials in which the response was maintained after a switch were classified according to their distance from the switch, and all other possible instances of switches or maintained responses also were coded.

Priming scores were calculated by subtracting the average response reaction times (RTs) for each response category, and for all primed trials together, from the average response RTs for novel items, separately for same and different exemplars. Proportional priming scores were computed to control for differences between experimental tasks (e.g., Lazzara et al., 2002; Schnyer et al., 2007) and were determined by dividing the priming scores for a given response category by the appropriate RTs for novel items [i.e., proportional priming = (novel RT – primed RT)/novel RT]. However, Table 1 also presents the priming scores in milliseconds for the proportional priming data that are presented graphically in Figure 3.

Results

Outlier screening. As noted above, preexperimental normative efforts provided us with an index of the expected switch points for each exemplar category. We used these data to determine participant accuracy, in that we compared the data set collected in Experiment 1 with the "standards" established by our pilot participants. Participants who did not achieve greater than 90% accuracy throughout the task were replaced. This criteria lead to the exclusion and replacement of one participant for whom accuracy was well below our expected accuracy guidelines, and their data are not included in the analyses reported here. We further screened each participant's data for individual responses that exceeded two standard deviations above or below the mean RT for all items within a particular condition, and these responses were also removed from the data set. Given that exclusion of these items made analysis of switch history for that exemplar or category inappropriate, we removed all subsequent responses made to that particular exemplar or category (mean number of items excluded per participant = 2.7). Finally, initial analysis of the data suggested some fatigue effects in the 5th block of trials, as evidenced by an overall pattern of delayed responding across all participants and tasks. Furthermore, relatively few exemplars were repeated five times into the 5th block (see Figure 2), limiting the sensitivity of an analysis for the 5th repetition of these items. Therefore, we focused only on RT data from the first four blocks. In all analyses reported below,

[1] Information regarding Psychology Software Tools can be found at www.pstnet.com

Table 1
Priming Scores (in Milliseconds) for Experiments 1 and 2

	Same exemplar			Different exemplar		
Experiment 1						
All response categories	Block 2	Block 3	Block 4	Block 2	Block 3	Block 4
Referent constant	36	63	63	24	43	48
Referent changes	44	29	47	23	25	27
Nonswitch responses alone	Block 2	Block 3	Block 4	Block 2	Block 3	Block 4
Referent constant	38	74	77	35	59	62
Referent changes	64	53	69	35	49	42
Experiment 2						
All response categories	Rep 2	Rep 3	Rep 4	Rep 2	Rep 3	Rep 4
Task constant	46	67	73	40	41	53
Task changes	18	43	38	17	21	19
Nonswitch responses alone	Rep 2	Rep 3	Rep 4	Rep 2	Rep 3	Rep 4
Task constant	54	80	82	59	57	66
Task changes	45	51	52	24	25	41

Note. Rep = Repetition.

noninteger degrees of freedom reflect the Greenhouse–Geisser adjustment for nonsphericity.

Responses to novel items. After screening for outliers, we first examined whether there were effects of task condition (constant referent or varied referent) and of experimental block (from Block 1 to Block 4) on response times to novel (unprimed) items. A 2 (task condition) × 4 (block) analysis of variance (ANOVA) on RTs for novel items showed no effect of condition ($F < 1$) but did show a significant effect of experimental block, $F(3.02, 163.20) = 8.64$, $p < .001$. Overall, the mean response times to the novel items in the four blocks containing primed items were 714, 683, 692, and 677 ms. Given that there were significant differences in novel RTs across blocks, we calculated proportional priming scores in Experiment 1 using the equation cited above by subtracting the observed RT for a primed trial from the novel RT for other items in that same block (e.g., Novel RT for Block 2 − Same Primed RT for Block 2; Novel RT for Block 2 − Different Primed RT for Block 2) and dividing the resulting values by the novel RT for that block. As all stimuli were novel (presented for the first time) in Block 1, the proportional priming analyses focus on Blocks 2, 3, and 4.

Proportional priming. Figure 3 presents the priming scores for the two task conditions (referent constant, referent changes) and stimulus types (same exemplar throughout or different exemplars throughout), separately for Blocks 2 through 4 (B2, B3, and B4). The clear bars show proportional priming when separately considering the subset of all trials that had constant responses throughout (that is, nonswitch responses only); the solid bars show proportional priming when combining across all response categories (e.g., nonswitched and switched yes–no responses). As can be seen from Figure 3, the magnitude of priming is greater when considering only the nonswitch responses versus all response categories, regardless of exemplar type and referent task. Priming also was greater when the same exemplar was presented throughout than when different exemplars were presented throughout.

