**Session #: ___________**

# STUDENTS WHO TAKE MORE TIME TO SWITCH BETWEEN TASKS REPORT MORE VIDEO GAME USAGE

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## ABSTRACT

Task-switching, or switching between two tasks in a short amount of time, has been shown to increase the amount of time that the tasks take to complete, as compared to performing a single task repeatedly[1]. This increased amount of time is known as the "switching-cost." This study examined whether students' everyday task-switching habits and video game behaviors affected their switching-costs, as measured by a card sorting test where students performed the same sorting tasks repeatedly in some trials and alternated tasks in others. An increased switching-cost is associated with a decreased ability to task-switch. Students who took the test also self-reported various demographic data, how many hours per week they spent playing video games, and what multi-tasking behaviors they engaged in while studying. We hypothesized that students who reported more video game use would have smaller switching-costs. However, we found a statistically significant ($p$<0.001, general regression, $n$ = 27) positive relationship between the number of hours of video games played per week and students' switching-costs. We also found that with each additional multi-tasking activity reported while studying, the self-reported time "on-task" while studying was reduced by an average of 4.5% ($p$<0.03, general regression, $n$=27).

## 1. INTRODUCTION

Task-switching is common in our society. A task is defined as "any activity in which systematic procedures must be applied to achieve a desired goal" (Meyer et al 1997). Task-switching is alternating between 2 or more tasks in a short period of time. Eating while driving, texting at stop lights, cooking dinner while watching the news, and social networking while studying are all common examples of task switching. Several factors have been shown to impact task-switching ability, including gender (Criss *et al* 2004, Halpern *et al* 1986), input-output modality (Stephan *et al* 2010), complexity of task (Rubinstein *et al* 2001) and the presence or absence of cueing (Rubinstein *et al* 2001).

Switching between 2 tasks has been shown to increase the amount of time that the tasks take to complete, as compared to performing a single task repeatedly (Meyer *et al* 1997). This increased amount of time is known as the "switching-cost." Switching-costs are often measured with the Wisconsin Card Sorting Test (WCST). The WCST involves subjects viewing a stimulus card that has several attributes (colors, shapes, etc.), and then selecting a matching ‘response card’ from a group of cards that each have one attribute that matches an attribute of the stimulus card. Response times on trials that involve responding to the same attribute repeatedly can be compared to response times on trials that change the response attribute, and used to calculate switching-cost. Switching-cost is considered a measure of the executive function of task-switching.

We investigated whether students’ daily activities (multi-tasking habits, video game usage, and the unit of time typically spent studying an individual topic) have an effect on their switching-costs. We hypothesized that students who reported playing more video games (either on game consoles or computers) would have lower switching-costs, or would be better at task switching, due to the fast-paced nature and high attentiveness demands of video games. We also hypothesized that students who reported more task-switching behaviors would have lower switching-costs due to practicing task-switching more often, and that students who reported studying in shorter units of time would have lower switching-costs, based on the idea that practicing task-switching behaviors might make people better at task-switching. Using a card sorting test similar to the WCST, we measured students’ switching-costs. We also collected demographic data and self-reported information about students’ multi-tasking and study habits. Our analyses of these data and qualitative follow-up interviews did not support our original hypotheses, and we ultimately proposed a possible physiological explanation for the trends we observed.

## 2. METHODS

### *1.1 Participant Recruitment and Compensation*

All participants were Rose-Hulman Institute of Technology students over the age of 18, and were recruited in dormitories or other places where students commonly live, or via email. Participants ($n$ = 28) who completed only a card-sorting test and a survey received no compensation. Participants ($n$ = 13) who completed the card-sorting test and survey, and also filled out an activity log, received cookies as a thank you for their time. Participants ($n$ = 3) who completed the card-sorting test and survey, filled out an activity log, and also completed a follow-up interview received a $20 iTunes gift card as compensation (Rose-Hulman Institute of Technology Institutional Review Board approval number RHS0149).

### *1.2 Card Sorting Test and Survey*

We used cards from the game “SET” for our sorting test. Each card displays an unambiguous shape, color, shading, and quantitative amount. In each experimental trial, a participant sorted 18 cards by shape and shading onto a “sorting board” (Figure 1). The entire board was visible during all trials to avoid effects of cueing (Rubinstein *et al* 2001). Cueing is when the stimulus in some way indicates the correct response. The sorting board was made of posterboard, and placed on either the table or floor in front of the subject. We placed a plain white tri-fold presentation board behind the sorting board for participants who were in visually cluttered environments, such as dorm rooms.

