Voluntary task switching under load: Contribution of top-down and bottom-up factors in goal-directed behavior.

Jelle Demanet

Frederick Verbruggen

Baptist Liefooghe

André Vandierendonck

Ghent University

Word count (text, references, footnotes, appendix): 3,911

Pages: 20

Figures: 0

Key words: goal-directed behavior, voluntary task switching, working-memory load, top-down control, bottom-up intrusions

Correspondence Address:
Jelle Demanet
Department of Experimental Psychology
Ghent University
Henri Dunantlaan 2
B-9000 Ghent (Belgium)
E-mail: jelle.demanet@ugent.be
Tel.: + 32 (0) 9-264.64.38 Fax: +32-(0)9-264.64.96

Abstract

The present study investigated the relative contribution of bottom-up and top-down control to task selection in the voluntary task switching (VTS) procedure. In order to manipulate the efficiency of top-down control, a concurrent working-memory load was imposed during VTS. In three experiments bottom-up factors such as stimulus repetitions, repetition of irrelevant information and stimulus-task associations were introduced to investigate their influence on task selection. We observed that the tendency to repeat tasks was stronger under load, suggesting that top-down control counteracts the automatic tendency to repeat tasks. The results also indicated that task selection can be guided by several elements in the environment, but that only the influence of stimulus repetitions depend on the efficiency of top-down control. The theoretical implications of these findings are discussed within the interplay between top-down and bottom-up control that underlies the voluntary selection of tasks.

Many researchers assume that goal-directed behavior relies on the intentional and controlled activation of task goals (Baddeley, 1992; Logan & Gordon, 2001; Miller & Cohen, 2001). However, several studies demonstrated that task goals can also be activated automatically by information in the environment (e.g. Mattler, 2003; Mayr & Bryck, 2007; Verbruggen & Logan, 2009) or by the retrieval of previously formed associations between a stimulus and a particular goal (e.g. Verbruggen & Logan, 2008; Waszak, Hommel & Allport, 2003). In the present study we examined the contribution of top-down and bottom-up activation of task goals in voluntary task switching (VTS).

In VTS, subjects switch between cognitive tasks. They are free to select the task to perform, as long as each task is selected an approximate equal number of times and subjects do not follow a predictable pattern of task selections (Arrington, 2008; Arrington & Logan, 2004; 2005; Liefooghe, Demanet, & Vandierendonck, 2009; Mayr & Bell, 2006). A general finding is that subjects repeat tasks more often than they switch (Arrington & Logan, 2005). This task-repetition bias has been linked to the efficiency of top-down control processes involved in the voluntary selection of task goals. For example, Mayr and Bell (2006) argued that subjects tend to repeat tasks because the task of the previous trial is still the most active one when selecting a new task. In order to overcome this bias, the activated task has to be inhibited. Thus, selection of tasks would depend on top-down control processes (see also Arrington & Logan, 2004, 2005). However, several studies showed that bottom-up processes also contribute to task selection in VTS (e.g. Arrington, 2008) and Mayr and Bell (2006) observed that the task-repetition bias was stronger when the stimulus of the previous trial was repeated compared to when the stimulus alternated. This stimulus-repetition effect suggests that voluntary task selection is not completely immune to bottom-up priming effects.