A 2 (referent condition) × 3 (experimental block) × 2 (exemplar type) mixed factor ANOVA on all responses revealed a significant effect of exemplar type, $F(1, 54) = 12.75$, $p < .001$), Cohen's $d = 0.97$; a marginal effect of referent condition, $F(1, 54) = 3.72$, $p = .06$, $d = 0.52$; and no interactions ($F < 1.4$). Across all responses, priming was significantly greater for same exemplars ($M_{\text{same}} = .06$) than for different exemplars ($M_{\text{diff}} = .04$)

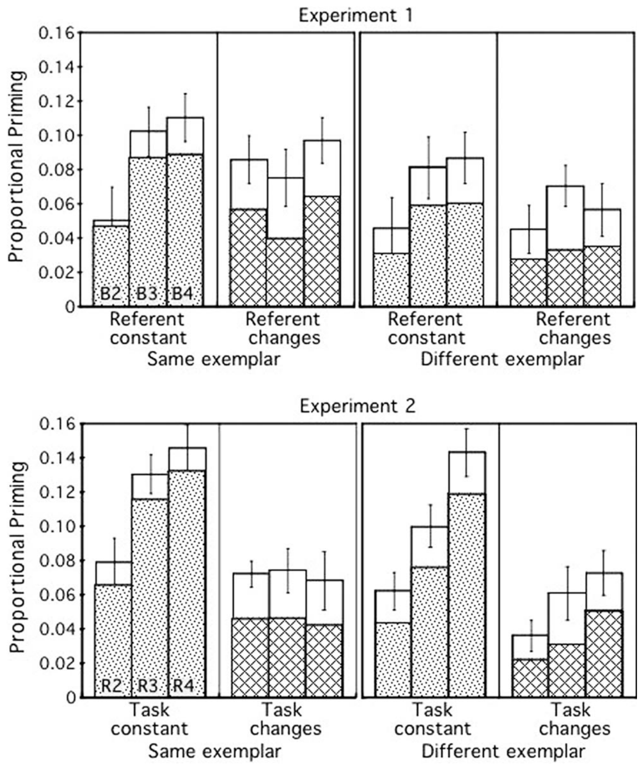

Figure 3. Proportional priming for all response categories, including both consistent and varied responses to repeated items (filled bars) and for nonswitch responses alone, for which priming would be maximized in the absence of a response switch (clear bars). Proportional priming is shown separately by referent or task condition (constant/changes) and exemplar type (same/different) for Blocks 2–4 (B2–B4, Experiment 1, top panel) and Repetitions 2–4 (R2–R4, Experiment 2, bottom panel). Error bars show the standard error of the mean.

and somewhat greater when participants made size judgments with the constant size referent throughout (M_{constant} = .06) than when the size referent changed (M_{varied} = .04).

A subsequent ANOVA on proportional priming scores for only nonswitched responses revealed significant effects of experimental block, $F(2, 108) = 3.15$, $p = .047$, and of exemplar type, $F(1, 54) = 11.23$, $p < .001$ (M_{same} = .09, M_{diff} = .06), $d = 0.91$, with now no main effect of condition ($F < 1$) and no interactions ($F < 1.7$). One-sample *t* tests revealed significantly above-zero priming for all nonswitch trials, for both same and different exemplars, and for both the referent-constant and referent-varied conditions regardless of experimental block, all $ts(27) > 2.53$, $p < .018$. These data indicate that nonswitch trials yielded faster responding to repeated stimuli, regardless of whether the size referent remained constant or changed (see open bars in Figure 3). Within-subject contrasts also showed a significant linear block effect, $F(1, 54) = 4.37$, $p = .041$, Cohen's $d = 0.57$, reflecting increasing priming across blocks.

To examine the effects of a *response change* on proportional priming scores, we analyzed data from the varied size-referent condition separately with a 2 × 2 ANOVA, including response category (nonswitched vs. first-switched response from Block 2) and exemplar type (same exemplar or different exemplar) as within-subject factors. This analysis revealed a large effect of response category, $F(1, 26) = 16.76$, $p < .001$, $d = 1.61$; no significant effect of exemplar type, $F(1, 26) = 2.50$, $p = .13$, $d = 0.62$; and no interaction ($F < 1$). As shown in Figure 4, there was substantial decision-change priming disruption on the trials on which participants made a different response from the one they had made on the previous presentation of an object—even though participants maintained the same higher order construal of the task across all trials (that is, they were always making larger than or smaller than size judgments, with only the referent for those judgments changing). One-sample *t* tests for the first switched responses demonstrated priming disruptions both for objects that were identical to those initially presented (M_{same} = –.04), $t(27) = -1.46$, $p = .16$, and for different exemplars (M_{diff} = –.06), $t(27) = -1.82$, $p = .08$, with the negative values showing a tendency toward *response change impairment*, involving slower responses to primed switch-trial items than to novel items. Analysis of further response changes (that is, additional switch trials after the first switch) showed similar priming disruptions, including significant response change impairment for the first switched responses for both same and different exemplars in Block 3, $t(24) = -2.47$,