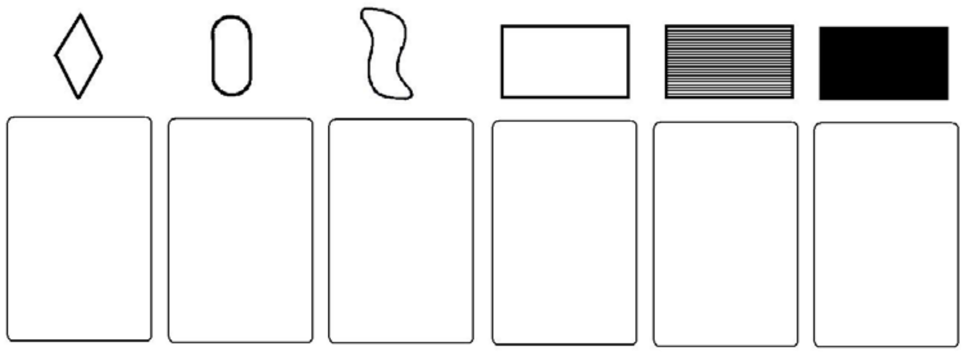

Figure 1: Sorting Board. Participants sorted cards onto this board for all trials. The left-most 3 positions were used for sorting the cards by the shapes displayed, and the others were used for sorting by shading (light, medium, or dark). The dimensions of the sorting board were 21 3/4” x 7” and there was a gap of 1 1/8” between each sorting pile.

Each participant completed a total of 12 experimental trials. The first 3 trials were untimed practice: participants sorted the cards first by shape, then by shading, and then alternated between sorting by shape and by shading, every other card. Subsequent trials were timed. To counterbalance the study, during the next 3 trials participants sorted the cards once by shape, once by shading, and once by alternating between shape and shading (the order of these sorting rules varied from participant to participant). The subsequent 2 sets of 3 trials each were conducted using the same order of sorting rules. While participants sorted cards, we discreetly kept track of how many cards were placed in the wrong position and then moved to the correct position. We recorded these movements as self-corrected errors. Between each trial, we checked for misplaced cards and also recorded this number. All trials contained 3 or fewer total errors, including both self-corrected errors and misplaced cards.

Following the card sorting test, we gave each subject an 11 question survey about their task-switching and technology habits, including how many hours of video games they typically played per week and the length of the time period in which they believed they were best able to study. We also asked students to identify task-switching behaviors they performed while studying.

### *1.3 Activity Logs*

Following the card-sorting test and survey, 13 participants voluntarily filled out an activity log for 3 weekdays. Participants recorded their activities in half-hour time slots. In the case of multi-tasking, participants recorded both their primary and secondary activities.

### *1.4 Interviews*

We then interviewed 3 participants who had filled out activity logs, asking questions about their study habits and their perception of their ability to switch between tasks. Two participants with relatively low switching-costs and one with relatively high switching-costs were selected for interviews. Each participant was interviewed separately, in a study room in the library, during school hours. Interview answers were voice recorded.

### *1.5 Data Analysis*

Equation 1, shown below, was used to calculate participants' switching-costs (Rubinstein *et al* 2001), and we performed linear regressions to investigate whether participants' switching-costs were related to the task switching and study behaviors reported on their surveys. In Equation 1 (Rubinstein *et al* 2001), $T_{switch}$ is the switching-cost. $T_1$ represents the average time for trials that involved participants sorting by shape (considered to be a single task trial). $T_2$ represents the average time for trials that involved participants sorting by shading (also considered to be a single task trial). $T_{12}$ represents the average time for trials that involved alternating between sorting by shape and by shading (considered to be task-switching), and n represents the number of trials performed.

$$T_{switch} = \frac{[T_{12} - 0.5 \times [T_1 + T_2]]}{n-1} \qquad (1)$$

We examined the activity logs to qualitatively judge whether participants tended to study in mostly short or mostly long units of time. We then performed two tailed t-tests to determine: if the participants who reported playing video games had a significantly different switching-cost from participants who did not report playing video games; if there was a difference between the switching-costs of males and females; and if there was a difference between the switching-costs of subjects who studied in mostly short or mostly long units of time. Only 5 of the activity logs could be used to identify the length of time participants spent studying individual subjects. In these cases, we calculated the average actual units of time that the participants studied each subject and how often the participants conducted a non-study-related activity when switching between subjects (Table 3). For all analyses, statistical significance was set at 0.05.

