Knowing When to Switch Tasks:

Effectiveness of Internal versus External Cues

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ABSTRACT

It is now commonplace in both personal and professional environments to perform multiple concurrent tasks. Sometimes people switch between tasks under their own volition (e.g., when they reach a good stopping point or finish the task). Other times, they are forced to switch by some external cue (e.g. phone call, knock at the door). Although research on task switching has shown that there is a time cost every time tasks are switched, it is unclear if there are performance differences when these switches are forced as opposed to when a person chooses to switch tasks. The current research used a category naming paradigm in which participants had to generate words from four categories. In one condition, they could switch between the categories whenever they wanted while in another condition they could only switch when cued by the computer. In both conditions there was a time cost associated with switching categories that was longer than the time between words within a category. No differences, however, were found between these conditions in the total number of words generated or the time to switch categories. These results suggest that people were able to perform multiple concurrent tasks with equal proficiency regardless of whether they switched between them on their own or were explicitly told when to switch. These findings have implications in driver distraction, suggesting that common activities like placing or receiving a cell phone call can both be disruptive and adversely affect a person's ability to operate an automobile.

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Our environments are getting more complex. With every new piece of technology or new way to communicate, people are becoming increasingly inundated with multiple tasks vying for their attention. As a result, it is not uncommon for a person to juggle many concurrent tasks and try to switch between them in order to get them all done. Sometimes these task switches are voluntary (e.g., you are working on a document and decide to check your email); other times external forces cue you to switch (e.g., someone enters your office and starts a conversation with you). What are the differences between these two types of switches? Is one more detrimental to overall task performance than the other? The answers to these questions have significant implications for how we should perform everyday tasks and can have serious ramifications in safety critical environments such as automotive and aviation settings. Specifically in the driving environment this work will help address the question of whether there is any difference between voluntarily placing a cellular phone call or receiving one.

Although the literature has not addressed these specific questions, the general study of multiple task performance is nothing new. This work shows that almost any time multiple tasks are combined, some decrements are observed(Brown, 1958; Jersild, 1927; Peterson & Peterson, 1959; Waugh & Norman, 1965). In interruption paradigms, these decrements have been shown in both primary task accuracy (Cutrell, Czerwinski, & Horvitz, 2001; Edwards & Gronlund, 1998)and completion time (Eyrolle & Cellier, 2000; Monk, 2004a; Monk, Boehm-Davis, & Trafton, 2004; Trafton, Altmann, Brock, & Mintz, 2003). In task switching paradigms (Monsell, 2003), a robust decrement in time to respond to a new stimulus – the switch cost – has been observed (Monsell, 2003; Wylie & Allport, 2000). In both paradigms (interruptions and task switching) the cost is measured by comparing the time to perform an action within a task versus the time to complete an action between tasks (or the first action on a new task). What differentiates the two paradigms is that in interruptions research, there is an intention to return to the primary task while in task switching, the focus is on the performance of two alternating tasks, each of which is completed before switching to the alternate task.

In interruptions research, the disruption in performance is measured by the time required to take the first action back on the primary task following an interruption. This is referred to as the resumption lag, and it has been shown to be longer than the inter-action interval, or time to perform actions within the primary task (Trafton et al., 2003). Within task switching paradigms, the decrement in performance is measured as the time required to switch between tasks. This is referred to as the switch cost, and it has been shown to be reliably longer than task repetition time, or the time to respond to stimuli when the task does not change from trial to trial (Monsell, 2003).

Across both the task switching and interruptions literatures, almost all of the work has examined tasks in which people are forced to switch to another task, whether due to an interruption or a different stimulus. In fact, only two studies have explicitly looked at the idea of voluntary task switching. Arrington and Logan (2004; 2005) found that even when people were allowed to switch between tasks whenever they wanted, there was still a time cost associated with this switch. However, there was no comparison drawn between forced and voluntary switching. This work simply pointed out that even voluntary switches have associated time costs.