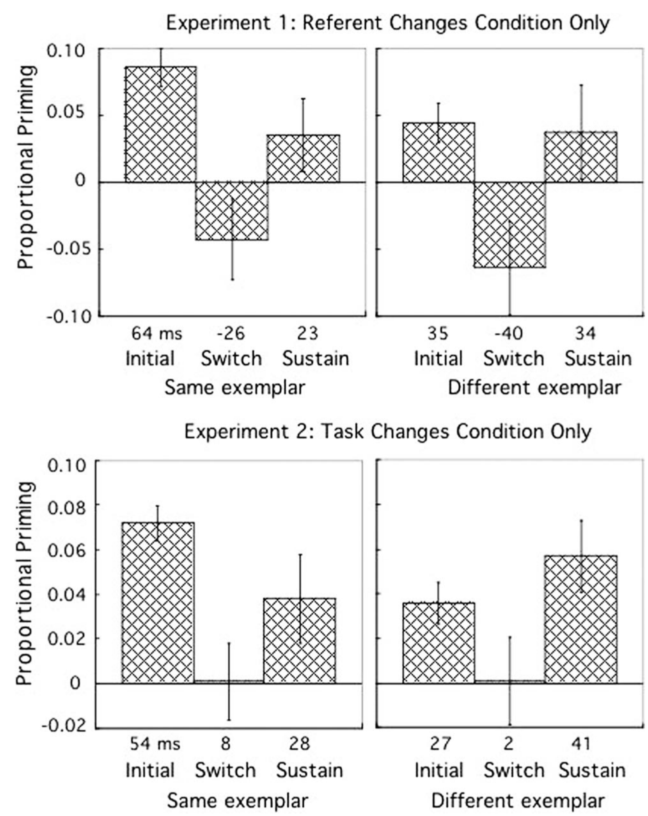

Figure 4. Proportional priming for initial responses, switch responses, and subsequently sustained (maintained) responses by exemplar type for the referent-changes (Experiment 1) and task-changes (Experiment 2) conditions only. The third bar shows proportion priming for the average of the first and second maintained responses following a switch from Blocks 3 and 4 (Experiment 1) or Repetitions 3 and 4 (Experiment 2). Also shown is the mean priming score in milliseconds for the response categories. Error bars show the standard error of the mean.

p = .02, and, $t(24) = -2.46$, p = .02, respectively; all other response switch trials in Blocks 2 through 4 also showed disruption of priming, yielding proportional priming scores that were not different from zero.

In order to identify the effects of maintaining a consistent response after an initial response change, we performed a 3 × 2 mixed factor ANOVA on proportional priming scores in the referent-varied condition, including response category (nonswitch, first switch, and first maintained response, from Blocks 2–4, respectively) and exemplar type as within-subject factors. There was a significant effect of response category, $F(1.29, 14.16) = 6.80$, $p = .005$, with no effect of exemplar type ($F < 1.3$) and no interaction ($F < 1.2$). Within-subject contrasts revealed a significant quadratic effect, $F(1, 11) = 7.65$, $p = .018$, reflecting a pattern of switch-related decrements in priming, with subsequent partial recovery of priming after the response was maintained (mean priming for initial switch-sustain response categories = .07, –.12, and .02, respectively). Calculation of subject-specific averages for all trials in Blocks 3 and 4 on which the new response was sustained for a second and/or third trial showed modest positive priming for both same ($M = .04$, $N = 22$) and different ($M = .04$, $N = 24$) exemplars. Although these sustained responses did not show significant positive priming (largest $t = 1.30$), there was no longer response change impairment, and the means approached those for all responses after a single repetition for this condition, suggesting that priming may gradually recover after a response or decision change if the new response is then sustained across subsequent trials, even though one of the key parameters of the task (the specific referent involved) continues to change on each repetition.

Discussion

Experiment 1 demonstrates that changes in the classification (yes–no) decisions that participants made to repeated objects led to a marked and significant disruption of priming. Equally important, these decision-change disruptions of priming *generalized across object exemplars:* Disruption of priming as a result of a changed classification decision (i.e., yes then no, or vice versa) occurred both for object exemplars that were identical across repetitions and for different variants (exemplars) of a given object. Together, these findings lend strong support to the view that priming is, at least in part, mediated by stimulus–response or stimulus–task bindings (Hommel, 1998; Logan, 1990) and furthermore that such stimulus–response or stimulus–task bindings are, to some extent, abstract, in that they generalize to categorically and perceptually similar instances.

These outcomes are consistent with the claims of Waszak et al. (2004), derived, however, from a task-switching paradigm. They clearly show that across-exemplar generalization of stimulus–response bindings also occurs for single objects (in addition to superimposed compound word-and-picture stimuli) and is observed in a standard long-term repetition-priming paradigm. In contrast, these outcomes are inconsistent with the findings of Schnyer et al. (2007) that response learning is highly stimulus specific. In the General Discussion section, we consider some possible methodological and other reasons for the divergence of our present results from those reported by Schnyer and colleagues. However, we defer that discussion until after Experiment 2, which further examines the degree to which decision learning transfers to perceptually and conceptually related stimuli under conditions involving several entirely different semantic classification tasks (rather than the same task but with a varied referent, as here).

The present findings also support perceptual specificity effects documented in previous research. Although robust priming effects were observed for both repeated-same and repeated-different items, priming scores for repeated-different items were found to be significantly smaller than for repeated-same items, supporting previous findings of processing differences for abstract and specific visual form information (e.g., Cave & Squire, 1992; Koutstaal et al., 2001; Simons et al., 2003). Note that these findings also provide counter evidence to a possible alternative account of the decision-change outcomes, namely that we observed transfer of stimulus-decision mappings to different exemplars because our "different exemplars" were really quite perceptually similar to the "same exemplars." If that were the case, then one might not expect to see attenuated positive transfer for the different exemplars, contra our findings.