## 3. RESULTS

### *3.1 Data Validity*

One participant was excluded from analyses because he was an outlier with respect to the amount of time he spent playing video games per week (Q= 1.92, Dixon's Q-test, *n*=28) (Rorabacher *et al* 1991). The remaining participants' switching-costs were normally distributed (*p*=0.15, AD=0.541, Anderson-Darling Test, *n*=27). A repeated measures analysis indicated that there was no statistically significant difference between the order of measurements ($F_{measure}$= 0.9, *p*=0.414, *n*=81), indicating that participants did not get better at task-switching in later trials. An ANOVA and Tukey's pairwise comparison (Minitab 2010) indicated that there was no significant difference among the switching-costs of participants whom we tested in the 6 different orders of sorting rules (F=2.32, One-factor ANOVA *p*=0.051, *n*=27). These data indicate that the design of the card-sorting experiment did not influence participants' switching-costs. The average time that it took students to perform a single-task experimental trial of sorting cards was not correlated to their switching-cost (*p*=0.887, general regression, n=27). This indicates that if a student performed tasks more slowly in general, this did not impact their switching-cost as measured in this study.

*3.2 Relationship Between Switching-Cost and the Number of Video Games Played Per Week*

Participants who reported playing some video games each week (gamers) and participants who reported playing zero hours of video games per week (non-gamers) did not have significantly different switching-costs. However, due to the small sample size in our study, the power of this t-test was very low (Power=0.37, post-hoc power analysis) (Faul *et al* 2009), and this test is therefore unlikely to be able detect a difference in switching-costs between gamers and non-gamers. The effect size on switching-cost of gamers vs. non-gamers was moderate (-0.66) (Cohen 1988), indicating that there may be potential differences in switching-costs between gamers and non-gamers. We performed a regression within the gamers group and found a statistically significant relationship between reported hours spent playing video games per week and switching-costs (Table 2 and Figure 2). The slope of our regression indicates that every additional hour of video games played per week corresponds to an increase in switching-costs by 0.048 seconds/task. Since the average measured switching-cost was about 0.29 seconds/task, the addition of one hour of video games per week corresponds a 16.5% increase in switching-cost. There was no significant difference between the switching-costs of male and female participants (Table 1). Additionally, there was no significant difference between the switching-costs of students who we judged to study mostly in short versus long units of time (Table 1).

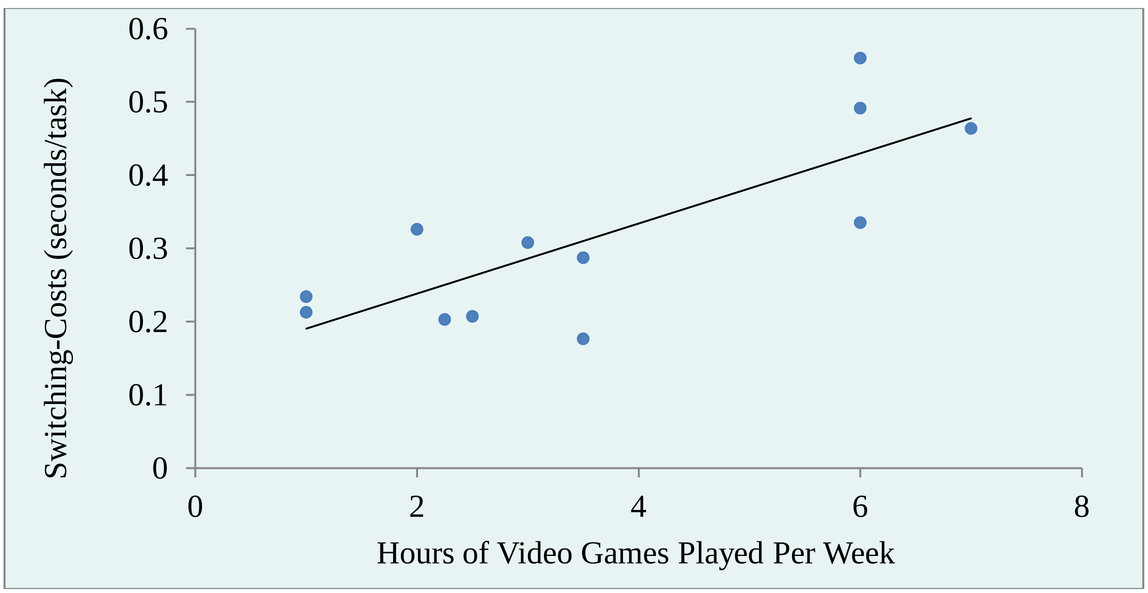


Figure 2: Relationship Between Hours of Video Games Played Per Week and the Switching-Costs of Gamers. In general, gamers who reported playing more hours of video games per week had higher switching-costs (*p*=0.001; T=4.45, *n*=13, R-squared=0.64).

