

The Stability/Flexibility Tradeoff On Task-switching

Sophia Angleton, Fiona Debernardi, Stephen Anti

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Abstract

This study is interested in understanding the relationship between task-switching and the cognitive stability-flexibility tradeoff. The design of this study will involve task-switching in an alternating runs manner, where there are two cues this task switches between, shape and color and these alternate in cycles of 4, each run being cycles of 4. This study will use alternating runs task-switching to understand the relationship between cognitive stability and cognitive flexibility. We will use the stability-flexibility tradeoff to inform our predictions, where we predict that 1) There is a negative relationship between expression of stability and expression of flexibility. We will see this relationship on three levels, within-subjects, in individual differences, and on the experimental level. Through a basic analysis of data, we saw there was a difference between stability and flexibility through a difference in switch cost measured in response time. This shows that there is a presence of stability and flexibility informing our task-switching study, however further analysis is required to understand the directionality of the relationship.

Introduction

The paradigm between cognitive stability and cognitive flexibility is a widely known and established relationship in the world of cognitive science. Both cognitive stability and flexibility are aspects of executive functioning, or what we understand as self-control (Monsell and Driver 2000). Cognitive flexibility centers itself in a domain of executive functioning called mental set shifting, and in previous literature, has been understood through the use of the task-switching paradigm. Tasks such as odds-evens, the Stroop task, or other alternating tasks where through the use of cues, participants need to identify an alternating attribute of a stimuli (Mayr, Kuhns, and Hubbard 2014). For this study, the task-switch paradigm is constructed through the identification of one of two attributes, color or shape, where they identify color of the stimulus or shape of the stimulus, respectively. According to the established stability/flexibility tradeoff, when one is performing a task that requires more cognitive stability, it is harder to also be more cognitively flexible. This is seen

in the task-switch paradigm within-subjects where they have less switch-costs when not switching task cues compared to higher switch-costs when switching from one cue to another (Mayr and Grätz 2024).

However, a recent reevaluation of the generalizability of the stability/flexibility tradeoff has posited that tradeoffs originally thought to explain a plethora of cognitive models, occur only in highly specified contexts (Mayr and Grätz 2024). Instead, there is newfound evidence of an anti-tradeoff pattern, meaning there is co-occurrence of cognitive stability and flexibility depending on the level of resolution encoding (Mayr and Grätz 2024). These recent findings in the field of decision-making suggest that the stability-flexibility trade off may not be as strong as once thought, however in this study we are still predicting we will see a negative relationship between the switch (flexibility) and no-switch (stability) variables through a comparison of error rate and response time until further studies explain more about a potential anti-tradeoff occurring. Indeed, using the stability-flexibility tradeoff to inform our predictions, we predict that: 1) There is a negative relationship between expression of stability and expression of flexibility. We will see this relationship on three levels, within-subjects, in individual differences, and on the experimental level. We will calculate the difference in reaction times between no-switch and switch trials. A smaller reaction time difference is interpreted as a higher level of stability, whereas a longer reaction time indicates a higher level of flexibility (Monsell and Driver 2000).

Methods

Data Cleaning

Using RStudio, the first major step for analyzing the dataset involved a clean-up process. The first clean up involved re-naming columns for better understanding of the dataset. Variables `dim1` was replaced with `dimshape`, `dim2` replaced with `dimcolor`, `time` replaced with `RT`, `cor` with `correct`, and `res` with `response`. Following from that, numeric values in the dataset were replaced with character strings for the variables `Task` and `Error`. Practice trials were then removed from the dataset since the ultimate for the final data is to isolate switch trials and control trials.

Determine and Remove Outliers

Outliers by Error: Since a key task of this study is to test for accuracy, it was necessary to operationalize accuracy by setting a criterion of 80% accuracy in all trials per participant. Out of the total of 896 trials, and using the 80% accuracy limit, at least 179 were needed to meet the accuracy threshold denoted by 0 in the error variable column. Grouping by `id` and summing by error and filtering out all those falling below the accuracy threshold, two people fell below the accuracy threshold and were removed (`id` : 70 and `id`: 87). These two were the outliers by error.

Outliers by Inter-response

A close inspection of the data and examining `RT` variable in descending order, showed that some participants only did 7 blocks of runs instead of 8. To account for this variance, the z-score for each sequence position along with switch and ambiguity were run on the `RT` variable and Z-Score was also run on each block.