The response-learning account was also more indirectly and generally supported by our observation of a trend (effect size d = 0.52, p = .06) toward greater overall priming in the constant referent condition than in the varied referent condition, and by the further finding that there was no longer any effect of condition when considering only the maintained (nonswitch) responses alone. Notably, these findings, and more strongly, the results of our response-switch analyses, demonstrate that the detrimental effects of a response switch may arise even under conditions that do not require a *reversal* of the *semantic judgment* to be made. Whereas any one participant in our study always made either *larger than* or *smaller than* judgments with respect to a changing size referent, a change in the response made by the participant was accompanied by elimination of the facilitative effects of prior encounters with the object.

Remarkably, when there was a response change for a particular item, performance was numerically *worse* (slower) than it had been during the item's initial presentation. These data suggest that negative priming disruptions do not necessarily require an overt change in the response requirements or task instructions, nor do these effects only arise under conditions in which the status of a particular stimulus (as a distractor or a target) changes across presentations, as is common (albeit not invariably true) in the negative priming literature (Waszak et al., 2003, 2004; Waszak, Hommel, & Allport, 2005).

One possible explanation for these effects may be based on the maintenance of constant higher order task demands, in that participants consistently performed the same size judgment classification task throughout the blocks (e.g., deciding whether each presented object, in the real world, was larger than the specified referent for that particular experimental block). If it is the case that both S–R and S–task associations are created when a particular object is initially presented (e.g., Waszak et al., 2003), it is yet unclear whether one of these associations has a larger impact than the other or whether these bindings are indeed separable from one another.

However, it is possible that prior S-task associations may account for these effects. When the same or a similar object is repeated but the size referent changes, certain elements of the original S-task association may be automatically activated, leading to significant processing confusion. Indeed, this same pattern of decision change-related impairment, involving slower rather than faster responding to repeated compared with novel items, was observed in a third, continuously varied referent condition that we tested (but, in the interests of space, did not report here), in which the task was again held constant throughout, but the particular size referent (from $1' \times 1' \times 1'$ to $5' \times 5' \times 5'$) increased or decreased in stepwise fashion over the course of the blocks. Alternately, performance declines may simply reflect a change in the S–R association, as the correct response for a particular item often changes when the size referent varies. It is important to note, however, that few long-term repetition priming studies have observed priming disruptions to the degree reported here, especially under conditions in which S–R bindings alone are under examination. Therefore, it is possible that the combination of interference from both S–R and S–task associations lead to the disruptions reported here.

Experiment 2 also, in part, provides a test of this suggestion. In Experiment 2, we used the same general procedure as in Experiment 1, except that we chose *five different semantic classification tasks so that the tasks varied maximally from one block to the next.* If S–task and S–R bindings each have an additive effect on priming disruptions, then the decreases in reaction times between novel and repeated presentations should be even more pronounced when the task changes dramatically between blocks. If, however, priming is not disrupted to the same degree as in Experiment 1, then it may instead suggest that there is something unique about the S–task association formed when the task itself varies little throughout the course of the blocks (e.g., one is making relative size judgments throughout), whereas the decisions to be made must switch due to changes in one particular parameter or aspect of the task (e.g., the referent point against which the relative size judgments are to made).

Experiment 2

Whereas Experiment 1 involved the repeated presentation of object exemplars while maintaining a constant higher order task construal, in Experiment 2 we sought to examine repetition priming under conditions that maximized the classification task differences between stimulus encounters, thereby both encouraging participants to extract more abstract representations of the stimulus form and minimizing the extent to which reliance on previously determined classification decisions was likely to prove beneficial to the present task. As with the prior experiment, in Experiment 2 our set of stimulus items were repeated in either the same or a different form as during their original presentation, with some objects repeatedly presented in the same format throughout all of the blocks (same exemplar condition), and others varied throughout (different exemplar condition). In this case, however, each of the five experimental blocks corresponded to a different and uncorrelated semantic classification task. To determine whether the five semantic judgments were, on average, uncorrelated with one another, a normative study ($N = 12$) was performed prior to Experiment 2 on the entire stimulus set, revealing an average pairwise correlation of .12 between the responses given on the various classification judgments. The five semantic classification tasks that we used differed in multiple respects, and probed information about the typical location of the object ("Is it found in an office?"), its material composition ("Does it contain metal?"), the object's typical size ("Is it larger than a $2' \times 2' \times 2'$ box?"), its functional characteristics ("Does it require energy?"), and associated sensory modality information ("Does it produce a distinctive sound?").

Method

Experimental design. As before, two between-subject conditions were used; in the constant-task condition, the same judgment (e.g., "Does it contain metal?") was repeated across all blocks, whereas in the varied-task condition, participants made different judgments in each block (see Figure 1). In the varied condition, the five semantic judgments were counterbalanced across lists so as to approximately equate the number of temporally contiguous combinations between any two judgments (e.g., "found in an office?" for one experimental block, immediately followed by "requires energy?" or vice versa). For the constant condition, the five judgments were counterbalanced such that, overall, a nearly equal number of participants performed that particular task throughout all trials (4 participants performed each of the five classification tasks, except for the office classification decision, for which 5 participants performed this judgment throughout).