In reality, as people work and perform various tasks throughout the day, there are probably instances when they choose to switch tasks in addition to those in which they are forced to do so. For instance, imagine you were typing a paper and in the middle of this task, you remember that you have to call the mechanic to check on your car. In this situation, you could ignore the thought and keep working on the paper, leave yourself some sort of note or explicit cue in the environment to remind you to call later, or stop typing the paper and call the mechanic immediately, with the intention of returning to the paper once you are off the phone.

How are you to know which of these actions will be the least costly to both tasks and which will lead to the greatest overall output? Intuitively, it makes sense that people would have some sense of their performance on a task and that they would know when it would be a good time to switch to a different task (i.e., they need a break, their productivity is falling, or they have run out of ideas). Previous work (Wylie & Allport, 2000) has suggested that when switches are expected, their associated costs are lessened. This would seem to suggest that people should be faster at switching between tasks on their own than if forced to do so by an automated system. However, it could also be that people do not have a good sense of their real-time performance on a task and will continue to perform that task at sub-optimal levels, when switching to a new task would be better for their overall productivity. In this case, people may be faster at switching tasks when explicitly instructed to do so by a system.

In order to answer these questions, we need to understand and measure the differences between forced switches (e.g., external interruptions) and voluntary switches (e.g. internal interruptions). Thus, the goal of this study was to determine whether there were any differences in performance when people were forced to switch versus when they were free to switch on their own. In line with the finding that switch costs are reduced when people have knowledge of when they are to occur and can prepare for them, we thought, *a priori*, that people would be both more productive and faster when they could switch freely (Rogers & Monsell, 1995).

METHOD

Design

This experiment used a within-subjects design with one, two-level, independent variable – Switch Type (auto, self).

Participants

Thirty-six undergraduates (31 women, 5 men) at George Mason University participated in this study for course credit. The average age of the participants was 19. All participants spoke English as their primary language.

Task and Materials

Both conditions (Auto-switch and Self-switch) of the category switching task and the typing test were programmed using E-Prime version 1.2 experimental presentation software and presented on a 17 inch LCD monitor on a PC. The typing test consisted of three texts; each consisted of what looked like a paragraph of words on the computer screen and was approximately the same length. One was a true paragraph; one was a paragraph of pangrams (each sentence contained every letter of the alphabet); and the last consisted of a series of random words. Measures of the number of words typed were collected in order to determine if individual differences in typing speed affected the participants' ability on the category member naming task. If these factors were found to affect the results, collecting these measures would allow their effects to be controlled in subsequent analyses.

An orally-administered verbal fluency test was developed to allow for individual differences in language ability (verbal fluency) to be co-varied from subsequent analyses. This test required participants to verbally identify as many examples as possible from the categories: *Foods People Eat* and *Jobs People Do*.

In the experimental task, four categories were presented at the top of the screen for both the Self-switch and Auto-switch conditions, with responses logged below (see Figure 1). Twelve total categories were used across the two conditions and for training. The training categories (*Colleges, States, Female Names,* and *Fruits*) were the same for both conditions. The eight categories used for the experimental conditions were split into two matched groups of four. Matching was based on the Battig and Montague (1969)category norms, which estimated each category's overall difficulty. One category group consisted of *Colors, Articles of Clothing, Four-footed Animals,* and *Types of Music* and the other consisted of *Parts of the Human Body, Relatives, Sports,* and *Musical Instruments*. The two groups of four categories were seen equally in both conditions.

Procedure

Participants filled out an informed consent form and a brief demographics survey prior to beginning the experiment. They next completed the orally-administered verbal fluency test in which they were given one minute to verbally identify as many examples of *Foods People Eat* and another minute for *Jobs People Do*. Following the administration of the verbal fluency test, participants completed the three paragraph typing test. They had one minute to type as much as possible from each paragraph.

