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Stimulus-Based Priming of Task Choice During Voluntary Task Switching

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Two voluntary task-switching experiments probed the influence of previous exposures to stimuli and categorizations of these stimuli on task choice during subsequent exposures to the same stimuli. Subjects performed origin and size judgments under standard voluntary task-switching instructions to perform the tasks equally often in a random order. Both when subjects voluntarily selected the task on the first exposure (Experiment 1) and when the experimenter manipulated the task on the first exposure (Experiment 2), subjects chose to perform the same task on subsequent exposures significantly more often than would be expected on the basis of the instructions to perform tasks in a random order. Presentation of a previously encountered stimulus may result in the retrieval of a stimulus–task binding or event file that biases task selection as well as task readiness. The pattern of data across the 2 experiments suggests that stimulus-based priming influences task choice through both retrieval of episodes within the context of the experiment and semantic memory mechanisms.

Keywords: cognitive control, stimulus priming, voluntary task switching

The concept of volitional control suggests behavioral choices that are relatively shielded from external influences (Haggard, 2008). However, behavior occurring in rich stimulus environments is frequently influenced by external stimuli. The choices people make about how to respond to these stimuli likely result from a combination of both goal-directed and stimulus-driven factors (Norman & Shallice, 1986). Here, we consider one possible external influence on task choice: the influence of previous exposures to stimuli and categorizations of the stimuli on task choice during subsequent exposures to those stimuli. If multiple tasks are equally appropriate, do people tend to perform the same categorization on stimuli when presented with those stimuli repeatedly?

Researchers interested in studying the balance of goal-directed and stimulus-driven influences on behavior in multitask environments have made wide use of the task-switching paradigm (Monsell & Driver, 2000). Task switching examines performance when a task is repeated from the previous trial versus when it is changed. Robust switch costs appear in response time (RT) and error data. Accounting for these switch costs is the focus of a growing literature. The behavioral deficits associated with switching tasks likely reflect a variety of both top-down and bottom-up mechanisms (Arrington, Logan, & Schneider, 2007; Koch & Allport, 2006; Meiran, Chorev, & Sapir, 2000; Ruthruff, Remington, & Johnston, 2001).

Relevant to the current study is a large body of research showing that substantial portions of switch costs may be accounted for by passive, stimulus-driven processes. The seminal work of Allport, Styles, and Hsieh (1994) proposed that carryover of task set activation from one trial to the next, or task set inertia, resulted in proactive interference on switch trials. Allport and Wylie (1999, 2000) updated the task set inertia hypothesis, elaborating on the positive and negative priming that occurs in task-switching environments, particularly when stimulus–response (S-R) mappings are partially overlapping. The occurrence of a stimulus paired with a particular response results in the formation of an S-R binding or episode that is retrieved automatically from memory when that stimulus is encountered again (Hommel, 1998; Logan, 1988). When stimuli are variably mapped to two unique tasks, the retrieval of previous episodes disrupts task performance (Koch, Prinz, & Allport, 2005). Waszak, Hommel, and Allport (2003) demonstrated the influence of such S-R bindings on task-switching performance. Subjects performing a word-reading task on picture–word Stroop-like stimuli showed increased switch costs for stimuli that were previously encountered in a picture-naming task. This effect occurred even if the items had been encountered only once and after many intervening trials. The authors argued that the presentation of the stimulus triggers the retrieval of the previous response, which then interferes with the selection of the response appropriate for the current task, a form of competitor priming (Waszak, Hommel, & Allport, 2005). The influence of S-R bindings on task performance is robust, surviving repeated task switches (Pösse, Waszak, & Hommel, 2006), and generalizes to semantically related items (Waszak, Hommel, & Allport, 2004).

Thus, substantial evidence shows that S-R bindings influence switch costs. However, performance measures capture only one aspect of behavior in multitask environments. A fuller picture of cognitive processes in multitask environments requires the consideration of processes engaged in task selection when all tasks are equally appropriate. Arrington and Logan (2004a) introduced a voluntary task-switching procedure that allows for examination of task choice. As in standard task-switching paradigms, subjects interleave multiple tasks; however, the task performed on any

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given trial must be selected by the subject rather than indicated by a task cue or prespecified task sequence. To ensure multitask behavior, subjects are generally instructed to perform the tasks equally often in a random sequence, thus allowing for both repetition and switch trials. In this environment, subjects commonly perform switches less often than expected on the basis of the task instructions, with this repetition bias decreasing as the time between trials increases (Arrington & Logan, 2005; Liefooghe, Demanet, & Vandierendonck, 2009). Although Arrington and Logan (2005) argued that voluntary task switching logically requires top-down control because the environment does not dictate a single response, evidence suggests that stimulus-driven factors may influence choice as well. Task repetitions are more frequent when the stimulus repeats from one trial to the next (Mayr & Bell, 2006). Arrington (2008) showed that when two tasks are afforded by separate stimuli (i.e., simple classification of digits or letters), the stimulus onset asynchrony between the two stimuli influences task choice with the probability of performing the task associated with the first stimulus increasing with increasing stimulus onset asynchrony. Finally, perceptual processing characteristics, such as hemispheric differences in processing local versus global features, bias task choice with subjects choosing to perform a given task on the basis, in part, of the location of the stimulus in the visual field (Arrington & Rhodes, in press).