To arrive at this, the first step was to separate switch trials, `c(1,5)` and control trials `!c(1,5)`. This means, if task is 1 or 5, we assigned switch, else, it was assigned as control. First trial after each block had to be thrown out because it is not a switch or no-switch. Cycle positions were separated into cycle positions of 4, making a total of 16 conditions.

Mean and Standard Error of Response Time

Second step involved calculating mean response times (RT) by trial type and calculating the z-scores. The z-score for both control and switch was 0 (the expected value) and that our Z-Standard Deviation (Zsd) is 1 (which is also the expected value). Looking at the mean for RT in both switch and control shows that the response time means tend to be a lot longer on average than the average response time for control trials (non-switch trials). The difference in means was by 311 where the switch trial takes 311 ms longer than the control or non-switch trials.

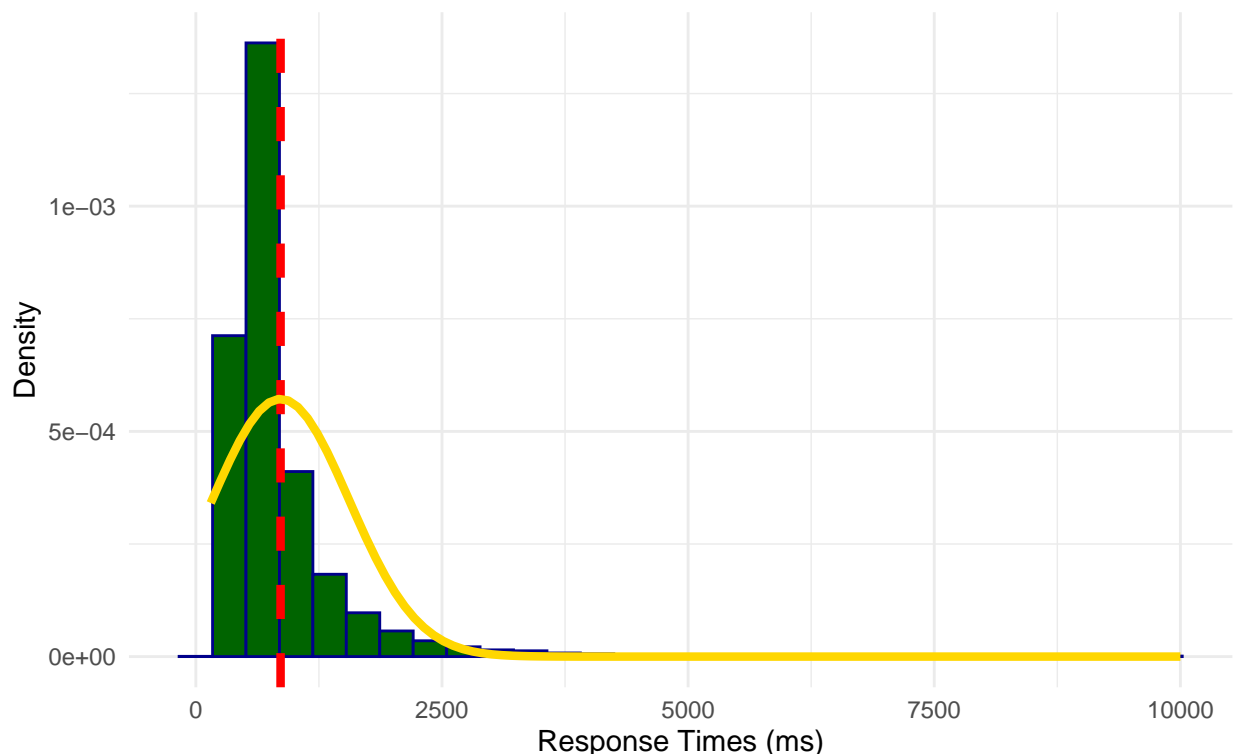
Outliers were identified for z-scores (scores beyond -3 and 3), means and standard error of response time for each trial type was also calculated.

Results

First, we created a density plot to examine how response times (RT) were distributed in the data set (See Figure 1). We wanted to first examine how participants were responding across all conditions, so we averaged participants response times and then put them into this density plot. The average response time (as indicated by the red dashed line) was 860 ms and the standard deviation was 697 ms.