In the present study, we focused on the contribution of top-down control and bottom-up priming in voluntary task selection. Studies in several paradigms have shown that bottom-up factors contribute more to behavior in cognitively demanding situations (see Lavie, 2005 for a review). A manipulation that is often used to reduce the efficiency of top-down control is a concurrent working memory (WM) load (e.g. Logan, 2007). To test the relative contribution of bottom-up and top-down processes in task selection, we manipulated WM load in the VTS paradigm in three experiments. Each experiment consisted of two conditions: a load condition and a no-load condition (see Logan, 2007). In the *load condition*, subjects were shown six letters which they had to remember (*study phase*), followed by 13 voluntary switch trials (*VTS phase*), followed by a *recall phase* in which subjects had to indicate which letters were shown in the study phase. In the *no-load condition*, the study phase was immediately followed by the recall phase, which was in turn followed by the VTS phase, so that there was no concurrent memory load during the test phase. We predicted that bottom-up control would contribute more to task selection in the load condition than in the no-load condition. The results of Experiment 1 confirmed this prediction and showed that the stimulus-repetition effects and the task-repetition bias were stronger in the load condition than in the no-load condition. In Experiments 2 and 3, we further tested how stimulus repetitions affected task-selection processes. We propose three accounts for the stimulus-repetition effect. First, the effect could be caused by the repetition of visual information on the screen; this could prime the decision to repeat the task (see also Arrington & Logan, 2005). Second, the effect could be caused by retrieval of associations that were formed between the stimulus and the task executed on the previous trial. When the stimulus repeats, this association is retrieved and the task goal of the previous trial is primed (see e.g. Verbruggen & Logan, 2008). Third, the effect could also be due to the retrieval of associations between the stimulus and the task-execution response (see e.g. Hommel, 1998; Soetens, 1998). When the stimulus repeats, the task-execution response of the previous trial is also repeated. This would suggest that subjects did not select a new task first; instead, they would have directly executed a response. Experiments 2 and 3 were designed to test these accounts by including repetitions of task-irrelevant features in Experiment 2 and by the formation of strong stimulus-task associations in a training phase in Experiment 3.

Experiments

Because the method and results sections of the three experiments strongly overlapped, we describe them together.

Method

Subjects and Materials

80 students from Ghent University participated for course requirements and credit (Exp.1: 24; Exp.2: 24: Exp.3: 32). They were tested individually by means of a Pentium III personal computer with a 17-inch color monitor running Tscope (Stevens, Lammertyn, Verbruggen, & Vandierendonck,

2006). We used an external response box with 4 buttons to register responses in the VTS phase and a QWERTY keyboard to register responses in the recall phase.

Procedure

The experimental session of Experiment 1 consisted of a study phase, a recall phase, and a VTS phase. In the study phase we presented six different low inter-confusable consonants (see Vandierendonck, De Vooght, & Van der Goten, 1998 for details). The consonants were presented in the center of the screen at a rate of one item per second (500 ms on; 500 ms off). In the recall phase subjects had to recall the memorized items in the correct order by typing the items on the keyboard. There were no time constraints in the recall phase. In the VTS phase subjects categorized a stimulus as smaller or larger than ‘5’ (magnitude task) or as odd or even (parity task). We used digits 1-9, excluding 5. The magnitude task (smaller: left-outer button; larger: left-inner button) and the parity task (odd: right-inner button; even: right-outer button) were mapped on a different hand. The task-to-hand assignment was counterbalanced across subjects. There were 13 trials in the VTS phase. Each trial started with the presentation of a stimulus. When a response was executed or the maximal response time of 3000ms had elapsed, a fixed response-stimulus interval of 100 ms started. The first trial was a filler; of the remaining 12 trials four were stimulus repetitions (25%). The experimental session started with three practice blocks in which subjects practiced a) the study and recall phase separately, b) the VTS phase separately and c) the combination of the three phases. Before the practice blocks, we presented the instructions of Arrington and Logan (2004) (in Dutch) on the screen and paraphrased them if necessary. The practice trials were followed by the experimental session, which consisted of 20 lists per condition (load condition: study-test-recall, or no-load condition: study-recall-test). The order of the conditions was counterbalanced over subjects. The experimental session lasted approximately 30 minutes.

Experiment 2 was identical to Experiment 1 except that in the VTS phase, stimulus repetitions were excluded. Instead, we presented a task-irrelevant shape on each trial. The target stimulus appeared inside one of four white non-filled shapes (circle, triangle, hexagon, square; each shape = 5.9cm^2). On 25% of the trials, the shape of the previous trial was repeated.