In the present study, we examined a potential role of S-R bindings in task choice in a voluntary task-switching procedure. Research suggests that S-R bindings may influence choice processes as well as performance measures, such as RT. Most relevant is a recent study by Hommel (2007), which examined the influence of stimulus feature repetition on response choice in a free-choice task. Participants performed two keypress responses following the sequential presentation of two simple stimuli: The identity of the first response (left or right keypress) was cued prior to the onset of the first stimulus, whereas the response to the second stimulus was chosen by the subject. Subjects were instructed to perform the two possible responses “freely and randomly.” The relationships between features of the two stimuli were manipulated to examine the effect of S-R bindings or event files on choice responses. The results indicated that subjects were more likely to repeat a response if features were repeated between the two stimuli. Thus, response selection showed influences of event files similar to those for the performance measures reported in earlier studies (Hommel, 1998). This study provides evidence that stimulus characteristics can influence response choice over a rapid time frame. Such temporary S-R bindings may also account for Mayr and Bell’s (2006) findings in a voluntary task-switching study. They found that task repetitions increase following stimulus repetitions. The immediate stimulus repetition may link to the previous response through a temporary event file, biasing choice toward a task repetition.

In summary, previous research has shown that S-R bindings influence task performance over both rapid trial-to-trial time frames (Sohn & Anderson, 2003) and across numerous intervening trials (Waszak et al., 2003). Also, research has shown that S-R bindings influence free-choice response selection over short trial-to-trial time frames (Hommel, 2007). These two lines of investigation suggest an influence of S-R bindings over task choice across extended time periods. However, demonstration of such an effect would be novel and some question remains as to whether such an effect would occur. First, in their revision of the task set inertia hypothesis, Allport and Wylie (2000) described a dissociation between “endogenous control of task set, in the sense of controlling *which task* is performed [and] ‘task readiness’ . . . measured by speed of performance” (p. 36). In voluntary task switching, the control over which task is performed on a given trial is assumed to be volitional, guided by overall instructions to perform tasks in a random sequence. Logically, volitional task selection may precede task set reconfiguration or preparation processes. If volitional task selection and task preparation occur in this sequential fashion, task choice may be relatively isolated from processes engaged in task readiness, which may be influenced by bottom-up processes that may affect only how efficiently a task set is implemented. Research with the voluntary task-switching procedure has found nonoverlapping variance between measures of task performance and task choice (Arrington & Yates, 2009; Mayr & Bell, 2006), suggesting that factors that influence performance measures (i.e., RT) may not have comparable effects on task choice. In addition, Koch and Allport (2006) suggested that endogenous control based on the interpretation of task cues is sustained over task performance, whereas stimulus-based activation of a task is transient. Similarly, Hommel (2007) described the event files used to account for the response selection effects as temporary bindings that influence choice over short interresponse intervals. Thus, if stimulus-based priming is transient, it may guide task readiness but may not influence top-down, endogenous control over task choice. Thus, past S-R episodes may not influence task choice, particularly when there is an extended separation between repeated presentations of a given stimulus.

Experiment 1

We examined the influence of previous exposure to a stimulus on the choice of how to respond to that stimulus in a voluntary task-switching procedure involving categorizations of a large set of stimuli. Most voluntary task-switching experiments have used small stimulus sets of four to eight items. Here, subjects performed origin (living/nonliving) or size (small/large) judgments on a set of 60 concrete nouns. This larger stimulus set provides the opportunity to analyze task choice for individual items across a limited number of exposures. If past experience performing a particular categorization on a stimulus influences how individuals choose to categorize that stimulus in the future, then we expect to see subjects biased to perform the same task on a stimulus as was performed in the initial exposure. To examine this hypothesis, we categorized subjects’ responses by whether they matched the task performed on the first exposure to a stimulus.

Methods

Subjects. Twenty-six undergraduates participated for partial course credit. All subjects had normal or corrected-to-normal vision.

Apparatus and stimuli. The presentation of stimuli and recording of responses were controlled by E-Prime software running on Dell Dimension computers with 17-in. CRT monitors. Stimuli were black on a light gray background and appeared at the center of the screen in 18-point Courier New font. Responses were made with the *d, f, j,* and *k* keys on a standard keyboard. The stimulus set consisted of 60 nouns, 15 in each living/nonliving by small/large cell (see the Appendix). Across cells, items were matched for frequency of use.

Procedure. Each experimental session began with three practice blocks. Subjects first practiced classifying nouns in separate origin and size single-task blocks. Subjects then received standard voluntary task-switching instructions to perform the tasks equally often in a random order (Arrington & Logan, 2004a) and performed a final practice voluntary task-switching block. The practice stimuli were not included in the experimental blocks. Subjects performed eight experimental blocks, each consisting of one presentation of each of the 60 stimuli. Stimuli appeared in a random order, with a 500-ms response–stimulus interval between trials.

Results and Discussion

Data from two subjects were removed because they did not perform task switches on more than 10% of the trials, suggesting that they did not follow basic task instructions. We coded the task performed on each trial on the basis of the hand used to respond. We coded trials as repetitions or switches on the basis of the task performed on trial n and trial $n - 1$. For Blocks 2 through 8, we further coded each trial according to whether the task performed was a match or a nonmatch to the task performed on that item during Block 1. This measure of *match to first exposure* was the primary measure of interest for assessing the influence of S-R bindings on task choice. For RT analyses, the first trial of each block and all trials with RTs less than 150 ms or greater than 4,000 ms were removed, resulting in the removal of 3.0% of the trials.

