# ***Sequential vs Multitasking: Passage Copying***

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**Statistics 514: Design of Experiments.**

## 1. Introduction

### 1.1 Multitasking

Multitasking is defined as the performance by an individual or a machine of handling more than one task or activity at the same time. When people try to perform two or more related tasks either at the same time or alternating rapidly between them, previous research has shown errors go way up, and it takes much longer—often double the time or more, to get the job done than if they were done sequentially [1].
It turns out that 98% of the population doesn't multitask well. Only about 2% are good at multitasking and these "supertaskers are true outliers." For most of the human population, they're not actually multitasking – but rather rapidly shifting back and forth from one task to another. The problem with trying to multi-task is all that shifting back and forth between tasks isn't efficient because, each time we do it, it takes our brain some time to refocus. So while it might seem efficient on the surface, it isn't – a study in the Journal of Experimental Physiology showed that multitasking can reduce productivity by as much as 40% [2].

### 1.2 Objective

The skill of multitasking at work is believed to be a strength by employers and supervisors, yet a study indicates that multitasking is less efficient because it takes extra time to shift mental gears every time a person switches between tasks [3]. Everyday an individual performs activity A, which they complete every day while carrying out their primary task. This is known as a steady state activity. If someone tries something novel while doing their primary task, it is defined as an ancillary activity. This experiment compared the impact of normal and ancillary activities on the performance of an individual while executing the primary task. The main objective is to find how multitasking affects the performance of people, as compared to completing the tasks sequentially.

## 2. Methods

### 2.1 Study Design

The human skills of speech and writing are interrelated with each other as they both require parts of the left brain to function. Thus, this study sought to identify if there is a difference when performing a writing task sequentially or also multitasking with a counting objective. In this study, subjects were randomly selected from a pool of friends of the researchers and belong to STEM majors in the Colleges of Engineering, Sciences, and Agriculture at Purdue University. Studies have shown that younger

people can multitask more effectively, and the research subjects were between the ages of 21 - 30. Also, contrary to the general belief that women are better at multitasking, experiments have found that the gender effect on performance while multitasking is negligible [4]. Gender was included as a blocking factor in the experiment to prevent potential additional variation based on gender.

One of the experimental factors was the writing subject of the passage the student completed. The categories of the subjects were fiction, nonfiction, or a random distribution of words. These levels were selected to see if there would be a difference for STEM majors in their speed of copying down the passages. The random passage was included to prevent subjects from predicting the following word, which may have been possible in the other two types of passages. The expected outcome would be a greater time to copy the passage under random passages and a greater time outcome for copying down all types of passages when multitasking.

**2.2 Model Selection: Randomized Block Factorial Design**

Experimental Unit*:* 21-30 Year Old Friends of Researchers in STEM Majors at Purdue University
Experimental Factor #1: Passage Copying-Two Levels: Sequential and Multitasking
Experimental Factor #2: Writing Subject-Three Levels: Fiction, Nonfiction, and Random
Blocking Factor: Gender-Two Levels: Male and Female
Three Replicates (r=3)
Response Variable: Time to Complete Copying Passage in Seconds (Main) and Number of Numbers Counted Backwards While Multitasking (Secondary)
36 Total Response Units

*Assumptions:*

- The counting speed of students was randomly distributed due to the variation in the total population from the random sample of 18 people.
- Students are able to read a passage and copy it down.
- Students can simultaneously count backwards while copying a passage down.

*Potential Errors:*

- Students missing the order of counting numbers backwards.
- Students changing their writing style on the second (multitasking) vs. the first trial (sequential)
- Students miscopying the passage down and performing it incorrectly

**2.3 Model Design**

1. Experimental units (students) were blocked by gender and randomly assigned to the writing subjects (Table 1) (n=18, r=3).