The Category Member Naming task, which was the main component of the experiment, required participants to type as many examples of various categories as possible in a two-minute period. The order of the two conditions (Auto-switch and Self-switch) was counterbalanced across participants, with half completing the Auto-switch condition first and the other half completing the Self-switch condition first.

Participants were first shown a series of instructions which were read aloud by the experimenter. These instructions gave an example of a category and some members from it and described how the participant should complete the experimental block (1 training and 1 experimental trial). In the Auto-switch condition, participants were instructed to work through the four categories in order and switch immediately upon hearing a tone from the computer. The tone was played every 15 seconds, allowing participants to work through each category twice. This allowed participants a second opportunity to recall category examples. In the Self-switch condition, participants were instructed to proceed through the categories in any order they wished. They were allowed to switch between the categories at any time, as often as they wanted. Following the instructions, in both conditions, participants completed a training trial matching the condition of the experimental block. Before beginning a trial, a screen was shown listing the four categories that were to be used in that trial. This was done to eliminate any lag associated with reading the categories at the beginning of the trial. Each trial had the four training categories followed by the four experimental categories. The conditions differed only in the presence or absence of an auditory tone presented every 15 seconds and the instruction to proceed in order or at random through the categories. The entire experiment lasted approximately 25 minutes.

RESULTS

The goal of this experiment was to determine if any performance differences occurred when people were told when to switch as opposed to when they were free to switch on their own. This task provided three primary performance metrics: time to switch between categories, time to switch between words, and word generation rate. However, prior to examining these performance metrics, we conducted co-variance analyses and a manipulation check.

Co-Variate Analyses

A series of four simple regressions were performed using Verbal Fluency and Typing Speed as predictors for the following criterion variables: time to switch between categories; time to switch between words within a category; total number of words; and cumulative time spent in a category for the Self-switch condition. Cumulative time spent in a category was not used as a criterion variable for the Auto-switch condition as participants were cued to switch after 15 seconds and cumulative time in a category in this condition only varied as a result of the participants' reaction time to the audible cue (with mean time spent in a category =15.02 s with a standard deviation of 3.62 s).

Verbal Fluency was found to significantly predict three of the four criterion variables – time to switch between categories (β = -.465, $p < .01$), time to switch between words (β = -.597, $p < .001$), and total number of words produced (β = .616, $p < .001$). Typing Speed only significantly predicted total number of words produced (β = .313, $p < .05$). Neither Verbal Fluency ($p = .96$) nor Typing Speed ($p = .96$) was found to significantly predict cumulative time in a category for the Self-Switch condition. Given these results, further analyses involving time to switch between categories or time to switch between words used Verbal Fluency as a covariate. Analyses involving total number of words used both Verbal Fluency and Typing Speed as covariates.

Manipulation Check

A two level repeated measures ANCOVA, with Verbal Fluency as the covariate, revealed that, as expected, the time to switch between categories (*M* = 4653.89 ms, *SD* = 945.03) was significantly longer than the time to switch between words (*M* = 1568.05 ms, *SD* = 284.69) across both the Auto- and Self-switch conditions ($F(1, 34) = 48.50$, $MSE = 374759.06$, $p < .001$, $\eta^2 = .59$) (See Figure 2). This is consistent with previous work showing the presence of the switch cost (Monsell, 2003) and/or resumption lag (Trafton et al., 2003).

Performance Data

Time to Switch between Categories. The question to be addressed here was how well people can manage multiple tasks on their own. To inform this question, time to switch between categories for both the Auto- and Self- switch conditions was compared using a two-level, repeated measures ANCOVA with Verbal Fluency as a covariate. One participant was excluded from this analysis due to an error in transferring data from the experimental computer. As can be seen in Figure 3, the time to switch between categories did not differ reliably between the Auto- (M = 4623.07 ms, SD = 1142.17) and the Self-switch (M = 4654.69 ms, SD = 1482.35 conditions (F (1, 33) = 1.70, MSE = 1449456.87, p = .20, η^2 = .05) (Figure 3). It could be that the switch cost is not affected by the type of cue used to initiate the switch (internal or external). It is also possible that it was easy to switch between categories in both conditions and there was a floor effect.