Task choice. Three measures of task choice were considered: task performed as a function of stimulus category, task transition, and match to first exposure. The first two analyses considered performance relative to the instructions to perform the tasks equally often in a random order. Table 1 shows the proportion of trials on which subjects chose to perform the origin task, p(origin), as a function of the stimulus categories. If subjects did not perform the tasks equally often, then p(origin) would differ from .5. Overall, subjects performed the two tasks equally often, p(origin) = .494, $t(23) < 1$. Choice of task was not significantly influenced by the stimulus category. A 2 (origin: living, nonliving) × 2 (size: small, large) repeated-measures analysis of variance (ANOVA) revealed nonsignificant main effects of origin, $F(1, 23) = 0.8$, $MSE = 0.105$, $p > .1$, and size, $F(1, 23) = 1.3$, $MSE = 0.003$, $p > .1$, as well as a nonsignificant interaction of the two variables, $F(1, 23) = 2.4$, $MSE = 0.004$, $p > .1$. The instruction to perform the two tasks in a random order should have resulted in a switch probability of .5. Subjects showed a repetition bias common during voluntary task switching. Mean switch probability was .428, which was significantly different from .5, $t(23) = 3.0$, $p < .05$, $d = .62$. Thus, overall task choice followed patterns similar to past voluntary task-switching experiments.

Table 1
Probability of Performing the Origin Task as a Function of Stimulus Category

	Origin/size			
Experiment	Living/ small	Living/ large	Nonliving/ small	Nonliving/ large
1	.507	.539	.468	.462
2	.596	.597	.498	.442

The primary analysis of interest examined whether subjects' choice of task was influenced by prior exposure to a stimulus. In particular, were subjects biased toward performing the same task on subsequent presentations of a stimulus that they performed on the first exposure? Figure 1 shows the mean probability of a match to first exposure, p(match), separated by block. The mean p(match) was .612, which was significantly greater than chance, $t(23) = 5.8$, $p < .05$, $d = 1.18$. The effect extended across the entire session, with a repeated-measures ANOVA showing no effect of block on p(match), $F(6, 138) = 1.5$, $MSE = 0.004$, $p > .1$.

The influence of prior categorization on task choice may also be considered by examining whether subjects were likely to perform the same task that was performed on that stimulus during the immediately preceding exposure. This measure of match to most recent exposure would be able to capture shifts in bias over time that were influenced by retrieval of the most recently stored episode involving a given stimulus. A second categorization of each trial in Blocks 2 through 8 was made on the basis of whether the task performed was a match or a nonmatch to the task performed on that item during the previous block (i.e., Block 3 was based on Block 2, etc.). According to this method of categorizing a match, the mean p(match) was .650, which was slightly larger in magnitude than the match to first exposure measure, $t(23) = 4.8$, $p < .05$, $d = 1.31$. The effect again showed no change over block, $F(6, 138) = 0.24$, $MSE = 0.006$, $p > .1$. The larger bias found when considering only matches between sequential blocks suggests some small shift in task selection over time but does not alter the interpretation of the primary measure of match to first exposure.

RT. Past research has shown effects of S-R priming on task performance, in costs associated with performing a new task on a stimulus previously associated with another task. These costs occur to a greater extent on switches than on repetitions (Waszak et al., 2003). Mean RTs for match versus nonmatch trials as a function of task transition appear in Table 2. Overall, task performance was influenced by S-R bindings established during the first exposure to a stimulus. Subjects were faster to respond on match trials ($M = 1,195$ ms) than nonmatch trials ($M = 1,284$ ms). Task performance also showed overall robust switch costs ($M = 208$ ms). Although the average values suggest that the effect of match to first exposure was greater on switch trials, this difference proved nonsignificant. A 2 (match to first exposure: match, nonmatch) × 2 (task transition: repetition, switch) repeated-measures ANOVA was performed on mean RTs. The main effects of both match and transition were significant, $F(1, 23) = 11.1$, $MSE = 16,912.9$, $p < .05$, $\eta_p^2 = .33$, and $F(1, 23) = 29.4$, $MSE = 35,394.4$, $p < .05$, $\eta_p^2 = .56$, respectively. However, the interaction was not significant, $F(1, 23) = 0.9$, $MSE = 6,938.6$, $p > .1$. The same ANOVA was performed on the basis of the match to most recent exposure classification of choice. The same general pattern of results occurred, with responses faster for match trials ($M = 1,193$ ms) than for nonmatch trials ($M = 1,308$ ms). Again both main effects were significant; for match, $F(1, 23) = 10.2$, $MSE = 30,801.1$, $p < .05$, $\eta_p^2 = .31$, and for transition. $F(1, 23) = 36.2$, $MSE = 33,563.8$, $p < .05$, $\eta_p^2 = .61$. The interaction again did not reach significance, $F(1, 23) = 1.2$, $MSE = 12,929.1$, $p > .1$. The lack of an interaction