Participants. The participants were 42 individuals (mean age = 20.9, $SD = 3.3$, mean years education = 14.8, $SD = 1.6$); they had not contributed to the previous normative studies, nor had they participated in Experiment 1. All participants reported normal or corrected-to-normal vision and color vision, were native speakers of English, and took part for course credit or for a small monetary compensation.

Procedure. Apart from the changes in the classification tasks, the procedure was the same as that used in Experiment 1.

Results

Outlier screening. As before, we removed RTs exceeding two standard deviations from the data set (mean number of items excluded per participant for Experiment 2 = 1.05). Unlike in Experiment 1, however, the correct judgment for some items under certain task conditions could vary depending on the unique experience of the participants (e.g., when presented with a picture of a vase, some participants may recall having seen this item in an office, whereas others would not). Because accuracy could not be determined by using a universal standard for all items, we selected 20 items from each of the five judgment conditions to serve as "accuracy checks." Each of these 20 items had received a given response more than 95% of the time in our earlier normative work, suggesting some objective standard for comparison with our experimental data. By examining the responses made by participants in Experiment 2 on these items, we established some measure of accuracy analysis. All of the participants in Experiment 2 adhered to the same 95% accuracy criterion as those in the prior normative study.

Responses to novel items. After screening for outliers, we first examined response times to the novel items as a function of the block within the experiment (Blocks 1–5) and of task condition (task constant or task changes). An initial ANOVA on RTs for novel items revealed no significant block, condition, or interaction effects; additionally, considering only Blocks 2–5 (i.e., the blocks that also contained primed trials) likewise revealed no effect of block and no interaction ($Fs < 1.1$). Given that no difference was found in the response times to novel items between the experimental blocks (Blocks 2–5, means of 722, 732, 718, and 714 ms, respectively), we calculated proportional priming scores for Experiment 2 using the average response time to all novel items in Blocks 2–5. Unlike in Experiment 1, this also enabled us to look at the effects of repetition (rather than block) on priming scores. We examined the effects of two, three, or four repetitions of the same exemplar, or of different exemplars on each repetition.

Proportional priming. Figure 3 (bottom panel) presents the proportional priming scores, separately for the two task conditions (task constant or task changes), for same exemplars and for different exemplars throughout the session, and for the second, third, and fourth repetitions (Rep-2, Rep-3, and Rep-4) of a given stimulus or of a categorically related stimulus. From Figure 3 it can be seen that proportional priming was greater for the task-constant than for the task-changes condition, and greater for same than for different exemplars. In addition, proportional priming was greater when separately considering only the nonswitch responses (open bars) than when considering all responses combined (filled bars).

We again first assessed effects on overall priming, combining across all response categories. A 2 (task) × 3 (repetition) × 2 (exemplar type) mixed factor ANOVA on proportional priming scores from all response categories revealed a significant effect of task condition, $F(1, 40) = 19.26$, $p < .001$, $d = 1.39$. Priming was more than twice as great in the task-constant ($M = .09$) than in the task-varied ($M = .04$) condition. Nonetheless, as shown in Figure 3, there was significant facilitation of responding even when the task changed for each presentation, both for same and for different exemplars (for Rep-2 to Rep-4, all $ts(20) > 3.84$, $p < .01$). There were also significant effects of repetition, $F(2, 80) = 22.47$, $p < .001$, and of exemplar type, $F(1, 40) = 9.71$, $p = .003$, $d = 0.99$. Although within-subjects contrasts showed a significant linear effect of repetition, $F(1, 40) = 37.10$, $p < .001$, $d = 1.93$, there was also a Repetition × Condition interaction, $F(2, 80) = 11.25$, $p < .001$, pointing to markedly greater *repetition-related gains* in priming across repetitions in the task-constant than in the task-varied condition, $F(1, 40) = 18.26$, $p < .001$, $d = 1.35$, for the linear component. Also observed was a Repetition × Exemplar-Type interaction, $F(2, 80) = 4.41$, $p = .015$, that reflected relatively larger priming gains in earlier repetitions for same exemplars than for different exemplars, $F(1, 40) = 5.02$, $p = .031$, $d = 0.71$, for the linear component.

A subsequent 2 (task condition) × 3 (repetition) × 2 (exemplar type) ANOVA on proportional priming scores for nonswitched responses alone revealed significant effects of repetition, $F(1.86, 74.27) = 19.38$, $p < .001$, and of exemplar type, $F(1, 40) = 4.36$, $p = .043$, $d = 0.66$. Unlike in Experiment 1, in which, for nonswitched responses, there was no effect of referent condition, when the *task judgment* changed, there was a significant main effect of task condition, even when responses remained constant (nonswitched responses only) across the tasks, $F(1, 40) = 14.11$, $p = .001$, $d = 1.19$. Within-subjects contrasts showed a significant linear effect of repetition, $F(1, 40) = 32.44$, $p < .001$, $d = 1.80$, reflecting increasing priming scores with each repetition. However, these repetition-related priming gains were primarily found in the task-constant rather than in the task-changes condition (see Figure 2), as shown both by a Repetition × Task Condition interaction, $F(1.86, 74.27) = 7.71$, $p = .001$, and a significant linear component within this interaction, $F(1, 40) = 13.21$, $p = .001$, $d = 1.15$.