Density plot of Response Times

The mean and normal density curve of RTs



Next, we examined whether the participants' response times in the control condition varied from their response times in the switch condition. We found that average response time varied by condition. In the control condition, participants responded more quickly ($M = 748$, $SD = 581$). In the switch condition, participants had slower response times ($M = 1186$, $SD = 891$). We pivoted the data to create separate columns for each condition, and then we calculated the mean and standard deviation of each column. We then created a table to depict these descriptives.

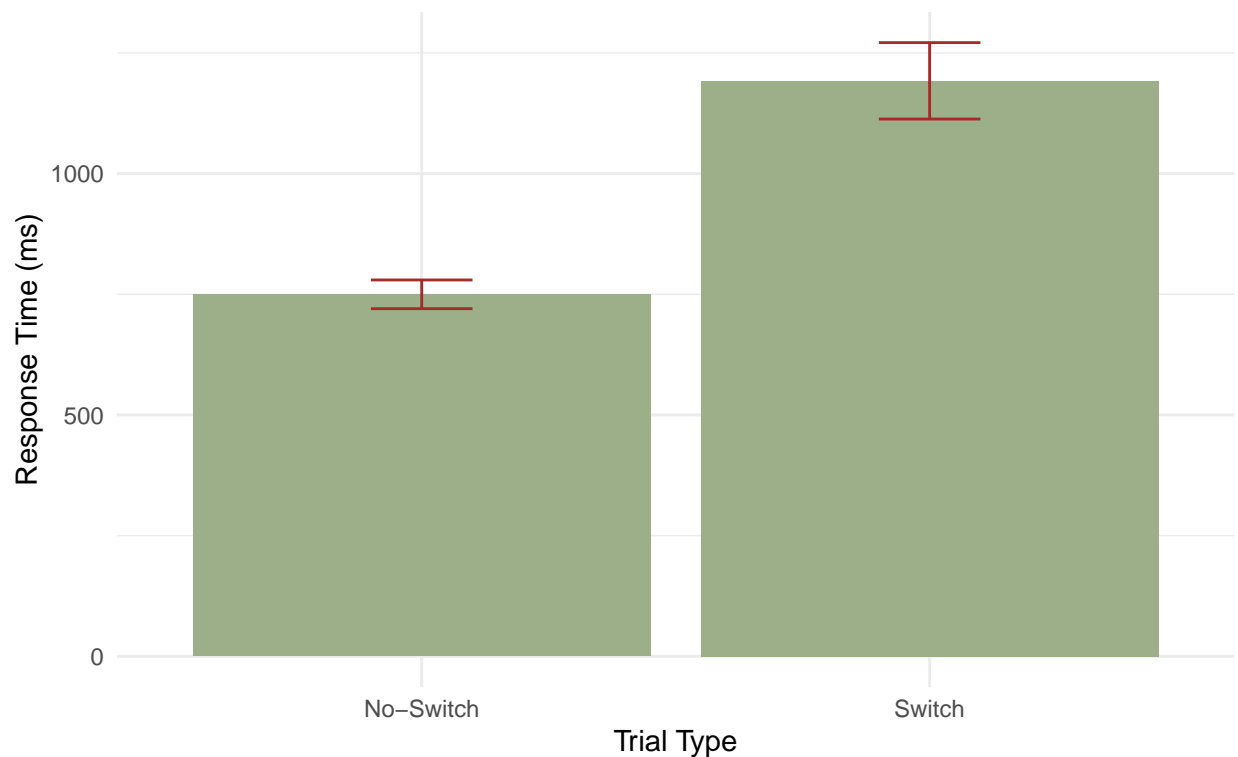
Table 1: Descriptive Statistics for Response Times

Statistic	Response_time_control	Response_time_switch
Mean	747.59	1186.02
Median	596.00	916.00
Standard Deviation	580.69	891.09

Finally, we created a bar chart to show the difference in response times by condition. This chart is another way of visualizing the results that we found above. The chart shows that when participants were told by the instructions to switch from one task to another (switch trial), they took longer than when they were doing the same task repeatedly (control trial).

Trial Type By Response Time

Relationship between response times and Switch/No-Switch trials



Discussion

The main goal of this study was to investigate task-switching and the trade off between cognitive stability and flexibility. The overall takeaway is that when participants need to switch instructions, their reaction times to the tasks are slower compared to when they are doing the same task repeatedly. In the future, more research is needed to examine whether the differences in responses to the conditions are statistically significant.

References

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