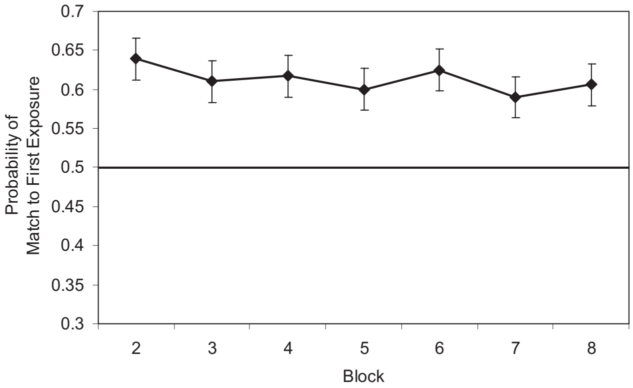

Figure 1. Mean probability of match to first exposure in Experiment 1. Error bars indicate 95% confidence intervals.

may seem contrary to findings that priming is greater on switch trials compared with repetition trials; however, the effect of priming on task switching varies as a function of preparation intervals (Koch & Allport, 2006; Rubin & Koch, 2006).

The results of Experiment 1 support the hypothesis that the initial exposure to and categorization of a stimulus influences responding to that same stimulus when it is presented again in the same multitask environment. Both the probability of choosing to perform a given task and the RTs for different categorizations suggested a bias in favor of repeating the earlier categorization. These results may arise because the stimulus primes a particular response through retrieval of a past experience with this S-R mapping or event file (Hommel, 1998; Waszak et al., 2003). However, one alternate interpretation of these results is that factors outside the current experimental environment may have influenced behavior as well. That is, the target words may have had pre-experimental associations leading toward one categorization or the other (i.e., *aspirin* has had more associations with the concept of small than with the concept of nonliving). Examination of individual items' categorizations across subjects did indeed show such biases for individual items. See the Appendix for mean *p*(origin) values for all items. Subjects may have selected the task on both the first and subsequent exposures to the item on the basis of past associations that made one task easier or more available to the subjects. Thus, the match to first exposure measure may capture more long-term biases rather than specific S-R bindings or event files formed when first exposed to the stimulus in Block 1. To address this concern, in Experiment 2 the task performed on the first exposure to a given stimulus was manipulated, thus eliminating any pre-experimental effects and isolating the effect of previous exposure within the context of the experiment.

Experiment 2

Two procedural changes were made in Experiment 2 to avoid the possibility that stimuli were differentially associated with particular tasks on the basis of pre-experimental experience. First, we selected a subset of the stimuli on the basis of the task choices made by subjects in Experiment 1. We removed words that showed the greatest association with a particular task across subjects in Experiment 1. Second, we ran the single-task practice blocks performed at the beginning of the experiment with the stimulus words that would serve as targets during the main portion of the experiment. Half of the words from the stimulus set were presented in one task, and half were presented in the other. Thus, the first categorizations of the stimuli were not freely chosen by the subjects but rather were determined by the experimenter. Therefore, the match to first exposure measure was a pure measure of event files formed in the experimental environment.

Method

Subjects. Experiment 2 included 26 undergraduates who had not participated in Experiment 1. All participated for partial course credit and had normal or corrected-to-normal vision.

Apparatus, stimuli, and procedure. The apparatus, stimuli, and procedure were the same as in Experiment 1 with the following exceptions. The stimuli were a subset of items from Experiment 1 (see the Appendix), selected to minimize any item-specific bias toward responding with a given task. For each cell (i.e., small/living, small/nonliving, large/living, and large/nonliving), eight items were selected that had the most balanced proportions of tasks performed across all subjects in Experiment 1. The 32 stimuli were divided into two groups of 16, equally split across the four cells and equated for the proportion of trials on which each task was performed in Experiment 1, $t(15) = 0.21$, $p > .1$.

The manipulation of first exposure to a stimulus was implemented during the single-task practice blocks. Unlike Experiment 1, the practice stimuli were those used throughout the experiment. One group of words was presented twice during the origin practice block; the other group was presented during the size practice block. The assignment of stimulus group to practice task was counterbalanced across subjects. Nine voluntary task-switching blocks followed the single-task practice. Each of the 32 target items appeared twice during each voluntary task-switching block for a total of 64 trials per block, roughly equivalent to the block length in Experiment 1.

Results and Discussion

Data from two subjects were removed because their accuracy was below 90% or they did not perform task transitions on more than 10% of the trials. The coding of trials according to tasks and task transitions occurred as in Experiment 1. For all trials, the task

Table 2
Mean and Standard Error for Response Times as a Function of Match to First Exposure and Task Transition

Experiment and task transition	Match to first exposure			
	Match		Nonmatch	
	M	*SE*	*M*	*SE*
Experiment 1				
Task switch	1,291	35	1,396	51
Task repetition	1,099	40	1,172	51
Experiment 2				
Task switch	1,227	52	1,240	56
Task repetition	1,009	47	1,035	51

choice was further coded to indicate either a match or nonmatch to the task performed on that stimulus during the single-task practice. For RT analyses, data trimming resulted in the removal of 1.8% of the data.