Table 1: Statistical Results from T-tests

| **Grouping Variable** | N | t-Value | $p$[a] | Estimate $\mu_0$ - $\mu_1$ | Effect Size [b] | Power[c] |
|---|---|---|---|---|---|---|
| Video Game Use: non-gamer=$\mu_0$, gamer=$\mu_1$ | $n_0$=14 $n_1$=13 | -1.7 | 0.106 | -0.070 | -0.66 | 0.38 |
| Gender: female=$\mu_0$ male=$\mu_1$ | $n_0$=15 $n_1$=12 | -1.12 | 0.276 | -0.047 | -0.43 | 0.19 |
| Qualitatively Judged Study Time Unit: mostly long = $\mu_0$, mostly short = $\mu_1$ | $n_0$=4 $n_1$=9 | -0.18 | 0.86 | 0.044 | 0.37 | 0.26 |

[a] From a two-tailed t-test (Minitab 2010)
[b] Cohen's D (Cohen 1988)
[c] Post Hoc power analysis (Faul *et al* 2009)

There was a statistically significant relationship between the self-reported percentage of time participants said that they were "on task" while studying alone and the number of multi-tasking behaviors they reported engaging in while studying, which is consistent with past observations of decreased productivity while engaging in task-switching (Meyer *et al* 1997). Participants reported that they were on-task 73% of the time while studying alone, on average (Table 3). Reported time "on-task" was inversely correlated with the number of reported multi-tasking behaviors while studying, with an average decrease of 4.5% of time spent on-task for every additional multi-tasking activity reported .

Age and the number of multi-tasking activities reported while studying was not related to switching-cost. The percentage of time that participants reported being on-task while studying by themselves also had no correlation to switching-cost. The preferred length of study-time and the qualitatively judged length of study time units were not related to switching-costs. The number of hours spent playing video games per week had no significant correlation with participant's preferred study time unit. Of the 5 students that reported their specific study topics in their activity logs, the average time spent per topic was 1.2 hours, and they engaged in other non-studying activities between about half of these study-sessions (Table 3).

Table 2: Regression Models for Switching-Cost

| **Predictor** | $p^a$ | Slope | R-squared (%) | N |
|---|---|---|---|---|
| Video Games (hours/week) | 0.001* | 0.001 | 38.30% | 27 |
| Video Games (hours/week) Gamers only | 0.001* | 0.048 | 64.30% | 13 |
| Multi-tasking Behaviors while studying | 0.599 | 0.007 | 1.10% | 27 |
| % of time on-task while studying by self | 0.105 | -0.002 | 10.20% | 27 |
| Preferred Study Unit | 0.816 | 0.0047 | 0.20% | 27 |

[a] from the slope of a general regression (Minitab 2010)

Table 3: Descriptive Statistics

| **Variable** | **Mean** | **Standard Deviation** | ***n*** |
|---|---|---|---|
| Self-reported percentage of time participant is "on-task" while studying by self | 73% | 15% | 27 |
| Number of multi-tasking habits reported while studying | 3.7 | 1.4 | 27 |
| Average self-reported preferred study time unit | 1.5 hours | 1 hour | 27 |
| Average study time per topic | 1.2 hours | 0.26 hours | 5 |
| Average percentage of study sessions between which students engaged in other activities | 49% | 17% | 5 |
| Switching-cost (seconds/task) | 0.29 | 0.10 | 27 |

### *3.3 Personal Interviews with Participants*

All 3 of the participants that we interviewed said that they prefer not to study in units of time less than 1 hour. One participant said, referring to studying when she had less than 1 hour of time, “I don’t like once you start getting focused on the homework you basically have to pack up and leave…so I wouldn’t if I had the choice to do something else.” Participants were asked if they were good at doing two things at once. One participant who has relatively low switching-costs said “I can…Two things like maybe one important thing and one less important… I do stuff like eat and put my makeup on at the same time.” Another participant who has relatively high switching-costs said that she isn’t good at doing two things at once, but she likes to because it makes her feel more productive. The third participant, who has low switching-costs, said that she thinks she is good at doing two things at once in terms of communicating with others while doing homework, but this was dependent on the mode of communication. She said, “I know I can keep up a conversation and text another person at the same…[or if] an email pops up I can do that and go right back to homework… it is harder for me if like I'm doing homework and then like people want to start having a conversation and then I'm kind of frustrated because that distracts me. But if it's something that I don't have to speak and do then I can do it." All 3 subjects agreed that, when studying, they prefer to finish all of one subject before switching to another, unless that one subject was likely to take a very long time. The subject with low switching-costs said that she does not like to switch between studying and non-studying activities. The participant with relatively low switching-costs said that if she is going from a studying activity to a non-studying activity, it does not take her any time to refocus her attention, but when switching from a non-studying activity to a studying activity, it takes her time to refocus. The participant with high switching-costs said that she likes to use non-studying activities to break up topics, but does not like to do non-studying tasks in the middle of studying a topic.