In Experiment 3, subjects performed an ‘animacy’ task (‘non-living’ or ‘living’), or a ‘size task’ (‘smaller’ or ‘larger than a basketball’) on nouns. 128 nouns were selected on the basis of word frequency (per million) and word length (average frequency: 11.0; average length: 5.6). For every participant, three different stimulus sets of 32 nouns were selected (matched for frequency and word length). All sets consisted of 8 large living, 8 small living, 8 large nonliving, and 8 small nonliving stimuli. Before the experimental session, subjects performed a training session of 16 single-task blocks (±40 minutes). In the training session, the first stimulus set was always used for the animacy task; the second stimulus set was always used for the size task. Subjects practiced one task in the odd-numbered blocks and the other task in the even-numbered blocks. Task-to-block mapping was counterbalanced. Each training block consisted of 32 trials, and each item of the relevant set was presented once. All trials in the training session started with the presentation of a noun in the center of the screen. This stimulus remained on the screen for 1,000 ms, regardless of the response time. The maximal-response time was 4,000 ms and the response-stimulus interval 750ms. Subjects responded orally by saying ‘[bu:]’ for living, ‘[bi:]’ for non-living, ‘[ba:]’ for small, and ‘[bo:]’ for large. The structure of the experimental phase of Experiment 3 was similar to that of Experiment 1. Because VTS stimuli were words, the WM load consisted of six different numbers (range 1-9). There were no other differences in the study or recall phase. In the VTS phase the animacy task was performed with one hand (non-living: left-outer button; living: left-inner button) and the size task with the other hand (small: right-inner button; large: right-outer button). Eight lists of VTS trials were used in both load conditions. In each VTS phase, twelve stimuli were presented: four stimuli of the ‘animacy’ set, four stimuli of the ‘size’ set, and four stimuli of the third stimulus set (the neutral set, which was not used in the training phase). The maximal response time in the VTS trials was 5,000ms because the tasks were more difficult than in Experiments 1 and 2.

Results and Discussion

The first trial of each VTS phase and trials following an error were discarded (data loss: Exp1 = 12.8%; Exp2 = 11.5%; Exp3 = 12.3%). In this study, we are interested in the processes that are involved in the voluntary selection of tasks. Therefore, in the results section, we will focus on task-choice data only. Analyses of response latencies are presented in Appendix A. The task-selection proportions appear in Table 1 and all analyses appear in Table 2.

Data of Experiment 1 were analyzed by means of a repeated measures ANOVA with load (no-load vs. load) and trial type (stimulus repetition vs. alternation) as factors, performed on the task-repetition proportions. When relevant, individual t-tests were performed to test whether proportions were different from .50. As shown in Tables 1 and 2 subjects repeated the task of the previous trial more often in the load (*M*=.579, *SE*=.029; comparison .50: t(23) = 2.68, *p* = .01) than in the no-load condition (*M*=.483, *SE*=.026; comparison .50: t(23) = -.66, *p* = .51). These results confirm the hypothesis that top-down control is needed to counteract the tendency to repeat tasks (e,g. Mayr & Bell, 2006). The absence of a tendency (in comparison with .50) to repeat tasks in the no-load condition is probably due to the length of the sequences. This result converges with the findings of Rapoport and Budescu (1997) indicating that in random selection of events there is a larger tendency to alternate for shorter sequences.

Importantly, we observed a stimulus-repetition effect in the load but not in the no-load condition of Experiment 1 (see Tables 1 and 2). Simple main effects showed that the effect of trial type was significant in the load, $F(1,23) = 4.93$, MSE = .0163, $\eta_p^2 = .18$, but not in the no-load condition, $F<1$. This suggests that bottom-up control contributes more to task selection in cognitively demanding situations (i.e. the load condition) than in less demanding situations (i.e. the no-load condition). The complete absence of a stimulus-repetition effect in the no-load condition is probably due to the relatively low number of stimulus repetitions (see also, Arrington & Logan, 2005, Experiments 3 and 4).

