The Effects of Radiation on Memory for Varying Age Groups

Research Paper

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1 Abstract

Cancer has always been one of the most prominent types of serious medical conditions around the world, with about half the people who get it seeking treatment through radiation therapy. While radiation is known to cause various forms of physical side effects such as nausea and vomiting, we decided to perform an experiment to test how radiation affects cognitive memory. Our goal with the experiment is to prove that various levels of radiation have effects on memorization; specifically, we looked at how two levels of radiation (1 GY and 3 GY) cause an increase in time to complete a memory game. We set up our study as a two-way randomized block design looks at the difference in time to complete the game before and after radiation. We chose to utilize age as a factor and gender as a block. Our results suggest that there is a statistically significant increase in time taken on a memory game, dependent on aging and dosage. This adds another potential threat to an already dangerous and commonly misunderstood form of cancer treatment.

2 Introduction

Over 14 million cases of cancer are diagnosed every year across the globe. The most common form of therapy is radiation, with the ability to increase the chances of being cured or receive palliative relief for around 7 million people. The prevalence of this disease and its main respective cure indicates the importance of analyzing the underlying side effects behind chemotherapy. Previous research suggests that radiation often leads to nausea, vomiting, and diarrhea sometimes within minutes of exposure. Research also reveals that chemotherapy specifically often leads to cognitive issues in regards to memory and concentration. In this study, we choose to address how radiation plays a role in memorization capabilities. It should be noted that research also shows that women tend to be more affected by radiation than men.

Radiation is a term often not fully understood by the general public. Physicists explain radiation as “the emission of energy as electromagnetic waves or as moving subatomic particles, especially high-energy particles which cause ionization.” Because the ionization causes damage to tissue in our bodies, high levels of radiation can be extremely harmful. Doses of radiation are measured in grays (GY) or sieverts (Sv). A GY is the deposit of a joule of radiation into the tissue. It takes about half of a GY for a patient to have noticeable symptoms of radiation, while 4-5 GY can lead to death in about 60 days. Symptoms of radiation are most notably physical, causing illness or damage to internal organs. For cancer patients undergoing radiation therapy to eliminate brain tumors, these symptoms may not be as noted. Radiation induced cognitive decline has been an issue more prevalent in the recent years among cancer patients who received treatment for brain tumors; however, not much data has been collected about the decline.

Therefore, our study aims to determine how different levels of radiation affect memorization abilities within subjects of varying age groups. We propose that since subjects aged 6-15 are younger, and thus are more prone to the effects of radiation, their memorization will be the most affected. Since brains do not fully develop until the age of 25, we propose that this age group between 16 and 25 will be the next most affected by radiation. Finally, since the brains of those between the ages of 26 and 35 are fully developed, we propose that this age group will be the least affected by radiation in terms of cognitive abilities. Since there is minimal research in existence that analyzes how different ages are affected by radiation in terms of memorization capabilities, we hope this study will shed light into how chemotherapy affects individuals not only physically, but cognitively. As such, we propose that radiation will decrease the memorization aptitude of all subjects in our study to varying degrees based on age and dosage levels.

3 Methods

3.1 Participants

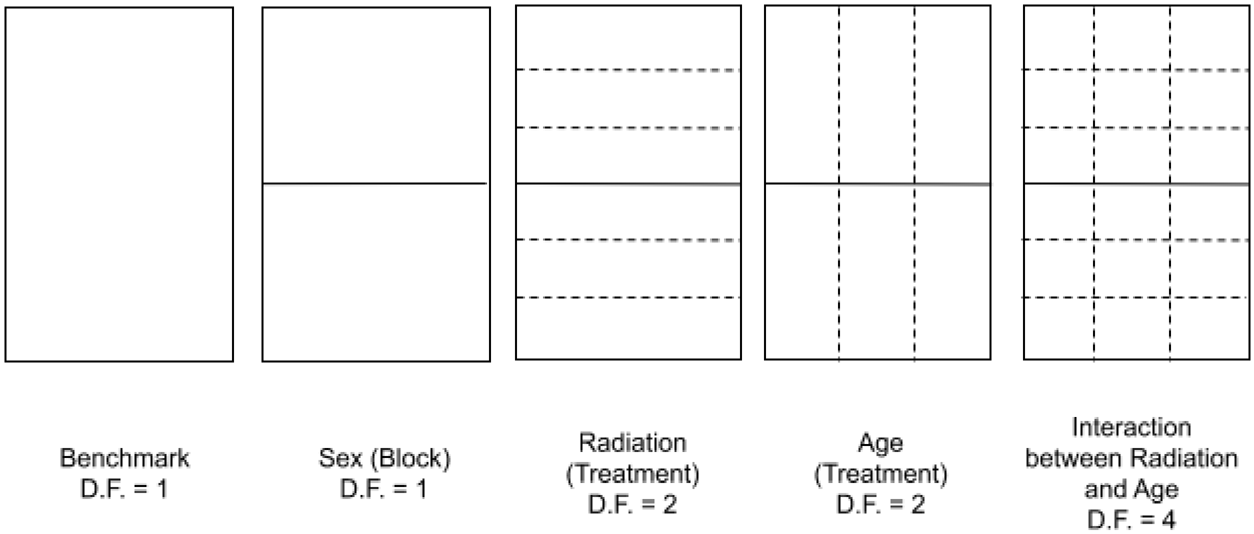
The participants for this study will islanders aged between 5 and 35. We found that this was most appropriate considering radiation affects younger age groups more (leading to the 5-15 age group); the brain stops developing at 25 (leading to the 16-25 age group), and adolescents are more prone to being affected by radiation than older individuals (leading to the 26-35 age group). Participants for this study will be islanders from Macondo. For each block, and age group, participants will be randomly assigned a radiation treatment group. Note that this will be a balanced design, and the number of people in each group will be the same.

