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SELECTIVE ATTENTION TO PERCEPTUAL DIMENSIONS AND SWITCHING BETWEEN DIMENSIONS

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Abstract

Selectively attention to perceptual dimensions and switching between dimensions have been studied in two separate literatures. The present experiment examined both of these abilities. Participants classified objects according to shape and brightness in ***single-task*** *conditions and switched between these tasks in mixed tasks conditions, including trials in which the classification rule switched (***switch***) or repeated (***repeat***). Saturation, was either constant (***base***) or varied orthogonally (***filtering***). Filtering (vs. base) influenced brightness classification (showing Garner Interference, GI) but not shape classification. This GI was largest in single-task conditions and smallest in switch conditions. Thus, challenging filtering/switching ability did not compromise the other ability. Systems Factorial Technology analyses of the brightness task show that, in most of the participants, switching cost (switch vs. repeat) and GI were related to serial self terminating processes while mixing cost (repeat vs. single task) and GI were related to parallel exhaustive processes.*

The ability to selectively attend to stimulus dimensions and the ability to switch attention between dimensions have been studied in two separate literatures. Garner and his colleagues (e.g., Garner & Felfoldy, 1974) studied the ability to selectively attend to stimulus dimensions. They asked participants to classify multidimensional stimuli based on perceptual dimensions such as color and shape. In the *Base* condition, the stimuli varied along the relevant dimension (e.g., they came in different colors during the color task) and their value along the irrelevant dimension was held constant (e.g., all of them were squares). In the *Orthogonal Filtering* condition ("filtering" for short), the stimuli also varied along the irrelevant dimension (e.g., some were squares and some were circles), but this variation was unrelated to the variation in the relevant dimension (e.g., half of the stimuli presented in a given color were circles and half were squares). The filtering condition required effectively ignoring this irrelevant variation. The performance decrement in filtering relative to base is called Garner Interference (GI). Garner's paradigm makes it possible to distinguish between *Separable dimension,* showing no GI, and *Integral* dimension, showing GI.

In many task switching studies (see Kiesel et al., 2010; Meiran, 2010, for review), participants are asked to switch their classification rule from one dimension, such as color, to another dimension, such as shape. In a commonly used version of the task switching paradigm, each trial starts with a task cue, instructing participants which classification rule is currently in effect (e.g., Rubin & Meiran, 2005). A common finding is the behavioral cost associated with switching. This cost is often broken into *switching cost* and *mixing cost* (Rubin & Meiran, 2005, for review). The design which permits this breakdown involves two types of experimental blocks and three conditions. There are *mixed-tasks blocks* involving task switching and *single-task blocks* without task switching. There is an additional distinction between *switch* and *repeat* trials within the mixed-tasks blocks, related to immediate task switch and task repetition, respectively. Switching cost is defined as the decrement in performance in switch trials relative to repeat trials. Mixing cost is defined as the decrement in performance in repeat trials relative to pure trials. (This set of contrasts is non-orthogonal but see Kray & Lindenberger, 2000, for another definition, involving orthogonal contrasts).

In the current experiment, participants switched between two separable dimensions, shape and brightness. In addition, the value of the third, never-relevant dimension, saturation, was either constant or varied orthogonally. This third dimension was chosen to be integral with the sometimes-relevant dimension of brightness and separable with the sometimes-relevant dimension, shape. The design permitted us to address the following two questions:

Q1: Are the two abilities dependent in the sense that challenging one of them compromises the other? We reasoned that a positive answer to Q1 would reflect either in enlarged switching/mixing costs in filtering conditions relative to base conditions or in enlarged GI in switch conditions relative to single-task or repeat conditions. Additionally, hitherto separable dimensions (shape and saturation) would become integral in highly demanding switching conditions.

Q2: Given a negative answer to Q1, how are the processes associated with the two abilities organized in the cognitive architecture? To this end we employed Systems Factorial Technology (SFT, Townsend & Nozawa, 1995).