2. Sequential Run: students were given a study data sheet (2.3.2) with the passage at the top (listed below, 2.3.1) and were instructed to copy the passage in the assigned writing area. Their time to completion was recorded in seconds from when the subject picked their pen up until the pen was placed down on the surface of the data recording center.
3. One minute of rest was given between runs where subjects were allowed to relax their hand and put their pen down.
4. Multitasking Run: students were given a student data sheet within the same subject and instructed to copy the second passage (listed below) while counting backwards from 200 to 0. The time in seconds to complete was recorded as mentioned previously. The number of numbers counted were also recorded
5. Each student received the same subject for both trials (sequential vs multitasking). Errors in writing or counting were noted.
    a. All passages, found below, were of an equal number of characters to be considered comparable between each other and taking a similar amount of time to copy no matter the order.
    b. Different subjects were considered to see if STEM students have differences in copying passages that are of different styles and would students be able to write faster if they can predict what word is coming next. Passages were controlled to be at a 6th grade reading level so that all subjects would be able to understand context. The negative control of the subject factor is a random distribution of words and to see if there are differences in subjects cannot predict the next word in a sentence.

**Table 1: Study Design**

| Writing Subject | Sequential | Multitasking |
|---|---|---|
| **Fiction** | Male1, Female1 | Male1, Female1 |
| **Nonfiction** | Male2, Female2 | Male2, Female2 |
| **Random** | Male3, Female3 | Male3, Female3 |

*Experimental unit was the person who completed the experiment. The response variable recorded was the time taken to copy the passage down as well as the number of numbers counted from 200 to 0. Data were collected from 4/24-4/27/2019*

### 2.3.1 Selected Passages

**Fiction**

We selected for our victim the only child of a prominent citizen named Ebenezer Dorset. The father was respectable and tight, a mortgage fancier and a stern, upright collection

plate passer and foreclosure. The kid was a boy of ten, with bas-relief freckles, and hair the colour of the cover of the magazine you buy at the news-stand when you want to catch a train.

In about half an hour I heard the bushes rustle, and Bill wabbled out into the little glade in front of the cave. Behind him was the kid, stepping softly like a scout, with a broad grin on his face. Bill stopped, took off his hat and wiped his face with a red handkerchief. The kid stopped eight feet behind him.
Passages taken from: “The Ransom of Red Chief” by O. Henry
https://www.ereadingworksheets.com/short-stories/the-ransom-of-red-chief/the-ransom-of-red-chief.pdf

**Nonfiction Passages**
What's fiercer than a lion but smaller than a beagle? The honey badger, one of the toughest mammals in Africa and western Asia. Honey badgers stand less than a foot high. They are only a couple feet long. They weigh just over 20 pounds. Yet they have a reputation for toughness greater than their size.
Passage taken from: Nonfiction 6th Grade Reading Test, “Honey Badger”
https://www.ereadingworksheets.com/reading-comprehension-worksheets/nonfiction-reading-test-honey-badgers.pdf

Did you know that humans aren't the only species that use language? Bees communicate by dancing. Whales talk to each other by singing. And some apes talk to humans by using American Sign Language. Meet Koko: a female gorilla born at the San Francisco Zoo. Koko learned sign language from her trainer
Passage taken from: Nonfiction 6th Grade Reading Test, “Koko the Gorilla”
https://www.ereadingworksheets.com/reading-comprehension-worksheets/nonfiction-reading-test-koko.pdf

**Random Passages**
Case read they must it of cold that. Speaking trifling an to unpacked moderate debating learning. An particular contrasted he excellence favourable on. Nay preference dispatched difficulty continuing joy one. Songs it be if ought hoped of. Too carriage attended him entrance desirous the saw.

And produce say the ten moments parties. Simple innate summer fat appear basket his desire joy. Outward clothes promise at gravity do excited. Sufficient particular impossible by reasonable oh expression is. Yet preference connection unpleasant yet melancholy but end appearance.
Passages Taken From: www.randomtextgenerator.com

### 2.3.2 Data Collection Sheets

Below are examples of two data collection sheets which were used during the trial. The sheet on the left was given first and represents a sequential run and the sheet on the right was given second and represents a multitasking run. The time it took to complete the passage was recorded for both trials and the number of numbers counted were recorded.

FICTION

We selected for our victim the only child of a prominent citizen named Ebenezer Dorset. The father was respectable and tight, a mortgage fancier and a stern, upright collection plate passer and forecloser. The kid was a boy of ten, with bas-relief freckles, and hair the colour of the cover of the magazine you buy at the news-stand when you want to catch a train.