Data of Experiment 2 were analyzed by means of a repeated measures ANOVA with load (no-loaded vs. load) and trial type (shape repetition vs. alternation) as factors. The analyses showed that tasks were repeated more often in the load (*M*=.570, *SE*=.024; comparison .50: t(23) = 2.91, *p* = .01) than in the no-load condition (*M*=.532, *SE*=.023; comparison .50: t(23) = 1.41, *p* = .17). Furthermore, tasks were repeated more often on shape repetitions (*M*=.569, *SE*=.022) than on shape alternations (*M*=.534, *SE*=.024), which suggests that repeating visual information can prime task repetitions. However, the size of the shape-repetition effect was comparable for the load and the no-load condition (see Table 2). The absence of an interaction suggests that the stimulus-repetition effect observed in Experiment 1 was not simply caused by the repetition of visual information on the screen.

The data of Experiment 3 were analyzed in two steps. First, we examined whether task selections were influenced by the training phase by means of a repeated measures ANOVA with load and stimulus set (animacy vs. size vs. neutral set) as factors. We focused on the proportions of the animacy task; we would get symmetrical results if the focus was on the size task. The analysis showed that there was a strong learning effect (see Table 2). Contrasts showed that the animacy task was selected more often for the animacy set (*M*=.554, *SE*=.012) than for the neutral set (*M*=.501, *SE*=.010), *F*(1,31)=10.31, MSE=.0088 , η_p^2= .25, and the size set (*M*=.458, *SE*=.011), *F*(1,31)=28.57, MSE=.0104, η_p^2= .48. The difference between the size and neutral sets was also significant, *F*(1,31)=7.94, MSE=.0074, η_p^2= .20, which suggests that subjects tended to choose the size task for the size set. Combined, these findings suggest that learned stimuli primed the selection of the task they were associated with in the training phase. However, this stimulus-priming effect was similar in the no-load and load condition (Table 2). The absence of an interaction shows that stimulus-task associations do not cause the priming effect in Experiment 1.

In a second step, we examined whether there was an influence of load on the general task-repetition bias, like in the other experiments. We analyzed task-repetition proportions with a one-way ANOVA with load as factor. Consistent with Experiments 1 and 2, we found that tasks were repeated more often in the load (*M*=.517, *SE*=.021; comparison .50: t(32) = .81, *p* = .42) than in the no-load condition (*M*=.472, *SE*=.020; comparison .50: t(32) = -1.44, *p* = .16), *F*(1,31)=6.55, MSE=.0050, η_p^2= .17. Again, this finding shows that the task-repetition bias is stronger in cognitively demanding situations.

Recall phase

The proportions of correct recall represent the probability that a particular item was remembered correctly in the correct order. We analyzed the proportions by means of a simple main effects ANOVA with load as the only factor. As shown in Table 3, proportions were higher in the no-load than in the load condition, which can be explained by the different order of the VTS and recall phases.

Conclusion

In the present study, we examined how bottom-up and top-down processes contribute to voluntary selection of tasks in situations that are cognitively demanding. In Experiment 1, we found that subjects repeated tasks more often in the load (demanding) condition than in the no-load (non-demanding) condition. We replicated this load effect in Experiments 2 and 3. The effect of load on the task-repetition bias is consistent with the idea that top-down processes are required to overcome the tendency to keep repeating the same task. This is consistent with the idea that top-down control inhibits the most recent task, which reduces the tendency to repeat tasks (Mayr & Bell, 2006; see also Lien & Ruthruff, 2008).