Task choice. Table 1 provides the mean *p*(origin) as a function of the stimulus category. Unlike Experiment 1, a slight bias in subjects' choice of task occurred, with the mean *p*(origin) of .533 differing significantly from .5, $t(23) = 3.9$, $p < .05$, $d = 0.78$. In addition, stimulus category influenced task choice. Subjects performed the origin task more often for living than nonliving stimuli, with this difference greater for large stimuli than for small stimuli. A 2 (origin: living, nonliving) × 2 (size: small, large) repeated-measures ANOVA revealed a significant main effect of origin, $F(1, 23) = 12.1$, $MSE = 0.032$, $p < .05$, $\eta_p^2 = .35$, as well as an Origin × Size interaction, $F(1, 23) = 4.7$, $MSE = 0.004$, $p < .05$, $\eta_p^2 = .17$. Subjects again showed a strong repetition bias with the switch probability of .393 significantly below .5, $t(23) = 4.5$, $p < .05$, $d = 0.93$.

In Experiment 2, the influence of initial exposure was considered by analyzing the match to first exposure that occurred during the single-task practice. Figure 2 shows the mean *p*(match) separated by block. Although the magnitude of the effect was reduced from Experiment 1, the *p*(match) still reflected a significant bias in task choice. Overall *p*(match) was .522, which was significantly greater than .5, $t(23) = 3.3$, $p < .05$, $d = 0.67$. Although significant overall, the *p*(match) did decrease across blocks. The repeated-measures ANOVA indicated a significant linear trend across blocks, $F(1, 23) = 6.1$, $MSE = 0.004$, $p < .05$, $\eta_p^2 = .21$.

The secondary measure of match to most recent exposure, calculated across Blocks 2 through 9, led to a mean *p*(match) of .610, which was significantly greater than the match to first exposure measure, $t(23) = 5.9$, $p < .05$, $d = 1.20$. Unlike the measure of match to first exposure, this measure did not vary across the blocks, $F(7, 161) = 1.52$, $MSE = 0.007$, $p > .1$. This larger bias for match to most recent exposure in the current experiment may reflect the fact that using this measure allows for the influence of pre-experimental associations to come into play as a mechanism by which sequential trials are biased toward the same task. This different pattern of results between the two ways of categorizing matches differs from our findings in Experiment 1. In Experiment 1, all tasks where chosen by the subject; thus, pre-experimental associations were available to influence both match to first and match to most recent exposure.

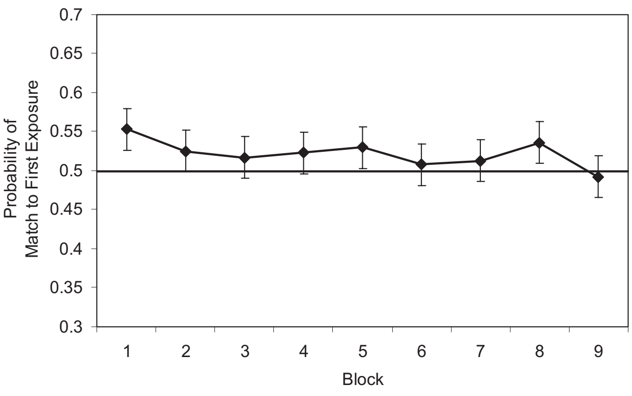

Figure 2. Mean probability of match to first exposure in Experiment 2. Error bars indicate 95% confidence intervals.

RT. The effect of initial S-R binding on task performance was considered in the RT data, presented in Table 2. The pattern of mean RTs indicated a similar direction in the effect of match to first exposure; however, the effect was not significant. A 2 (match to first exposure: match, nonmatch) × 2 (task transition: repetition, switch) repeated-measures ANOVA showed a significant main effect only of transition, $F(1, 23) = 51.6$, $MSE = 20{,}810.4$, $p < .05$, $\eta_p^2 = .69$, with subjects showing the expected switch costs ($M = 212$ ms). The main effect of match and interaction were both nonsignificant, $F(1, 23) = 2.1$, $MSE = 4{,}528.7$, $p > .1$, and $F(1, 23) = 0.4$, $MSE = 2{,}345.9$, $p > .1$, respectively. When the trials were categorized on the basis of the match to most recent exposure, the match variable did show a significant effect, $F(1, 23) = 17.9$, $MSE = 4{,}977.7$, $p < .05$, $\eta_p^2 = .44$, with faster responding on match trials ($M = 1{,}061$ ms) than on nonmatch trials ($M = 1{,}122$ ms). The effect of transition was also significant, $F(1, 23) = 41.0$, $MSE = 23{,}396.5$, $p < .05$, $\eta_p^2 = .64$, but the interaction was nonsignificant, $F(1, 23) = 0.004$, $MSE = 3{,}604.8$, $p > .1$.

Comparison of Experiments 1 and 2. Finally, as can be seen in a visual comparison of Figures 1 and 2, the magnitude of the match to first exposure bias is much larger in Experiment 1 than in Experiment 2. With experiment as a between-subjects effect, analysis showed this difference in match to first exposure to be a highly significant effect, $t(46) = 4.4$, $p < .05$, $d = 0.90$. Comparison of the RT data confirmed the difference between experiments of the effect of match to first exposure, $F(1, 46) = 5.3$, $MSE = 10{,}720.8$, $p < .05$, $\eta_p^2 = .10$. However, the experiments looked much more similar when considering the match to most recent exposure effects. The probability of a match did not differ between experiments, $t(46) = 1.3$, $p > .1$, $d = 0.27$, and neither did the RT differences between match and nonmatch trials, $F(1, 46) = 1.9$, $MSE = 17{,}889.4$, $p > .1$.