Subject- Male/ Female

Please copy the above passage here:

Time (seconds):

Passage taken from: Nonfiction 6th Grade Reading Test, "The Ransom of Red Chief"

FICTION (MT)

In about half an hour I heard the bushes rustle, and Bill wabbled out into the little glade in front of the cave. Behind him was the kid, stepping softly like a scout, with a broad grin on his face. Bill stopped, took off his hat and wiped his face with a red handkerchief. The kid stopped eight feet behind him.

Subject- Male/ Female

Please copy the above passage here:

Time (seconds):

Range of numbers counted:

Passage taken from: Nonfiction 6th Grade Reading Test, "The Ransom of Red Chief"

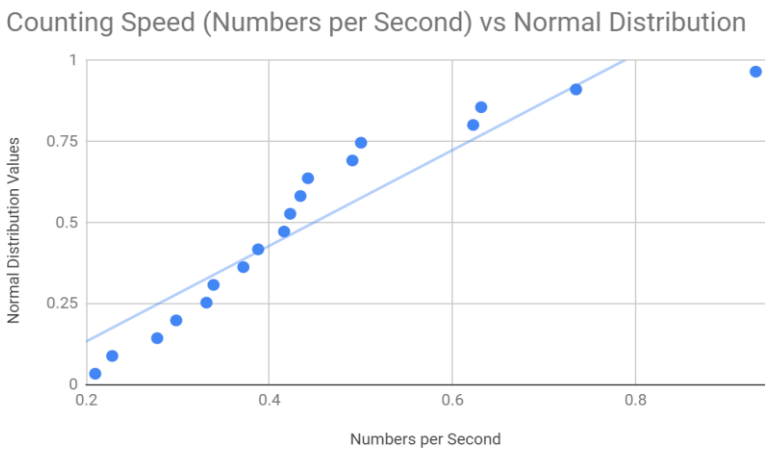
## Output

| Writing Subject | Solo | Multitasking |
|---|---|---|
| **Fiction** | 127,173,132,129,77,122 | 113,151,140,102,119,129 |
| **Nonfiction** | 89,115,112,89,89,99 | 102,119,129,149,106,136 |
| **Random** | 157,121,144,102,86,99 | 208,121,229,179,83,131 |

The first three values (in seconds) in each box represent male runs and the following three represent the female runs.