In Experiment 1, we found that stimulus repetitions elicited more task repetitions in the load than in the no-load condition. This observation seems to support the idea that bottom-up control contributes more to task selection in cognitively demanding situations (for a similar idea; Arrington, 2008; Lavie, 2005). In Experiments 2 and 3, however, we observed priming effects of repeating shapes and acquired stimulus-task associations but these effects did not interact with load. This suggests that some bottom-up driven effects occur independently of the cognitive demands of the situation. Furthermore, the results of Experiments 2 and 3 suggest that the stimulus-repetition effect, which was observed in Experiment 1 and which interacted with load, was not caused by repetition of visual information or the retrieval of stimulus-task associations. Instead, we propose that the stimulus-repetition effect is caused by the retrieval of associations between the stimulus and the task-execution response. When the stimulus is repeated, the task-execution response of the previous trial is activated and executed again. Interestingly, this suggests that on a proportion of the trials, a response is executed without advance selection of a new task. The interaction with load in Experiment 1 suggests that there are more non-selection trials when top-down control is degraded in highly demanding situations. In less demanding situations, however, top-down processes can counteract this response-repetition tendency. This seems to suggest that an important function of top-down control in VTS is to protect task-selection from automatically triggered responses. This function of top-down control can be related to the response-inhibition account of Hübner and Druey (2006), which states that in a task-switching context a response has to be inhibited in order to avoid its automatic re-execution on the following trial (for a similar idea, Logan & Gordon, 2001). In this perspective, the present study contributes by showing that when a response is inhibited less efficiently in a high demanding situation, the chance to re-execute this response on the next trial is increased on stimulus repetitions. In sum, this study showed that different bottom-up factors can guide task selection but also that top-down control is necessary to shield task selection from the effects of stimulus-response associations, and to counteract the tendency to perseverate tasks.

In conclusion, the data of the present study also allowed us to formulate an answer to the question what is really “voluntary” or “intentional” in the VTS paradigm. We obtained convincing evidence for the ideas that task goals are automatically triggered by factors in the environment (e.g. Waszak et al., 2003) but also that subjects can inhibit recently activated task goals and suppress automatically triggered responses to protect intentional goal-directed behavior. Thus, maybe the intentional or voluntary act in VTS is not to activate what is “willed” but to suppress what is “unwilled”.

References

Allport, A., & Wylie, G. (2000). Task-switching, stimulus-response bindings, and negative priming. In S. Monsell & J. S. Driver (Eds.), *Control of cognitive processes: Attention and Performance XVIII* (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. doi: 10.3758/MC.36.5.991

Arrington, C.M., & Logan, G.D. (2004). Episodic and semantic components of the compound-stimulus strategy in the explicit-task cuing procedure. *Memory & Cognition, 32,* 965-976. doi: 10.1111/j.0956-7976.2004.00728.x

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. doi: 10.1037/0278-7393.31.4.683

Baddeley, A. D. (1992). Working memory. *Science, 255,* 556-559. doi: 10.1126/science.1736359

Hommel, B. (1998). Event files: Evidence for automatic integration of stimulus-response episodes. *Visual Cognition, 5,* 183-216. doi: 10.3758/APP.71.2.352

Hübner, R., & Druey, M.D. (2006). Response execution, selection, or activation: What is sufficient for response-related repetition effects under task shifting? *Psychological Research, 70,* 245-261. doi: 10.1007/s00426-005-0219-8

Lavie, N. (2005). Distracted and confused?: Selective attention under load. *Trends in Cognitive Sciences, 9,* 75-82. doi: 10.3758/PBR.16.5.864

Liefooghe, B., Demanet, J., & Vandierendonck, A. (2009). Is advance reconfiguration in voluntary task switching affected by the design employed? *Quarterly Journal of Experimental Psychology, 65,* 850-857. doi: 10.1080/1747021080257099

Liefooghe, B., Vandierendonck, A., Muyllaert, I., Verbruggen, F., & Vanneste, W. (2005). The phonological loop in task alternation and task repetition. *Memory, 13,* 550-560. doi: 10.1080/09658210444000250

Lien, M.C., Ruthruff, E. (2008). Inhibition of task set: Converging evidence from task choice in the voluntary task-switching paradigm. *Psychonomic Bulletin & Review, 15,* 950-955. doi: 10.3758/PBR.15.6.1111

Logan, G.D. (2007). What it costs to implement a plan: Plan-level and task-level contributions to switch costs. *Memory and Cognition, 35,* 591-602.