The results of Experiment 2 support the hypothesis that the task performed on the first exposure to a specific stimulus influences the later choices about what task to perform on that stimulus when given the freedom to choose a task. As shown in the comparison analyses across experiments when we used match to first exposure, the magnitude of this effect was markedly reduced from Experiment 1. However, the comparison when we used the match to most recent exposure showed more similarities across experiments, suggesting that the influence of extraexperimental effects may have a larger influence on task selection than the short-term event files generated within the experiment.

General Discussion

Across two experiments, we assessed the impact of previous pairings of a particular stimulus with a particular task on subsequent choices about what task to perform on that stimulus in a voluntary task-switching environment. Both when subjects voluntarily selected the task on first exposure (Experiment 1) and when the experimenter manipulated the task on first exposure (Experiment 2), subjects chose to perform the same task on subsequent exposures significantly more often than would be expected on the basis of a random task selection. This result complements previous research examining the effect of retrieval of event files on task performance measures of RT in task-switching studies (Waszak et al., 2003) and free-choice in a response selection task (Hommel, 2007). Of importance, the current study extends previous research to consider the role of stimulus-based priming on the selection of behaviors under volitional control in multitask environments. Building on these previous lines of investigation, we propose that the presentation of a stimulus results in the retrieval of an instance or event file stored during previous trials. The reactivation of an event file increases activation of one of the possible tasks in response to a stimulus. This activation makes that task more available and biases the subjects' task selection under conditions when either task is equally appropriate given the higher order instructions.

We propose two possible mechanisms by which this effect occurs. Task selection and task readiness may represent two separate components of preparation for a task (Allport & Wylie, 2000), where task selection represents an intent to perform a particular task and task readiness represents activation of the task set at the level of subordinate processes that implement response selection (Logan & Gordon, 2001). In voluntary task switching, the intent to perform a particular task is conceived of as an act of volitional choice. Task readiness is strongly bound to task selection (Koch & Allport, 2006) given that the intent to perform a task (whether based on some external cue or volitional choice) results in top-down control over task set reconfiguration or preparation. However, task readiness may also be influenced by past experience and stimulus-based priming. In the present context, retrieval of an event file may (a) impact task selection processes at an intentional level or (b) act on task readiness, directly changing the likelihood that a given task will be performed. The second pathway may be more likely to occur when task selection is weak and intention to perform a particular task has not been established (Arrington, 2008). Given that the current paradigm categorizes task choice on the basis of the response performed, disentangling these two possible mechanisms requires further research that will be critical for developing a model of cognitive control in multitask environments that includes mechanisms of both task selection and task readiness.

A question that remains open is whether the first exposure bias results from links between the stimulus and a particular response or from links between the stimulus and some abstract task representation. Priming models of task switching allow for the possibility that the presentation of a stimulus will prime the specific response that has been associated with that stimulus, a mental representation of the response category, or an abstract task representation or rule (Koch & Allport, 2006; Waszak & Hommel, 2007; Waszak et al., 2004). Does presentation of a stimulus previously categorized simply increase the availability of a particular response or response category, or does it increase the availability of the more abstract task representation? One approach to addressing this question is through considering the effect of congruency of the responses for the two tasks for specific stimuli. If the first exposure bias results from retrieval of specific S-R bindings, the effect is likely to be stronger for incongruent stimuli when the two S-R mappings for a stimulus are in conflict. The current design is not ideal for testing congruency because of the univalent nature of the responses; however, we did consider the possibility that congruency across hands based on the finger being used to make the response might influence the task choice bias. No effect of congruency on task choice was found in the current data set; however, the weak nature of the congruency classification also failed to produce an effect on RT, making the lack of an effect on task choice difficult to interpret.[1] A more direct test of this question comes from recent work by Demanet, Verbruggen, Liefooghe, and Vandierendonck (in press). They performed an experiment very similar to the current Experiment 2 that used a change in response modality between the practice and voluntary task-switching blocks from vocal to manual responses. They also found item-specific priming of task choice based on the pairing of stimuli with practice task. This effect strongly supports the conclusion that a stimulus–task representation binding rather than a simple S-R binding underlies the priming seen here, a conclusion consistent with other findings in the literature (Koch & Allport, 2006; Rubin & Koch, 2006).

The comparison between Experiments 1 and 2 indicated significantly larger first-exposure biases in Experiment 1. Two possible causes for this difference exist. First, in Experiment 1, the task performed on the first exposure to the stimulus was selected by the subject in a voluntary task-switching context. This procedure made the first exposure more similar in all of the demands and characteristics of the event in the later test trials than in Experiment 2, where the subjects were instructed about which task to perform on the first exposures to the stimuli. The similarity between first exposure and later trials would have been greater in Experiment 1 than Experiment 2, and that similarity may have caused the larger task choice bias. Second, the items used in the current experiments were familiar concrete nouns with which subjects had past experience. Such past experience may lead to a predisposition to categorize specific items on dimensions with which they have been associated more strongly in the past (see the Appendix). There was some evidence for systematic factors at play in these biases, for example, the influence of stimulus category on task choice in Experiment 2, where living items were more likely than nonliving items to be categorized in the origin task. It is likely that animals and plants are associated with the concept of living more often than manmade objects are associated with the concept of nonliving. Thus, the categorization of living things on the living/nonliving dimension would potentially be a more available categorization and would bias task choice. In recent work, Gollan and Ferreira (2009) made a similar argument for lexical accessibility influencing the language in which bilingual subjects chose to label an object in voluntary task switching between languages.