Time to Switch between Words. We may also ask a similar question about the time to switch between words within a category across the Auto- and Self-switch conditions. The time to switch between words is similar to the task repetition time in task switching paradigms or the inter-action interval in interruptions paradigms. It would make sense intuitively that there would be no differences in time to switch between words in either condition. The within-category word generation task is identical across both conditions and therefore should be performed the same regardless of where the cue to switch originates. However, there is evidence from both task switching (Allport, Styles, & Hsieh, 1994) and interruptions (Monk, 2004b; Monk et al., 2004) that suggests that the disruptive effects of either being interrupted or switching tasks may have residual interference that carries over into later uninterrupted or non-switch actions. In other words, if the type of switch (Auto- or Self-) had a differential effect on persisting disruptiveness across subsequent non-switch trials, then we would expect to see a difference in the time to switch between words by condition. If the time to switch between words was faster in the Auto-switch condition, it could be that participants were not monitoring their own performance well and were continuing within a category until they were performing at sub-optimal rates. This may not occur in the Auto-switch condition as they were forced to switch before this slow down occurred. If the reverse occurs, it may be that forcing people to stay in a category longer than they wanted to increases response time. If this were the case, we would expect to see longer times between words and categories emerge towards the end of the 15 second blocks.

A two-level repeated measures ANCOVA, with Verbal Fluency as a covariate, was performed to investigate this issue. Once again, one participant was excluded from this analysis due to computer errors in data transfer. As with the time to switch between categories, the time to switch between words was not significantly different across the Auto- (M = 1445.12 ms, SD = 287.62) and the Self-switch (M = 1614.22 ms, SD = 439.41) conditions ($F < 1$) (Figure 4). This suggests that participants were performing the category member task similarly in both conditions and that the differential cueing (internally cued switch versus externally cued switch) did not have any effect.

These results also suggest that any persisting disruption did not differ between the Auto- and Self-switch conditions. That is, the time course of recovery was not affected by the type of cue commanding the switch. This is not consistent with previous work in both the interruptions (Monk, 2004b; Monk et al., 2004) and task switching (Allport et al., 1994) literatures.

Word Generation Rate. A measure of the overall efficiency or productivity for the category member naming paradigm is the total number of words generated. It is possible that the total number of words they generated would be affected by the type of switch-cue, even though the type of switch did not affect the time to switch between either words or categories. If, in the Self-switch condition participants were switching categories less frequently than the participants in the Auto-switch condition, they would have most likely produce a larger number of total words generated.

We can examine these hypotheses by comparing the total number of words and the total time spent in categories or the overall word generation rate across the Auto- and Self-switch conditions. This serves as a measure of total productivity. A difference by condition in word generation rate could be caused by either a difference in the total number of words generated within each category or more frequent category switches – either way suggesting more overall efficiency for the condition with the higher word generation rate. In calculating the word generation rate, the first word in each category was excluded as this word reflected the much longer category switch time as opposed to the word switch time. Task-switching research suggests that participants performance returns to baseline reaction times by the second trial following a switch cue (Altmann, 2004). There was no difference in participants' word generation rate (calculated after removing the category switch time) within categories between the Auto-switch (M = .498, SD = .120) and Self-switch (M = .506, SD = .113) conditions (F (1, 33) = 2.34, MSE = .010, p = .131, η^2 = .07) (Figure 5). This suggests participants' overall productivity was not affected by the switch cue type and that across the total 120 seconds of each trial participants were generating a similar number of words.

DISCUSSION

The goal of this study was to determine whether there were any differences in performance when people were forced to switch versus when they were free to switch on their own in terms of either total output or time to switch between categories or words. In line with the finding that switch costs are reduced when people have knowledge of when they are to occur and can prepare for them, we thought, *a priori*, that people would be both more productive and faster when they could switch freely. However, the data did not show any advantage to either self or forced switches.