As in Experiment 1, we next considered the effects of a *response change* on proportional priming scores. A 2 (response category: nonswitched vs. first switched response from Rep-2) × 2 (exemplar type) ANOVA on proportional priming scores for the task changes condition separately revealed significant main effects of response category, $F(1, 20) = 18.68$, $p < .001$, $d = 1.93$, and of exemplar type, $F(1, 20) = 15.73$, $p = .001$, $d = 1.77$, with no interaction ($F = 1.87$). Most notably, response change again clearly disrupted priming for both same exemplars and for different exemplars (see Figure 4). Whereas one-sample t tests demonstrated significant priming for nonswitched trials in the task-changes condition both for same exemplars ($M = .07$), $t(20) = 9.22$, $p < .001$, and for different exemplars ($M = .04$), $t(20) = 3.91$, $p = .001$, items for which a switched response was provided (first switched responses) did not show priming for either same or different exemplars ($ts < 1$, $Ms = .01$ and .0003, respectively). Priming remained nonsignificant for further switched responses (e.g., items that, across the blocks, were responded to with decisions of "yes," "no," "yes") regardless of whether this change represented a return to the original item response following a response change.

Finally, we again evaluated the effects of a *maintained* post-switch response. An ANOVA on proportional priming scores, including response category (nonswitch, first switch, and first maintained responses from Rep-2 and Rep-3) and exemplar type as within-subject factors, revealed a significant response category effect, $F(1.62, 32.29) = 5.47$, $p = .013$, with no exemplar-type effect ($F = 1.98$) and no interaction ($F < 1$). Within-subject contrasts again demonstrated a significant quadratic effect, $F(1, 20) = 8.56$, $p = .008$, $d = 1.31$, reflecting a pattern of switch-related decrements in priming with subsequent partial recovery after the response was maintained (mean priming for initial-switch-sustain = .05, .01, and .03, respectively). Calculation of subject-specific averages for all trials in Rep-3 and Rep-4 on which the new response was sustained for a second and/or third trial showed positive priming for both same exemplars ($M = .04$), $t(20) = 1.89$, $p = .07$ and for different exemplars ($M = .06$), $t(20) = 3.48$, $p = .002$, again suggesting that priming may gradually recover after a response change if the new response is then sustained across further trials—even when the particular classification judgment that is performed changes on each and every repetition, and thus never involves the "same answer" except at the level of affirmative versus negative responses or decisions.

Discussion

There are two key findings from this experiment. First, we again found that a change in the classification decision that was made to a stimulus (a yes response, followed by a no response, or vice versa) resulted in attenuation—indeed, elimination—of positive transfer or priming. This elimination of priming was observed both for the same stimulus and when the stimulus was a never previously presented categorically related exemplar, pointing to "semantic generalization of stimulus-task [S-task] bindings" as originally reported by Waszak and colleagues (2004) using a task-switching paradigm. Notably, this generalization was obtained even when the classification tasks that were performed were, on average, uncorrelated with one another, and participants were aware—for each block—that they only needed to make decisions regarding the currently relevant semantic classification (unlike in task-switching paradigms, in which within any small number of trials, more than one task may be, or may soon become, relevant). This provides strong support for the proposal that previously established stimulus–response or stimulus–decision bindings may be elicited largely automatically when the stimulus (or a categorically similar stimulus) again is perceived even in a different task context.

Second, it is notable that provided a given decision or response classification was maintained, significant response facilitation (positive transfer) was still observed despite multiple changes in both the required classification task and the object exemplars across presentations. These findings may reflect the lexical/conceptual processes that were needed to identify the objects, such as accessing the objects' names or basic semantic information concerning the object, regardless of the particular classification decision that was required. The observation of positive transfer across the uncorrelated classification tasks suggests that it is not necessary that the tasks be highly similar or semantically related to one another for facilitation to be observed (e.g., Xiong et al., 2003). Nor is it necessary (as was suggested by Bruce et al., 2000) that perceptual priming of objects be based on preformed or pretrained categorizations, rather than newly computed semantic classifications, at least given the apparently arbitrary nature of some of the classification decisions that we elicited here (e.g., does the object contain metal?—or—does the object make/have a distinctive sound?). At least with a sufficient number of items and with pictorial stimuli, provided that the response remains constant, *robust positive transfer can be found across repeatedly varied object exemplars, and across repeated and uncorrelated variations in the classification task*. The marked and significant attenuation of priming arising from a change in the abstract classification response made to an item (i.e., changing from a yes to a no response across uncorrelated task judgments) in the face of the preservation and repetition of these abstract lexical/conceptual components is thus all the more striking.