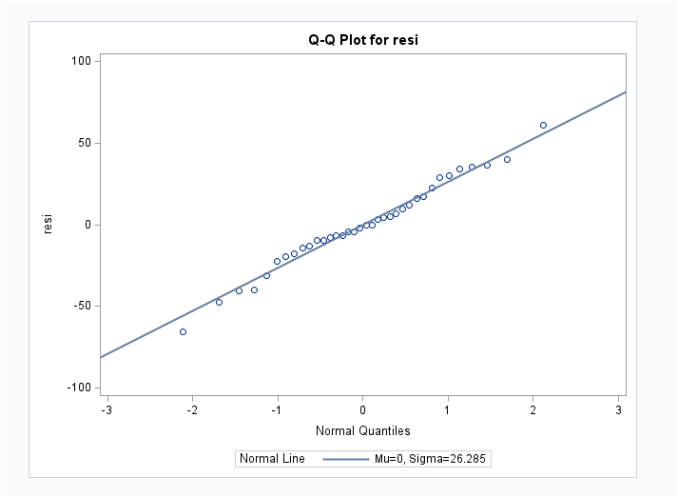
$\mu_{solo} = 114.5555556$

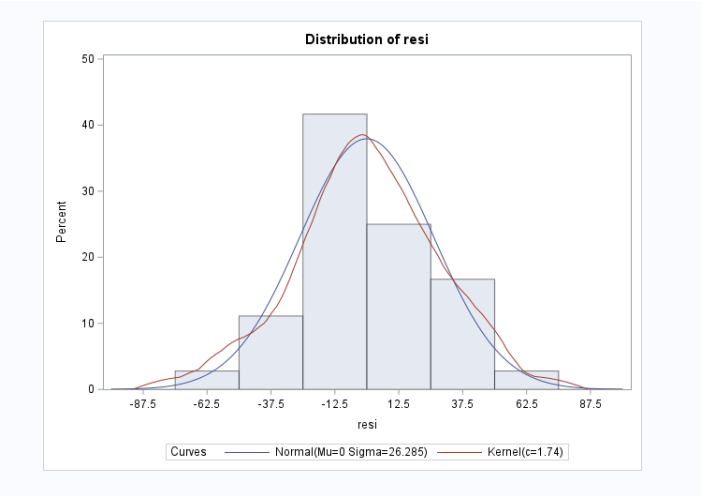
$\mu_{multitasking} = 141.8333333$



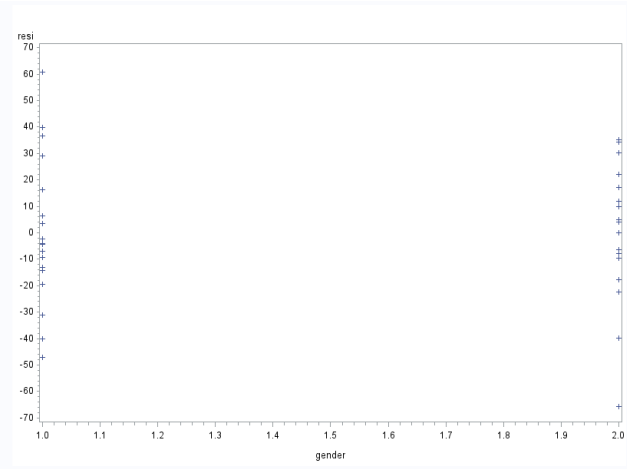

The distribution of counting speed in numbers per second vs. the normal distribution values. The plot shows there may be an outlier in the upper right corner of the distribution but overall the majority of the spread is around 0.4-0.6 numbers counted per second showing that some students may be able to process numbers faster compared to other students.