This can be understood in the context of an activation based account or model(Altmann & Trafton, 2002). A simple activation model would suggest that switching to a category requires activation of that category (and possibly the inhibition of related categories). Each time an example from a given category is retrieved, that category would receive additional activation and this process would continue until a switch occurred. At the time of a switch (regardless of whether it was internally or externally cued) the activation of the switched-from category would immediately begin to decay and the activation of the switched to category would begin to increase. This process, which is the same across both conditions, would account for the observed switch costs. The switch cost here consists of the time to activate a new category (and possibly inhibit an old one), which would be independent of what caused the switch. If this is the case, there also would be no differential persistent disruptive effects, and thus no differences in the time to switch between words within a category across types of switches.

Although simple activation could be one mechanism involved in the category switching process, it is not clear if this is the only mechanism. It is also possible that inhibitory processes combine with the simple activation to affect performance in switching between categories. Many theories of task switching costs posit such an inhibitory component which results from the need to actively inhibit previous task set configurations (Rogers & Monsell, 1995). The role of the inhibitory component in switching categories involves the suppression of the previous category to such a level that the new category can drive behavior. It has been argued that this is unique to the first trial (or in this case the first word) following a switch (Altmann, 2007) and involves both preparatory and inhibitory process. Interpreted in light of the results of this experiment, it would make sense that there would be no differences between the Auto- and the Self-switch conditions because both involve the same type of first trial (or word). The only difference is in the type of cue used to switch and this explanation is cue irrelevant.

Additionally, Rogers and Monsell (1995) suggest that the amount of inhibition needed to switch to a new task or category is directly related to the number of tasks or categories that have previously been active within some time frame. This is, once again, a cue irrelevant explanation and as both conditions had the same number of categories, both would incur similar needs for inhibitory processes. Finally, a third cue irrelevant explanation of similar switch costs suggests that inhibitory processes must be employed during response selection (Schuch & Koch, 2003). All of the trials in this paradigm involve both response selection and response execution and therefore, would be subject to equal inhibitory processes across conditions.

In reality, it is most likely some combination of activation and inhibition components that led to the presence of similar timing performance across both the Auto- and the Self-switch conditions. This research suggests that there is always an initial cost to switching categories or mental sets and that the magnitude of this cost is not affected by the specific cue which instructs the switch. Further work is needed to tease apart the specific processes involved and why the cue seems to have no effect on the cost of switching.

This work has implications for switching in real-world environments. For example, in an environment such as driving, where our goal is to minimize distraction regardless of its source, it may be that the best course of action is to minimize any need of the driver to switch attention between the road and peripherals such as GPS devices or cell phones. It may not make a difference if the driver chooses to make a call or simply receives one – both of these actions will be distracting and potentially dangerous. The more time that the driver can focus on the road the safer that person’s drive will be.

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Figure 1. Example of Category Switching Stimuli

Colleges
States
Female Names
Fruits

Penn State	XXXXX	XXXXX	XXXXX
Tufts	XXXXX	XXXXX	XXXXX
MIT	XXXXX	XXXXX	XXXXX
Virginia Tech	XXXXX	XXXXX	XXXXX
Rhode Island	XXXXX	XXXXX	XXXXX
Nevada	XXXXX	XXXXX	XXXXX
Banana	XXXXX	XXXXX	XXXXX
Orange	XXXXX	XXXXX	XXXXX
Apple	XXXXX	XXXXX	XXXXX
Rebecca	XXXXX	XXXXX	XXXXX
Michelle	XXXXX	XXXXX	XXXXX
Nicole	XXXXX	XXXXX	XXXXX

Figure 2. Category switch and word switch times across conditions (error bars are standard error of the mean).