The significant influence of first exposure following random assignment of items to tasks in Experiment 2 along with the evidence for extraexperimental influences suggest that both retrieval of specific episodes formed from exposure to the stimulus on earlier trials within the experiment and semantic associations developed through extraexperimental exposure may prime task choice. Previous research has demonstrated episodic and semantic influences on task performance in an explicit task-cueing proce-

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[1] Data from a separate experiment in which both tasks were mapped to keypresses with the index and middle fingers of the right hand showed a strong congruency effect on RT ($M = 1{,}277$ ms for compatible and $M = 1{,}335$ ms for incompatible), $F(1, 18) = 17.4$, $MSE = 7{,}337.3$, $p < .05$, $\eta_p^2 = .49$. However, even with this stronger congruency manipulation, there was no evidence of congruency influencing a match to first choice measure ($M = 0.549$ for compatible and $M = 0.546$ for incompatible, $F < 1$). This result provides support for a stimulus–task representation binding.

dure (Arrington & Logan, 2004b). Thus, the current findings further highlight the role of memory in task choice during voluntary task switching. The event file formed during the first exposure to a stimulus is retrieved from long-term memory and guides task choice. Recently, Weaver and Arrington (2010) demonstrated that information maintained in working memory also influences choice. Subjects performing voluntary task switching within the delay period of a working memory task showed increased likelihood of choosing to perform a task that matched information being maintained in working memory. These accumulated findings indicate the importance of basic memory processes in task choice.

Whether driven by priming of particular event files or semantic biases in categorization of particular stimuli, the current findings show that task choice is influenced by the stimulus on which the task is being performed. That is, individuals do not always select the task separately from the stimulus identity. This result converges with evidence from other voluntary task-switching experiments showing effects of stimulus repetition (Mayr & Bell, 2006), stimulus availability (Arrington, 2008), perceptual processing biases associated with lateralized presentation of hierarchical stimuli (Arrington & Rhodes, in press), and lexical accessibility in bilinguals (Gollan & Ferreira, 2009). This mounting body of evidence for the multiple influences of stimuli on task choice raises the question of the degree to which task choice in the voluntary task-switching paradigm is indeed voluntary, the degree to which it is under the endogenous control of the individual, and the degree to which it is stimulus driven. Volitional control is not thought to occur in an environmental vacuum; however, it is considered to be less directly, or immediately, determined by external stimuli (Haggard, 2008). In the voluntary task-switching paradigm, subjects are instructed to perform the tasks randomly, but they are not specifically instructed to ignore or inhibit environmental factors in making their task selection. As such, a balance of top-down control based on internal representations of the higher order goal of random selection and bottom-up influences, such as stimulus-based priming, is likely to occur. Further research is needed to understand this balance between top-down and bottom-up factors influencing task choice during multitasking.

References

Allport, A., Styles, E. A., & Hsieh, S. (1994). Shifting intentional set: Exploring the dynamic control of tasks. In C. Umilta & M. Moscovitch (Eds.), *Attention and performance XV: Conscious and nonconscious information processing* (pp. 421–452). Cambridge: MA: MIT Press.

Allport, A., & Wylie, G. (1999). Task-switching: Positive and negative priming of task-set. In G. W. Humphreys, J. Duncan, & A. Treisman (Eds.), *Attention, space and action: Studies in cognitive neuroscience* (pp. 273–296). Oxford, England: Oxford University Press.

Allport, A., & Wylie, G. (2000). Task switching, stimulus–response bindings, and negative priming. In S. Monsell & J. Driver (Eds.), *Attention and performance XVIII: Control of cognitive processes* (pp. 35–70). Cambridge, MA: MIT Press.

Arrington, C. M. (2008). The effect of stimulus availability on task choice in voluntary task switching. *Memory & Cognition, 36,* 991–997.

Arrington, C. M., & Logan, G. D. (2004a). The cost of a voluntary task switch. *Psychological Science, 15,* 610–615.

Arrington, C. M., & Logan, G. D. (2004b). Episodic and semantic components of the compound-stimulus strategy in the explicit task-cuing procedure. *Memory & Cognition, 32,* 965–978.

Arrington, C. M., & Logan, G. D. (2005). Voluntary task switching: Chasing the elusive homunculus. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31,* 683–702.

Arrington, C. M., Logan, G. D., & Schneider, D. W. (2007). Separating cue encoding from target processing in the explicit task-cuing procedure: Are there "true" task switch effects? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33,* 484–502.

Arrington, C. M., & Rhodes, K. M. (in press). Perceptual asymmetries influence task choice: The effect of lateralized presentation of hierarchical stimuli. *Laterality.*

Arrington, C. M., & Yates, M. M. (2009). The role of attentional networks in multitask behavior. *Psychonomic Bulletin & Review, 16,* 660–665.

Demanet, J., Verbruggen, F., Liefooghe, B., & Vandierendonck, A. (in press). Voluntary task switching under load: Contribution of top-down and bottom-up factors in goal-directed behavior. *Psychonomic Bulletin & Review.*

Gollan, T. H., & Ferreira, V. S. (2009). Should I stay or should I switch? A cost–benefit analysis of voluntary switching in young and aging bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 35,* 640–665.