General Discussion

These experiments substantially clarify—but also qualify—our understanding of the role of response/decision learning in repetition priming. First, in line with other recent studies using an across-task priming paradigm (e.g., Horner & Henson, 2008, 2009), our findings demonstrate that decision-change disruption does not simply reflect interference generated from making a judgment that is the opposite of that initially performed. We have shown that priming disruptions, resulting from a change in the response, are observed even when the classification decisions to be made *do not require a reversal* of the earlier decision (as in the initial studies by Dobbins et al., 2004, and in Schnyer, 2007). We observed significant priming disruptions both when the type of decision was held constant but the task referent changed (Experiment 1) and when the classification decision tasks were, on average, uncorrelated with one another (Experiment 2). Taken together, these findings substantially extend the circumstances under which changes of initially acquired decision-to-stimulus bindings are shown to contribute to repetition priming.

Second, and more importantly, in both experiments we showed that decision-change disruption *extended to perceptually and conceptually similar object exemplars* that had not previously been presented. This outcome shows that the representations that contribute to such decision-change disruption are not necessarily "hyperspecific," but are to some degree abstract, a finding that is in stark contrast to the results reported in Schnyer et al. (2007). There are several possible explanations for the incongruity between these findings, all relating to methodological differences. One difference is that Schnyer and colleagues examined the effects of a decision change on across-exemplar priming only for "highly primed" items (objects that were repeated three times), and this may have fostered conditions that strongly favored item-specific rather than more abstract processing. We investigated the effects of a decision change for items that often had received only one initial priming trial in an independent task context, perhaps encouraging abstraction across experimental tasks.

Moreover, Schnyer et al. (2007) examined decision changes to objects that were repeated in blocks of 30 contiguous test trials. This procedure may have provided participants the opportunity to establish a more global response pattern to repeated stimuli and also reduced sensitivity to evidence of decision-change disruption (cf. Waszak & Hommel, 2007). In the paradigm of Schnyer and colleagues (2007), although the direction of the response (yes–no) was unpredictable inasmuch as it was dependent on the object size and the objects occurred in a randomized order, the response to all *primed* items nonetheless remained a *predictable reversal* of the prior response. Stated differently, if an object was a repeated (primed) object, then participants could respond to the size classification task for that object by simply reversing their earlier decision for it. In contrast, our study allowed for both same and switched responses that were randomly interleaved within a given block, with some primed items requiring a change, and others not, depending on the unique properties of that exemplar category with respect to the task at hand. For the five uncorrelated semantic classification tasks that participants were asked to perform in Experiment 2, the response to a particular exemplar category could not be determined on the basis of prior responses to that item.

The paradigm used in the present work also considerably extends the findings initially reported by Waszak et al. (2004), showing that generalization of stimulus-decision responses to different exemplars arises even under conditions in which only one task is currently relevant. Whereas in the earlier response-switching study participants were required to switch between tasks every two trials, in our procedure, participants maintained a uniform task set for between 54 and 108 stimulus presentations. In addition, whereas the experimental design adopted by Waszak et al. did not allow for equated lags for the identical and semantically related items, impelling them to approximately equate lags using a post hoc sorting procedure, the lags in our experiment for identical and different exemplars were equated, and varied considerably across items, with an intervening lag involving as many as 25 items or more.

Our demonstration of priming effects that generalized across perceptually and conceptually related exemplar categories, including both positive transfer and negative transfer, may have been bolstered by our use of multiple categorically related stimuli.

Whereas many prior efforts in this area made use of only two exemplars of a given category (see, for instance, Bruce et al., 2000; Dobbins et al., 2004; Schnyer et al., 2007), we were able to demonstrate the costs and benefits of within- and across-task performance using five exemplars within a given category, thereby maximizing the opportunities for the extraction of abstract, task-invariant features. In this respect, our approach was more similar to that of Waszak et al. (2004), who included between 6 and 24 related items within each of their semantic categories, although their items were instances of superordinate categories (e.g., animals, furniture, vehicles) as compared with the subordinate categories (e.g., horses, chairs, trains) we used in our design. Also, unlike the stimuli of Waszak and colleagues, our stimulus set included richly detailed color images of objects (not the Strooplike superimposition of words and line drawings).

Third, Experiment 2 demonstrated significant overall priming even when both the task and the object exemplar varied across repetitions. This preserved repetition-related facilitation may reflect lexical/semantic processes that remained constant across differing tasks and instances of an object category. Nonetheless, *increments* in priming with further repetitions were markedly greater when the task judgment was constant, perhaps reflecting more rapid retrieval of instance-based representations from a less mixed "population" of potential stimulus–response associations. Recent evidence has shown that persons with amnesia do not show such additional repetition-related increases when the task remains constant (Schnyer et al., 2006). Therefore, priming in global amnesia may derive from recapitulated perceptual and/or lexical semantic processes rather than episodic stimulus–response associations. Nonetheless, it would be informative to examine the performance of global amnesic patients in the highly sensitive paradigm we used in Experiment 2, to determine whether their classification performance is completely free from decision-change-related disruption, as would be expected if such disruptions entirely reflect episodic stimulus–response-context bindings. This would also allow examination of the question of whether, for the switched response items, unlike individuals with intact memory (who show no priming for switched response items), global amnesic patients show *positive transfer*—reflecting the benefits of recapitulated lexical/semantic processing without the costs arising from accessing episodic representations with inappropriate stimulus–response bindings.