## 4. DISCUSSION

Why do we multi-task? The participant with high switching-costs told us that she isn't good at multi-tasking but sometimes does it because it makes her feel productive. One participant with lower switching-costs told us she can do two things at once as long as one is important and the other is not. All 3 of the participants indicated that they use some sort of task-planning strategy, be it mentally, on post-it notes, or in an hourly planner. Possibly all of the little "unimportant" tasks such as answering texts, checking email, grooming, and having a snack aren't accounted for when we plan our tasks for the day, so we do them at the same time as our planned tasks. Are we actually good at doing two things at once? The trend observed in this study, in which self-reported time spent "on-task" was negatively correlated with the number of reported multi-tasking behaviors while studying, indicates that we are not.

### *4.1 Length of Time that Students Study*

We thought that students who have higher switching-costs would study in longer continuous amounts of time, either because studying in only large units of time might cause someone to have a high switching-cost, or because students might accommodate their high switching-costs by adapting their study habits. It seems that the length of time that students study is related to their schedule constraints rather than their switching-costs. Most of the students we interviewed prefer to study in periods of time greater than 1 hour.

### *4.2 Modality of Task*

One of the participants with low switching-costs said that she can easily do homework while communicating with other people as long as it doesn't involve talking, which is consistent with previous findings related to input-output modality (Stephan *et al* 2010). Going from a visual stimulus to manual output (such as moving from reading to writing or typing) is moving between compatible modalities. Switching to an activity such as having a conversation - an auditory input with vocal output - is considered switching to a different modality (Stephan *et al* 2010). Changing the modality of tasks, or incompatible modalities (such as an auditory stimulus with a manual response) increases switching-costs (Stephan *et al* 2010).

*4.3Complexity of Task*

One of the subjects with low switching-costs indicated that it takes her more time to become focused when going from a non-studying activity to a studying activity. This is consistent with past findings that switching from an easy activity to a difficult activity is associated with a higher switching-cost than switching from a difficult activity to an easier activity (Milan *et al* 2010).

*4.4 Video Game Usage and Switching-Cost*

In this study, we observed a trend in which students who reported playing higher amounts of video games per week also had higher switching-costs. Although we did not observe a main effect of video games between gamers and non-games, the power of this test was low, and the significant dosage effect suggests that playing video games does have some relationship with switching-costs. The reason for this observed trend is still unclear. Do people with higher-switching-costs simply enjoy video games more, or does playing video games lead to higher switching-costs? One possible physiological explanation for the latter question is related to the dorsolateral prefrontal cortex region of the brain. It has been reported that there is a significant and sustained decrease in oxygenated hemoglobin levels in the dorsolateral prefrontal cortex when playing video games (Matsuda *et al* 2006). The left dorsolateral prefrontal cortex is highly involved in task switching, among other executive functions (Meyer *et al* 1997). Decreased oxygenated hemoglobin in this region of the brain might impact switching-costs— but this is only one potential explanation for the results of this study. To continue and expand this area of inquiry, researchers could measure the switching-costs of non-gamers, have them play video games for several hours per day for an extended period of time, and then re-measure their switching-costs to see if they change. In a similar study on internet browsing, non-experienced web-users had significantly less activity in the prefrontal cortex while browsing than did experienced web-users (Carr 2010). After the non-experienced web-users browsed the internet for 1 hour per day for 1 week, there was no significant difference in their prefrontal cortical activity and that of experienced web-users. These data suggest that the activity— browsing the internet for 1 hour per day for a week—changed the prefrontal cortical activity in the previously non-experienced web-users.

One flaw in our study is that we did not determine which video games students played most often, and we did not then determine whether they actually involve a lot of task-switching. Perhaps these games are more akin to repeating a single task than to task-switching. In an email conversation with one participant, we asked if he felt that video games involved a lot of task-switching or if he felt they were repetitive. He replied in part: “The games I play most won’t be ones that are stimulating my brain. After a long day of school I will want to just relax and not have to think. Ever try to talk to someone while they are playing a videogame? It is fairly hard, because people almost become brain dead while playing.” Although “brain dead” is an exaggeration, this experienced gamer might be onto something, and the relationship between video game usage and switching-costs should be investigated further.

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