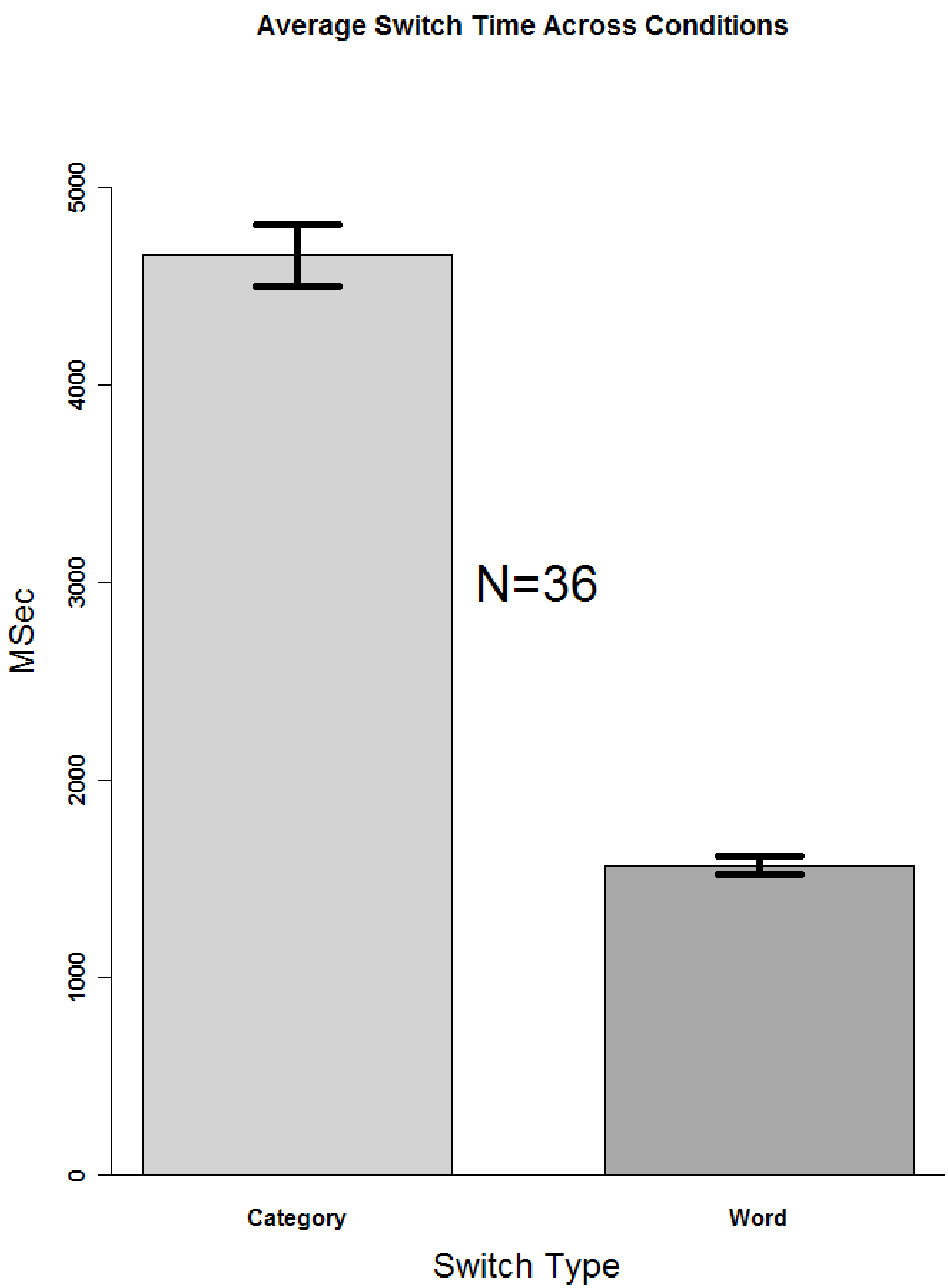

Figure 3. Category switch times across conditions (error bars are standard error of the mean).