EXPERIMENT

Method

Participants

Participants were 16 undergraduate students from Ben-Gurion University of the Negev and Achva Academic College. They took part in the present experiments in return for partial course credit or for 30 NIS (approximately 8 US$). All the participants reported having normal or corrected-to-normal vision.

Stimuli and Procedure

The task cues were a white square for “shape” and a blue rectangle for brightness. The target stimuli were high/low saturation red bright/dull circles or triangles.

The assignment of the target values (e.g., CIRCLE, TRIANGLE) to response keys was counterbalanced between the participants as was the constant saturation value in the base condition, creating 8 counterbalancing conditions. The experiment included single task blocks and mixed blocks. In the single task blocks, the participants had to accomplish only one of the tasks, brightness or shape, throughout the block, while in the mixed blocks, they switched between shape and brightness. These blocks were accomplished in two Filtering conditions: base (in which saturation was constant) and filtering (in which saturation varied orthogonally).

In order to control for the effect of block position within the experiment, we adopted a “sandwich” design (Rubin & Meiran, 2005) that included six block types shape-base, shape-orthogonal, brightness-base, brightness-orthogonal, mixed-base and mixed-orthogonal. Each participant started and finished the experiment with the single-task blocks, while the mixed task blocks were in the middle. The order of the different single-task blocks, shape → brightness and brightness→shape, their Filtering condition and the order of the base-vs.-filtering conditions in the mixed blocks were counterbalanced between the participants. There were 24 experimental blocks, 48 trials each. Each time the participant started a new type of block, s/he received an explanation and a practice block. The session took approximately 45-50 minutes to accomplish.

Each trial started with a black screen presented for a fixed response-cue interval of 500 ms. It was followed by the presentation of the task cue for 500 ms. Then, the target that was added below the task-cue and both of them were kept on the screen until the response was given. Participants were instructed to respond by pressing the "A" (left) and "L" (right) keys with their two index fingers, according to the specific task instructions.

Results

Analysis of Variance (ANOVA)

Mean correct reaction times (RTs) were submitted to a 2 (Task: shape vs. brightness) x 2 (Filtering: base vs. filtering) x 3 (Transition: single-task, switch, repeat) ANOVA. There were significant main effects of all the variables including Task, $F(1, 15)=35.52$, $MSE=6{,}511.90$, $p<.0001$, $\eta_p^2=.70$, Transition, $F(2, 30)=64.64$, $MSE=19{,}415.26$, $p<.0001$ $\eta_p^2=.81$ (mean RT was 462, 602 and 744 ms in single-task, repeat and switch, respectively, reflecting mixing cost of 140 ms and switching cost of 142 ms), and Filtering, $F(1,15)=17.62$, $MSE=7{,}716.23$, $p<.001$, $\eta_p^2=.54$. In addition, the two way interactions between Task and Transition, $F(2, 30)=7.12$, $MSE=4{,}093.69$, $p<.005$, $\eta_p^2=.32$, and Task and Filtering, $F(1, 15)=45.98$, $MSE=3{,}848.72$, $p<.0001$, $\eta_p^2=.75$, were significant. All the above effects were qualified by a significant triple interaction, $F(2, 30)=7.05$, $MSE=1{,}788.72$, $p<.005$, $\eta_p^2=.32$. Because of its theoretical importance, we began by exploring the Task by Filtering interaction. There was a significant GI of 114 ms in the brightness task, $F(1, 15)=36.46$, $p<.0001$, and a non significant GI of 7 ms in the shape task, $F=.44$, ns.

Next we probed the triple interaction. We computed the simple interaction between Transition and Filtering separately for each task. This simple interaction was significant for the brightness task, $F(2, 30)=8.03$, $p<.005$, and non-significant for the shape task, $F(2, 30)=1.06$, ns. The significant simple interaction in the brightness task reflects the diminishing GI when moving from single-task (162 ms, $F=59.88$, $p<.0001$) to mixed task conditions including repeat (77 ms, $F=13.07$, p<.005) and switch (103 ms, $F=16.61$, $p<.001$).