Logan, G.D., & Gordon, R.D. (2001). Executive control of visual attention in dual-task situations. *Psychological Review, 108,* 393-434. doi: 10.1037/0033-295X.108.2.393

Mattler, U. (2003). Priming of mental operations by masked stimuli. *Perception and Psychophysics, 65,* 167-187.

Mayr, U., & Bell, T. (2006). On how to be unpredictable: Evidence from the voluntary task-switching Paradigm. *Psychological* Science, 9, 774-780. doi: 10.1111/j.1467-9280.2006.01781.x

Mayr, U., & Bryck, R.L. (2007). Outsourcing control to the environment: effects of stimulus/response locations on task selection. *Psychological Research, 71,* 107-116. doi: 10.1007/s00426-005-0039-x

Miller, E.K., & Cohen, J.D. (2001). An integrative theory of prefrontal cortex function. *Annual Review of Neuroscience,* 24, 167-202. doi:10.1146/annurev.neuro.24.1.16

Rapoport, A. & Budescu, D.V. (1997). Randomization in individual choice behavior. *Psychological Review, 104,* 603-617.

Soetens, E. (1998). Localizing sequential effects in serial choice reaction time with the information reduction procedure. *Journal of Experimental Psychology: Human Perception and Performance, 24,* 547-568.

Stevens, M., Lammertyn, J., Verbruggen F., & Vandierendonck A. (2006). Tscope: A C library for programming cognitive experiments on the MS Windows platform. *Behavior Research Methods, 38,* 280-286.

Vandierendonck, A., De Vooght, G. & Van der Goten, K. (1998). Does random time interval generation interfere with working memory executive functions? *European Journal of Cognitive Psychology, 10,* 413-442.

Verbruggen, F., & Logan, G.D. (2008). Automatic and controlled response inhibition: associative learning in the go/no-go and stop-signal paradigms. *Journal of Experimental Psychology: General, 137,* 649-672. doi: 10.1037/a0013170

Verbruggen, F. & Logan, G.D. (2009). Automaticity of cognitive control: Goal priming in response-inhibition paradigms. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 35,* 1381-1388. doi: 10.1037/a0016645

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. doi: 10.1016/S0010-0285(02)00520-0

Table 1: Task-repetition proportions as a function of load, trial type and task transition for Experiment 1 and 2 and task-selection proportions as a function of load, trial type and task for Experiment 3.

	no-load condition		*load condition*	
Repetition proportions	*task repetitions*	*task switches*	*task repetitions*	*task switches*
Experiment 1				
stimulus repetitions	.48 (.04)	.52 (.04)	.62 (.04)	.38 (.04)
stimulus alternations	.48 (.02)	.52 (.02)	.54 (.02)	.46 (.02)
Experiment 2				
shape repetitions	.55 (.02)	.45 (.02)	.59 (.03)	.41 (.03)
shape alternations	.51 (.03)	.49 (.03)	.55 (.02)	.45 (.02)
Task proportions	*animacy task*	*size task*	*animacy task*	*size task*
Experiment 3				
animacy stimuli	.54 (.02)	.46 (.02)	.57 (.02)	.43 (.02)
size stimuli	.46 (.02)	.54 (.02)	.46 (.02)	.54 (.02)
neutral stimuli	.51 (.02)	.49 (.02)	.49 (.01)	.51 (.01)

Note – Standard errors are presented within brackets.

Table 2: Outcome of the ANOVAs conducted on the selection proportions of task repetitions for Experiments 1 and 2, and of the task-selection proportions for Experiment 3.