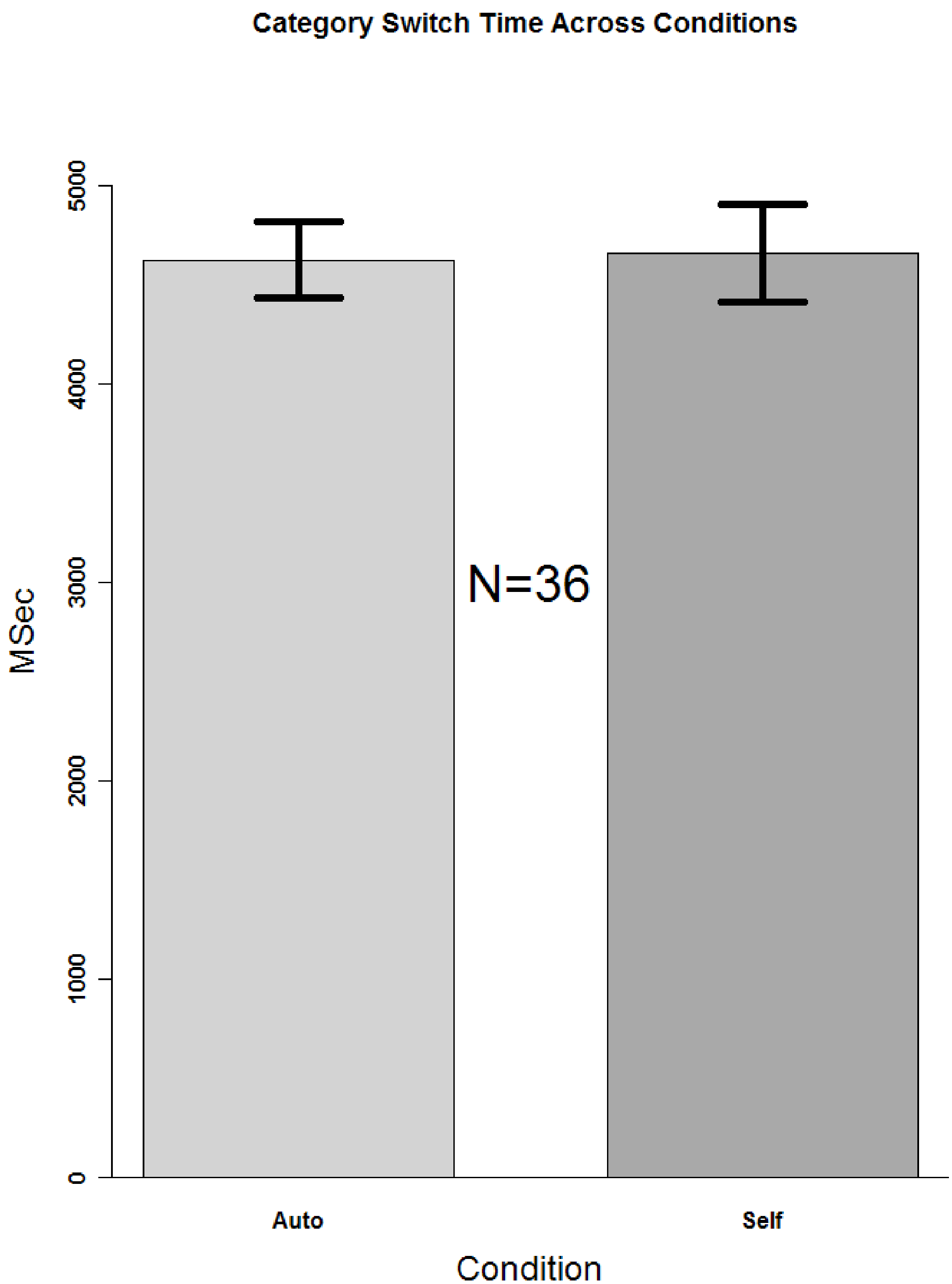

Figure 4.Word switch time across conditions (error bars are standard error of the mean)