SFT analyses

In order to examine the organization of the processes related to switching and filtering, we employed SFT (Townsend & Nozawa, 1995) in the analysis of the brightness task. We did so twice, once for switching cost (switch vs. repeat) and once for mixing cost (repeat vs. single-task). The analyses were performed on the results of individual participants and included the Survivor Interaction Contrast (SIC), significance testing of maximal positive/negative SIC deflections (Haupt & Townsend, 2010), and Mean Interaction Contrasts (MICs) which are the interactions between the relevant cost contrast and Filtering. Before conducting the analyses, violations of selective influence were examined using Kolmogorov-Smirnov tests. A lenient $\alpha=.10$ was adopted to offset for the reduced statistical power associated with examining results of individual participants. Significant violation of selective influence was noted in one participant (Participant 13, mixing cost analysis). The results are presented in Figures 1 and 2 and in Table 1.

Table 1: Mean Interaction Contrast values in ms. Significant (p<.10) values are underlined. Positive values indicate over-additive interactions and negative values indicate under-additive interactions.

Participant															
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Switching cost analysis															
-8	-56	-35	**199**	115	34	89	115	22	**-140**	71	**-111**	51	80	-18	6
Mixing cost analysis															
15	-51	**-194**	**-136**	**-130**	1	**-148**	**93**	-64	-9	**-139**	-76	*	-80	-84	**-83**

* Value was not computed because of violation of selective influence.

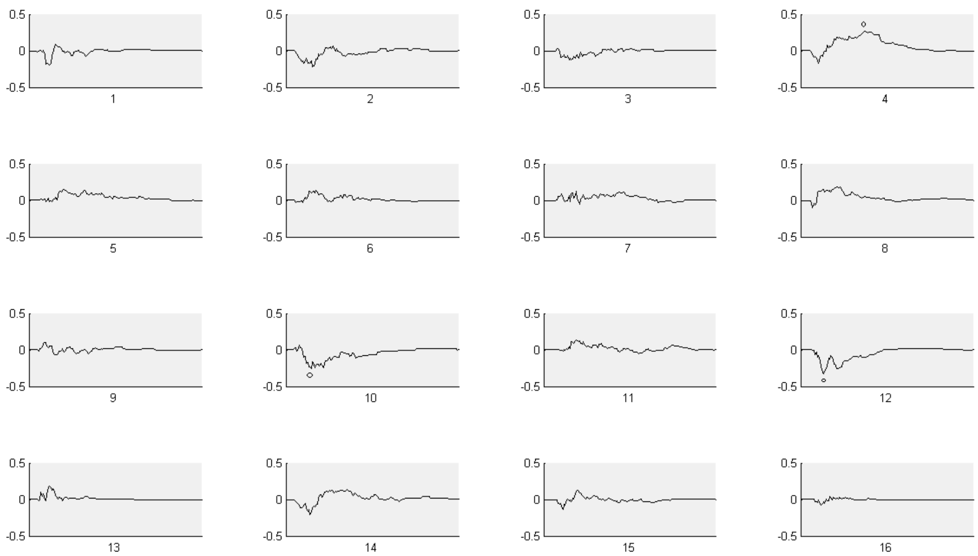

Figure 1: Survivor Interaction Contrasts for the switching-cost (switch vs. repeat) analysis. Significant (p<.10) deflections from zero are marked by a small circle.