		Experiment 1		
		Proportion task repetitions		
	MSe	*(df1,df2)*	*F*	η_p^2
load	.0118	(1,23)	18.70*	.45
trial type	.0254	(1,23)	1.41	.06
load*trial type	.0034	(1,23)	12.96*	.36
		Experiment 2		
		Proportion task repetitions		
	MSe	*(df1,df2)*	*F*	η_p^2
load	.0045	(1,23)	7.46*	.24
trial type	.0027	(1,23)	10.84*	.32
load*trial type	.0025	(1,23)	.00	.00
		Experiment 3		
		Proportions ‘animacy’task		
	Wilks	*(df1,df2)*	*F*	η_p^2
load	.9986	(1,31)	.04	.00
trial type	.5204	(2,30)	13.83*	.48
load*trial type	.9390	(2,30)	.98	.06

Note – *: $p<.05$

Table 3: Mean proportions of correct recall in the no-load and load condition and the results of the main effect ANOVAs on these proportions with load as the only factor.

	no-load	load	main effect load			
			(df1,df2)	*F*	*MSe*	η_p^2
Experiment 1	.93 (0.1)	.84 (0.2)	(1,23)	42.80*	.0025	.65
Experiment 2	.91 (0.1)	.84 (0.2)	(1,23)	31.74*	.0020	.58
Experiment 3	.97 (0.1)	.83 (0.3)	(1,31)	27.36*	.0101	.47

Note – *: $p<.05$. Standard errors are presented within brackets.

Appendix A

The mean RTs and analyses are presented in Tables A1 and A2. Error rates were very low (Exp1 = 3.6%; Exp2 = 3.1%; Exp3 = 4.6%) and not further analyzed.

We analyzed the mean RTs of Experiments 1 and 2 with a repeated measures ANOVA with the factors load (no-load vs. load), trial type and task transition (task repetition vs. task switch). In both experiments, we found main effects of load [RT(no-load) < RT(load)] and task transition [RT(repetition) < RT(switch)]. The main effect of trial type was also significant, indicating that repetitions of stimuli or shapes induced faster responses than alternations. In Experiment 1, the interaction between trial type and task transition was reliable indicating that the switch cost was smaller on stimulus repetitions than alternations (see Allport & Wylie, 2000). The interaction between load and task transition was significant, indicating that the switch cost was smaller in the load than in the no-load condition. A contrast showed that this was especially due to marginally slower task repetitions in the load than in the no-load condition, $F(1,23)=3.75$, MSE=9861, $\eta_p^2 = .14$, and not by faster switches, $F<1$ (for similar results Liefooghe et al., 2005). In Experiment 2, the interaction between load and task transition was not significant. Possibly this difference between Experiment 1 and 2 is due to the inclusion of stimulus repetitions in Experiment 1.

We analyzed mean RTs of Experiment 3 with a mixed ANOVA with the factors load, trial type (animacy vs. size vs. neutral stimulus set), task transition and task We found main effects of load [RT(no-load) < RT(load)] and task transition [RT(repetition) < RT(switch)]. Also, the main effect of trial type was significant. Contrasts showed that responses to neutral stimuli were slower than responses to stimuli of the size stimulus set, $F(1,31)=17.12$, MSE=18931, $\eta_p^2 = .36$. The differences between neutral and animacy and the differences between animacy and size were not significant; $F(1,31)=1.61$, MSE=34019, $\eta_p^2 = .05$, and $F(1,31)=2.64$, MSE=42558, $\eta_p^2 = .08$, respectively. The interaction between trial type and task was significant, indicating that performing task on a stimulus that is associated with that same task leads to better performance than performing another task. Contrasts confirmed this for both the animacy, $F(1,31)=18.19$, MSE=39806, $\eta_p^2 = .37$, and size stimulus set, $F(1,31)=17.43$, MSE=21759, $\eta_p^2 = .36$, but not for the neutral stimulus set, $F<1$.