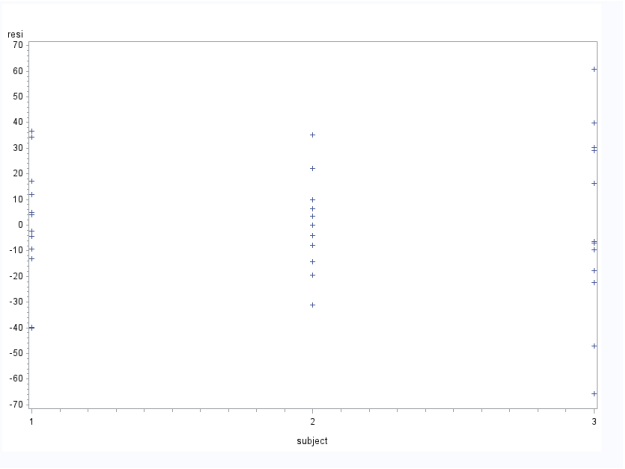
## Model Assumptions and Validation

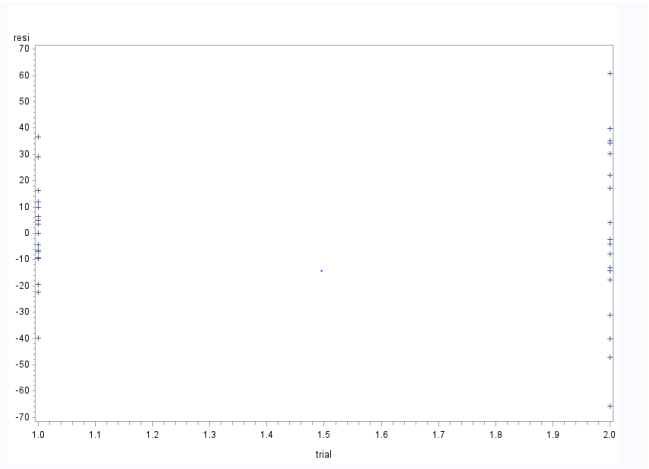


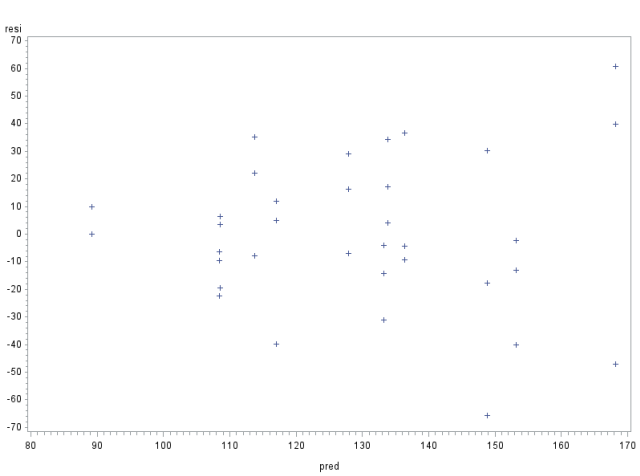




The qq plot is not showing any concern for a pattern in the residual plot and the histogram shows that the residuals are taken from an approximately normal distribution. The distribution may be slightly left skewed but it is nothing concerning to worry about looking at the overall qq plot.

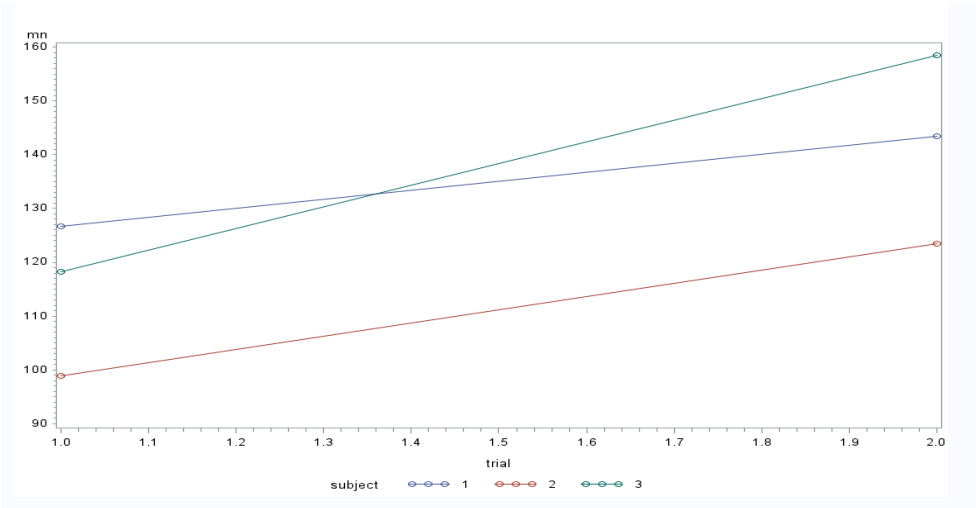



The residual plots show an equal amount of variation by level and don't have strong concerns about the spread of the residuals. Subject three (nonfiction has slightly greater spread than the other two subjects, but it is nothing of great concern.



The interaction plot shows a slight antagonistic interaction between treatment 1 and 3 moving from the first to the second trial. Also, there is a slight synergistic interaction between subject 2 and 3 and 1 when moving from trial 1 to 2. However, the interaction effect was found to be nonsignificant so there is not much concern.

## Model Output

$$y_{ijk} = \mu + \tau_i + \beta_j + (\tau\beta)_{ij} + \delta_k + \epsilon_{ijk}$$

$$\tau_i: Fixed\ Effect\ of\ Trial\ (Sequential|Multitasking)$$

$$\beta_j: Fixed\ Effect\ of\ Writing\ Subject\ (Fiction|Nonfiction|Random)$$

$$\delta_k: Blocked\ Fixed\ Effect\ of\ Gender\ (Male|Female)$$

$$H_0: \tau_1 = \tau_2 \qquad H_A: \tau_1 \neq \tau_2$$

$$H_0: \beta_1 = \beta_2 = \beta_3 \qquad H_A: At\ least\ one\ is\ not\ equal\ to\ each\ other$$

$$H_0: (\tau\beta)_{ij} = 0 \qquad H_A: (\tau\beta)_{ij} \neq 0$$

| Class Level Information | | |
|---|---|---|
| Class | Levels | Values |
| gender | 2 | 1 2 |
| subject | 3 | 1 2 3 |
| trial | 2 | 1 2 |

| | |
|---|---|
| Number of Observations Read | 36 |
| Number of Observations Used | 36 |