One tentative finding that may require further investigation derives from a comparison of the response-related specificity effects in Experiment 1 versus Experiment 2. Although both experiments showed disruption of priming when the response changed from an initial response, there was evidence of greater interference (decision-change disruption) in Experiment 1, in which more aspects of the task construal were maintained across the task-referent changes, than in Experiment 2, in which the semantic classification judgments were, on average, uncorrelated with one another. As noted earlier, this pattern of decision-change disruption was also observed in an additional, unreported continuously varied-referent task condition, in which the referent changed from a 1-foot (.3048-m) to a 5-foot (1.52-m) cube in continuously ascending or descending order across experimental blocks. The results from this condition largely paralleled those for the discontinuously varied-referent condition, so to conserve space, only data from the discontinuously varied and constant conditions were reported here.

There are two possible accounts for this pattern of decision-change disruption across tasks. First, if decisions are being made in a mostly new context, then the stimulus may be "returned to baseline status" when mapping a new decision to a stimulus that was repeated earlier, and would thereby show neither facilitation nor impairment from the previous episodic encounter. This would appear to be quite "adaptive," as it could allow for the rapid adoption of a new approach for dealing with a particular object, perhaps helping to foster more flexible thinking, deciding, and acting. This insight is largely reflected in prior research findings, from Oliphant's (1983) observation that prior encounters with high-frequency words offer no benefits to later performance unless there is a clear similarity between task contexts, to the findings cited by proponents of a transfer-appropriate processing framework, who consistently report attenuated responses to repeated stimuli when the semantic or lexical domain varies across presentations (Blaxton, 1989; Franks et al., 2000; Jacoby, 1983b; Morris, Bransford, & Franks, 1977). A second plausible explanation for these results[2] holds that this effect is the result of two counteracting processes. The automatic retrieval of an S–R episode may lead to some behavioral facilitation, but these effects are diffused by the automatic retrieval of a conflicting response that is now inappropriate for the current item. This interpretation could also explain the findings in Experiment 1, in which the absolute magnitude of positive priming effects in the case of a complete match was larger than the absolute magnitude of negative priming in the case of a partial match.

It is worthwhile to consider briefly the primary similarities and differences between theoretical approaches, such as Logan's (1990) instance-based representations, Hommel's (1998, 2004) event files, and Waszak et al.'s (2003) stimulus–response learning. Our interpretation of these theories highlights the potential duration and stability of the bindings or associations predicted by each model. Whereas Logan appears to predict the formation of an ongoing association between the various contextual elements, Hommel's description of S-task bindings conceptualizes these associations as more fleeting, and therefore more flexible. Although a complete evaluation of the relative strengths and weaknesses of these approaches is beyond the scope of this article, our findings of rapid, cross-task priming tend to provide some support for Hommel's binding perspective. Our second experiment required participants to rapidly compute a new response to a repeated item, as opposed to accessing preexistent semantic categorizations. If these stimuli were indeed bound to a stable association between contextual and response-related elements, then such a restructuring of cognitive processes would perhaps lead to even greater decrements to task performance than we observed.

The most notable limitation to the present work is that we have demonstrated that decision learning can generalize, but not how it does so. The mechanisms that support such generalization of decisions or responses are still poorly understood (e.g., the relative roles of perceptual vs. semantic or conceptual similarity), and there remains a persistent puzzle of whether priming can be accounted for by a purely episodic account or whether it also reflects contributions from a nonepisodic, abstract component. In apparent support for this latter view, researchers have demonstrated subliminal

[2] An anonymous reviewer identified this explanation.

priming that generalizes to novel stimuli using both words (Kiesel, Kunde, Pohl, & Hoffmann, 2006) and single digits (Naccache & Dehaene, 2001), perhaps reflecting the facilitation granted by a more abstract representation. Combined, these prior efforts and the present report highlight the importance of considering whether experimental conditions favor the extraction of item-specific information and reliance on specific representations or whether they allow for greater abstraction of generalized representations that can be applied across encounters to novel situations.

To conclude, we found that decision-change disruption in priming may arise even when there has only been one previous primed presentation of an object, and each presentation involved a different decision task. We observed this decision-change disruption both for repeatedly presented objects of the same form (same exemplars) and for exemplars that varied on each presentation. Given that we observed significant decision-change disruption even when there were no repetitions of a given stimulus within the same task judgment—so that the varying and uncorrelated task judgments provided little incentive for participants to intentionally or voluntarily retrieve earlier responses—these outcomes are consistent with an interpretation of decision-change disruption as arising from the rapid and automatic binding of a stimulus with a response into an "event file" (Hommel, 1998). Such binding is assumed to occur incidentally, entirely as a consequence of temporal contiguity. When a stimulus is repeated and the stimulus requires the same response, response times are facilitated; however, when the repeated stimulus demands a different response, response times are slowed. More broadly, these findings point to important shared processes across repetition priming for single objects and related domains such as associative tasks that require a response on the basis of the relation between two stimuli (e.g., Dennis & Schmidt, 2003), negative priming (e.g., Frings, Rothermund, & Wentura, 2007; MacDonald et al., 1999), and task switching (e.g., Waszak et al., 2003), through the fundamental—and pervasive—processes involved in binding perception with action.

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Received December 28, 2007
Revision received December 9, 2008
Accepted December 18, 2008 ■