Table 1A: Mean RTs as a function of load, trial type and task transition for Experiment 1 and 2 and mean RTs as a function of load, trial type and task transition and task for Experiment 3.

	no-load condition		*load condition*	
Experiment 1	*task repetitions*	*task switches*	*task repetitions*	*task switches*
stimulus repetitions	624 (31)	889 (29)	656 (32)	849 (33)
stimulus alternations	831 (25)	940 (27)	877 (33)	965 (34)
Experiment 2				
shape repetitions	798 (35)	930 (45)	796 (31)	989 (39)
shape alternations	809 (41)	962 (46)	837 (35)	1010 (42)

Experiment 3	*animacy task*	*size task*	*animacy task*	*size task*	*animacy task*	*size task*	*animacy task*	*size task*
animacy stimuli	974 (52)	1063 (62)	1155 (52)	1233 (62)	1000 (52)	1165 (68)	1233 (55)	1327 (77)
size stimuli	1042 (58)	1006 (62)	1145 (46)	1091 (39)	1138 (63)	1066 (50)	1286 (59)	1140 (55)
neutral stimuli	1054 (59)	1112 (69)	1228 (54)	1177 (43)	1097 (58)	1137 (53)	1244 (51)	1267 (59)

Note – Mean RTs and standard errors are given in milliseconds. Standard errors are presented within brackets.

Table 2A: Outcome of the ANOVAs conducted on the RTs for Experiments 1, 2 and 3.

Experiment 1

	MSe	*(df1,df2)*	*F*	η_p^2
load	16665	(1,23)	.72	.03
trial type	16818	(1,23)	63.04*	.73
task transition	30245	(1,23)	42.59*	.65
load*trial type	8087	(1,23)	2.31	.09
load*task trans	5549	(1,23)	4.76*	.17
trial type*task trans	7083	(1,23)	28.73*	.56
load*trial type*task trans	3836	(1,23)	2.00	.08

Experiment 2

	MSe	*(df1,df2)*	*F*	η_p^2
load	31502	(1,23)	1.67	.07
trial type	4213	(1,23)	7.89*	.26
task transition	15822	(1,23)	80.79*	.78
load*trial type	1901	(1,23)	.55	.02
load*task trans	4970	(1,23)	3.88	.14
trial type*task trans	4059	(1,23)	.00	.00
load*trial type*task trans	2700	(1,23)	1.89	.08

Experiment 3

	Wilks	*(df1,df2)*	*F*	η_p^2
load	.8501	(1,31)	5.47*	.15
trial type	.6417	(2,30)	8.37*	.36
task transition	.4100	(1,31)	44.60*	.59
task	.9712	(1,31)	0.92	.03
load*trial type	.9387	(2,30)	0.98	.06
load*task trans	.9878	(1,31)	0.38	.01
trial type*trans	.8244	(2,30)	3.20	.18
load*task	.9997	(1,31)	0.01	.00
trial type*task	.4647	(2,30)	17.28*	.54
task trans*task	.8849	(1,31)	4.03	.12
load*trial type*task trans	.9999	(2,30)	0.00	.00
load*trial type*task	.8751	(2,30)	2.14	.12
load*task trans*task	.9992	(1,31)	0.03	.00
trial type*task trans*task	.9959	(2,30)	0.06	.00
4-way interaction	.8699	(2,30)	2.24	.13

Note – *: $p<.05$

Author Note

Jelle Demanet, Frederick Verbruggen, Baptist Liefooghe, André Vandierendonck, Department of Experimental Psychology, Ghent University, Belgium. Frederick Verbruggen is a Postdoctoral Fellow of the Research Foundation Flanders (FWO-Vlaanderen). We thank the reviewers for their comments on a previous version of the paper.

Correspondence about the paper can be directed to: Jelle Demanet, Department of Experimental Psychology, Ghent University, Henri Dunantlaan, 2, B-9000 Gent, Belgium. E-mail: Jelle.Demanet@UGent.be.