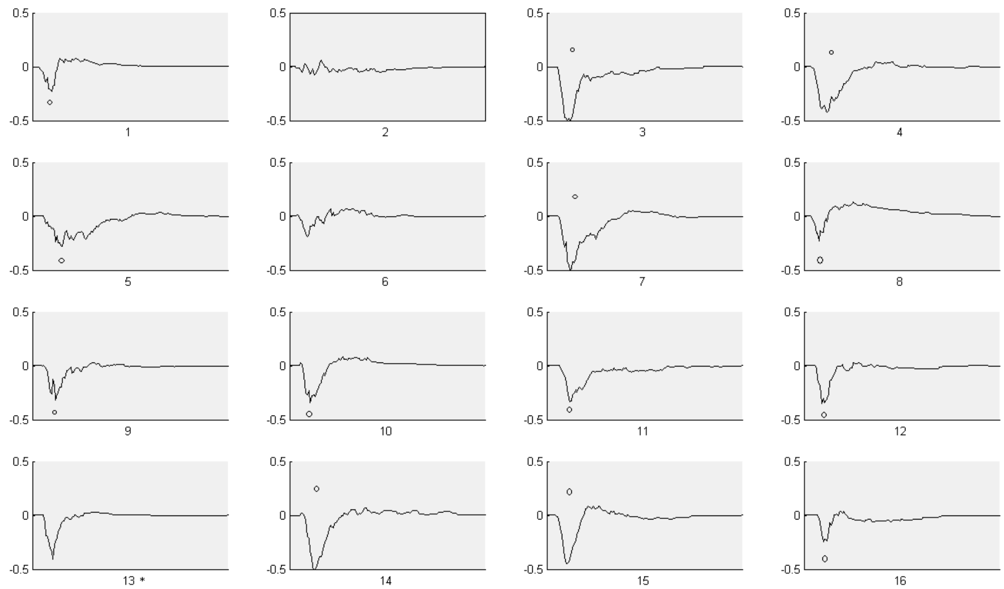

Figure 2: Survivor Interaction Contrasts for the mixing-cost (repeat vs. single-task) analysis. Significant (p<.10) deflections from zero are marked by a small circle.

* because selective influence was violated, significance was not computed for this participant.

Discussion

The ANOVA results show that despite the switching requirement, participants were able to selectively attend to shape and ignore saturation. Moreover, there was no indication that the requirement to switch attention compromised the ability to selectively attend to brightness and ignore saturation. In fact, in the brightness task GI became smaller moving from single-task to mixed tasks conditions. These results provide further evidence for the separablility of shape and brightness. More importantly, the results show that challenging switching ability (as indicated by switching cost and mixing cost) did not compromise selective attention and vice versa.

The SFT analyses of the switching cost contrast show that in most of the participants, there were no significant SIC deflections or a significant MIC, suggesting that the processes influenced by switching (vs. repeating) and those influenced by Filtering are arranged in a serial self-terminating architecture. This result challenges current theorizing (e.g., Kiesel et al., 2010; Meiran, 2010, for review). We tentatively suggest that the two parallel routes are the following: In the “task switching” route, non-filtered information generated by perceptual processes enters response selection. Because the information is not filtered, there is no GI. In this route, there is a need to assign differential weights to relevant and irrelevant information during response selection, causing switching cost (Meiran, 2000; Meiran, Adi-Japha, & Kessler, 2008). In the selective visual-attention route, the information entering response selection is already filtered and thus there is GI. However, because the information entering response selection is already filtered, differential weighting of evidence is rendered unnecessary resulting in lack of switching cost.

The SFT analyses of the mixing cost contrast show that in most of the participants, there was a significant negative SIC deflection. Moreover, in most of the participants MIC was numerically negative and often significantly so. This pattern is indicative of parallel exhaustive processing. Namely, the processes influenced by task mixing and by Filtering operate in parallel and all must be completed. This result provides further evidence that switching cost and mixing cost are dissociable processes. A possible explanation for this result is that mixing cost reflects task conflicts (see Rubin & Meiran, 2005). Such conflict is enhanced in mixed tasks conditions because participants maintain readiness to execute both tasks. Moreover, the target stimuli afford both tasks and as such, they retrieve the conflicting task identity resulting in conflict. Our results therefore suggest that overcoming this conflict is performed in parallel with the perceptual analysis of the target stimulus.

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