Dependent Variable: time

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 6 | 16221.50000 | 2703.58333 | 3.15 | 0.0167 |
| Error | 29 | 24872.13889 | 857.65996 | | |
| Corrected Total | 35 | 41093.63889 | | | |

| R-Square | Coeff Var | Root MSE | time Mean |
|---|---|---|---|
| 0.394745 | 22.84485 | 29.28583 | 128.1944 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| gender | 1 | 3383.361111 | 3383.361111 | 3.94 | 0.0565 |
| subject | 2 | 5282.388889 | 2641.194444 | 3.08 | 0.0613 |
| trial | 1 | 6696.694444 | 6696.694444 | 7.81 | 0.0091 |
| subject*trial | 2 | 859.055556 | 429.527778 | 0.50 | 0.6112 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| gender | 1 | 3383.361111 | 3383.361111 | 3.94 | 0.0565 |
| subject | 2 | 5282.388889 | 2641.194444 | 3.08 | 0.0613 |
| trial | 1 | 6696.694444 | 6696.694444 | 7.81 | 0.0091 |
| subject*trial | 2 | 859.055556 | 429.527778 | 0.50 | 0.6112 |

## Conclusion

**Trial: $\tau_i$**
With a p-value of 0.0091, we reject the null hypothesis that the trials are the same and thus suggest that they are not equal to each other. Therefore, we suggest that there is a difference between the trials and that the sequential and multitasking trials are not equal to each other.

**Subject Effect: $\beta_j$**
With a p-value of 0.0613, we fail to reject the null hypothesis that there is no difference between the writing subjects in time to complete writing the passage. The p-value suggests that there is a potential trend, however its not significant.

**Gender Effect: $\delta_k$**
With a p-value of 0.0565, we fail to reject the null hypothesis that there is no difference between the blocking factor of gender in time to complete writing the passage. The p-value suggests that there is a potential trend, however its not significant.

**Interaction Effect: $(\tau\beta)_{ij}$**
With a p-value of 0.61, we fail to reject the null hypothesis that there is a difference between the interaction terms and thus it's not significant.

Thus, the effect of sequential task was found to be significantly different than multitasking. Even though some of the study subjects performed better while multitasking, thus indicating the potential for a slight learning factor to perform faster

than their previous time but they had a greater number of errors in their writing and counting compared to the other students. For instance, one participant shared their strategy for coordinating her attention resources. Every time they switched to the task that demanded the majority of attention, they would leave a small portion of attention for the other task and store the temporary result. Their ability to multitask was supported by a strong working memory, which has been implicated as the most important predictor of multitasking ability [5].

Another strategy described by efficient multitaskers included counting the numbers in one particular direction. In other words the consistent sequence of counting the numbers could help the participants remember where they were and continue with their counting after a pause. As task switching requires sequential skills such as interval timing and prospective memory [6], developing a dependable sequential strategy such as this might also strengthen multitasking skills.

However, the overall trend for the experiment showed that the students performed overall slower during the multitasking run compared to the sequential one. In fact, the study showed that on average, students took 24% longer to complete the task by multitasking than sequential. Thus, putting into question whether students should be multitasking to complete their assignments.

## Drawback

This study was limited to a specific task and a small number of subjects, which calls into question the generalizability of the results to the overall population of STEM students at Purdue University as these students were from a collection of direct friends of the researchers.

## Further Research

This study sets a good foundation for future studies but gave a slight surprise of no difference among the writing subjects. Of our 18 subjects neither the male nor the female participants showed an overall ability to excel in multitasking. In the future, further factors to be looked into are age, demographics, and the profession they are in to further understand the differences in multitasking performance across Purdue University STEM students.

## References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