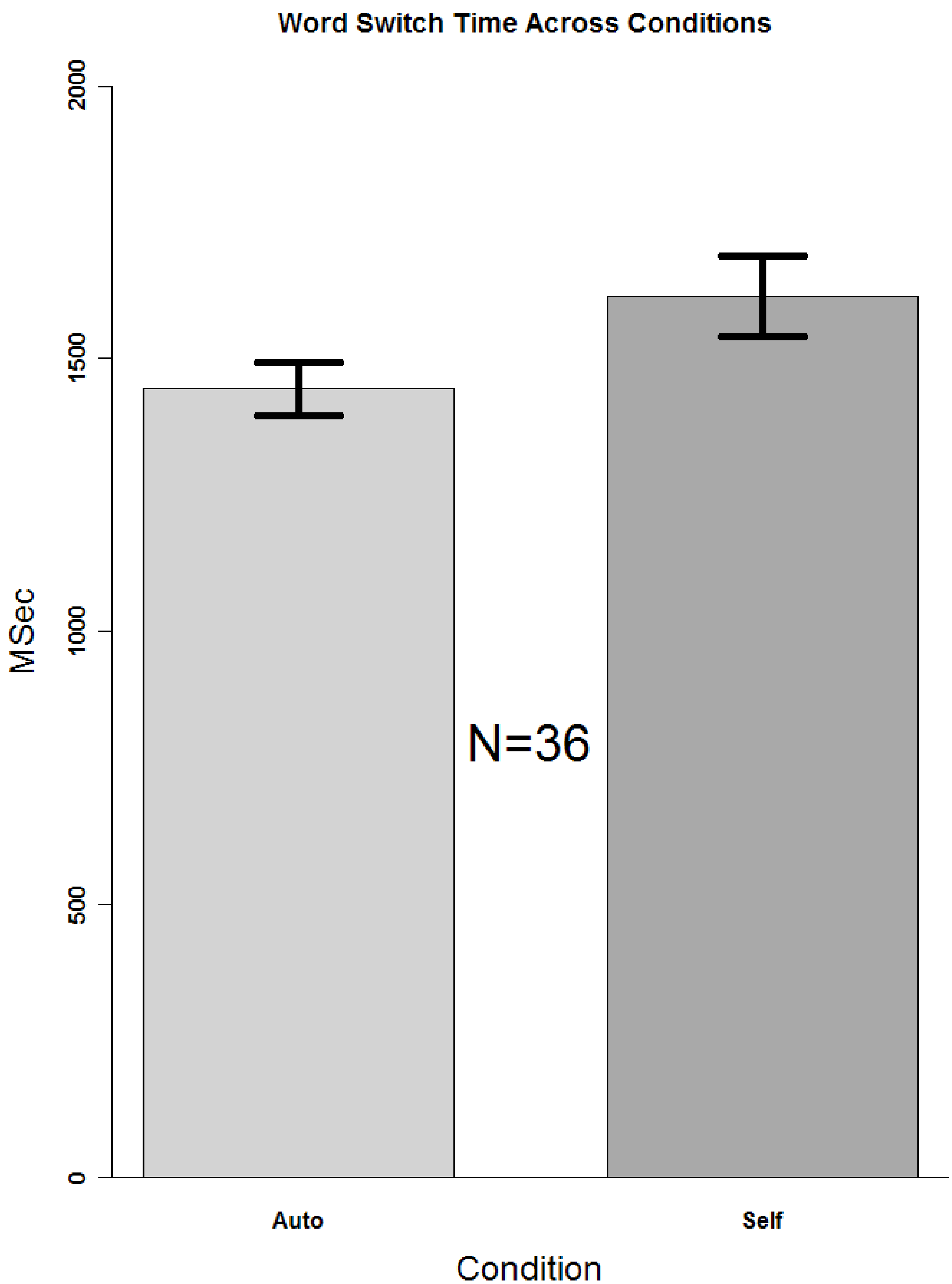

Figure 5.Word generation rate across conditions (error bars are standard error of the mean).