Haggard, P. (2008). Human volition: Towards a neuroscience of will. *Nature Reviews Neuroscience, 9,* 934–946.

Hommel, B. (1998). Event files: Evidence for automatic integration of stimulus–response episodes. *Visual Cognition, 5,* 183–216.

Hommel, B. (2007). Feature integration across perception and action: Event files affect response choice. *Psychological Research, 71,* 42–63.

Koch, I., & Allport, A. (2006). Cue-based preparation and stimulus-based priming of tasks in task switching. *Memory & Cognition, 34,* 433–444.

Koch, I., Prinz, W., & Allport, A. (2005). Involuntary retrieval in alphabet–arithmetic tasks: Task-mixing and task-switching costs. *Psychological Research, 69,* 252–261.

Liefooghe, B., Demanet, J., & Vandierendonck, A. (2009). Is advance reconfiguration in voluntary task switching affected by the design employed? *Quarterly Journal of Experimental Psychology, 62,* 850–857.

Logan, G. D. (1988). Toward an instance theory of automatization. *Psychological Review, 95,* 492–527.

Logan, G. D., & Gordon, R. D. (2001). Executive control of visual attention in dual-task situations. *Psychological Review, 108,* 393–434.

Mayr, U., & Bell, T. (2006). On how to be unpredictable: Evidence from the voluntary task-switching paradigm. *Psychological Science, 17,* 774–780.

Meiran, N., Chorev, Z., & Sapir, A. (2000). Component processes in task switching. *Cognitive Psychology, 41,* 211–253.

Monsell, S., & Driver, J. (2000). *Attention and performance XVIII: Control of cognitive processes.* Cambridge, MA: MIT Press.

Norman, D. A., & Shallice, T. (1986). Attention to action: Willed and automatic control of behavior. In R. J. Davidson, G. E. Schwartz, & D. Shapiro (Eds.), *Consciousness and self-regulation: Advances in research and theory* (Vol. 4, pp. 1–18). New York, NY: Plenum Press.

Pösse, B., Waszak, F., & Hommel, B. (2006). Do stimulus–response bindings survive a task switch? *European Journal of Cognitive Psychology, 18,* 640–651.

Rubin, O., & Koch, I. (2006). Exogenous influences on task set activation in task switching. *Quarterly Journal of Experimental Psychology, 59,* 1033–1046.

Ruthruff, E., Remington, R. W., & Johnston, J. C. (2001). Switching between simple cognitive tasks: The interaction of top-down and bottom-up factors. *Journal of Experimental Psychology: Human Perception and Performance, 27,* 1404–1419.

Sohn, M.-H., & Anderson, J. R. (2003). Stimulus-related priming during task switching. *Memory & Cognition, 31,* 775–780.

Waszak, F., & Hommel, B. (2007). The costs and benefits of cross-task priming. *Memory & Cognition, 35,* 1175–1186.

Waszak, F., Hommel, B., & Allport, A. (2003). Task-switching and long-term priming: Role of episodic stimulus–task bindings in task-shift costs. *Cognitive Psychology, 46,* 361–413.

Waszak, F., Hommel, B., & Allport, A. (2004). Semantic generalization of stimulus–task bindings. *Psychonomic Bulletin & Review, 11,* 1027–1033.

Waszak, F., Hommel, B., & Allport, A. (2005). Interaction of task readiness and automatic retrieval in task switching: Negative priming and competitor priming. *Memory & Cognition, 33,* 595–610.

Weaver, S. M., & Arrington, C. M. (2010). What's on your mind: The influence of the contents of working memory on choice. *Quarterly Journal of Experimental Psychology, 63,* 726–737.

Appendix

Stimuli Used in Experiment 1 and Experiment 2 (Indicated With Asterisks) With Mean Proportion of Trials on Which an Origin Judgment Was Performed, *p*(origin), During Experiment 1

Living/small		Nonliving/small	
Item	*p*(origin)	Item	*p*(origin)
beetle	.611	aspirin	.406
daisy*	.515	badge	.420
dandelion	.559	binoculars*	.544
duck*	.517	candlestick*	.486
ferret*	.534	cigar	.451
firefly*	.527	dime	.385
fly*	.512	domino*	.490
frog*	.498	fork*	.488
hummingbird	.534	harmonica	.483
owl	.549	lollipop	.483
pansy	.605	pancake*	.493
snail*	.522	peg*	.510
starfish*	.522	pen	.451
termite	.595	shawl*	.525
woodpecker	.542	teapot*	.485

Living/large		Nonliving/large	
Item	*p*(origin)	Item	*p*(origin)
baboon	.629	barn	.456
bull*	.512	bathtub	.463
camel*	.547	bus*	.483
donkey*	.537	cabin*	.483
hippo*	.554	canoe*	.525
hog	.580	cello	.448
hydrangea	.650	crib	.427
penguin*	.564	garage*	.490
pony	.597	helicopter	.449
redwood	.590	jet	.442
reindeer	.591	scarecrow*	.546
rhododendron	.610	seesaw*	.478
tiger*	.566	torpedo*	.519
wildebeest*	.540	tricycle	.464
yak*	.571	wheelbarrow*	.485

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