3.2 Design

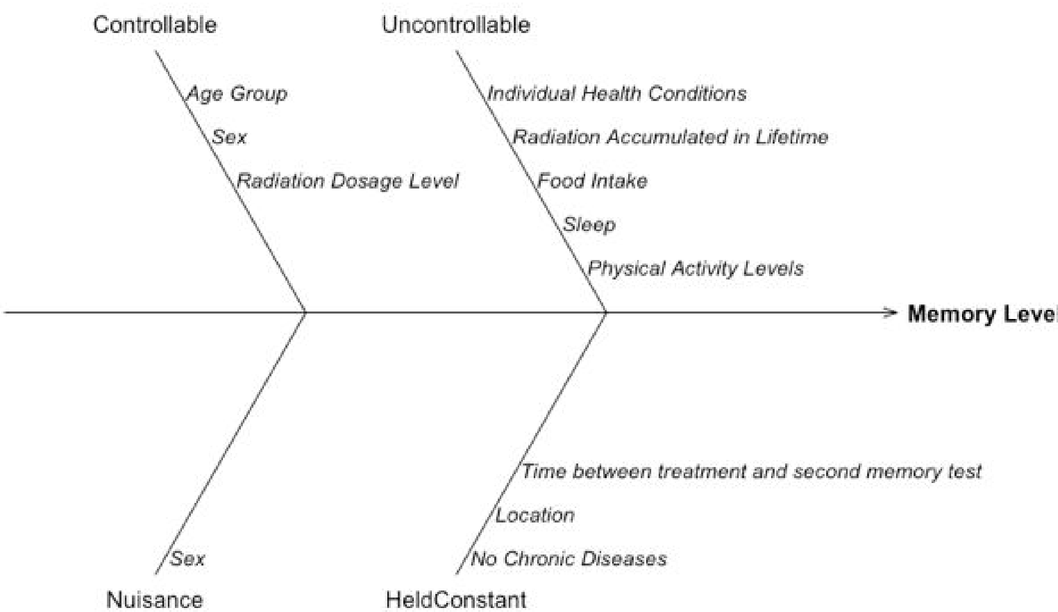
The study will be set up as a Two-Way Randomized Block Design (detailed below):

Response Variable	**Memory Test**		
Factor 1 (Radiation)	0 gY	1 gY	3 gY
Factor 2 (Age)	6-15	16-25	26-35
Blocking (Sex)	Male	Female	

The Factor Diagram (detailed below):



Studies have been done to show that radiation affects memory, and other cognitive skills. The aim of this clinical study is to find the extent to which this occurs by testing different levels of radiation. We will block on sex, to ensure this is not an influencing factor. We aim to investigate the difference in the effect of radiation on memory for each age group.



It is important to note the controllable, uncontrollable, nuisance, and held-constant factors this experimental design consisted of, as these influence the results of the experiment. These factors can be seen in the above Cause-and-Effect diagram.

3.3 Instruments

The treatment level, radiation, will be provided to participants by exposing them to varying quantities of ionizing radiation. The response variable, memory, will be measured through a memory test. This test is a pairs memory game with 30 cards, to be completed as quickly as possible.

3.4 Procedure

1. Find and obtain consent from islanders from Macondo (finding an equal number of males and females in each of the three age groups). Ensure all the islanders do not have any chronic diseases.
2. For each age group, and sex block, assign islanders numbers from 1 to 30. Randomly shuffle these islanders, and randomly assign them into one of the three treatment groups.
3. Assign each islander the task of playing a memory game.
4. Apply the assigned treatments to each islander.
5. Assign each islander the task of playing a memory game again.
6. Compute the difference in memory test scores before and after the treatment (this is the response variable).

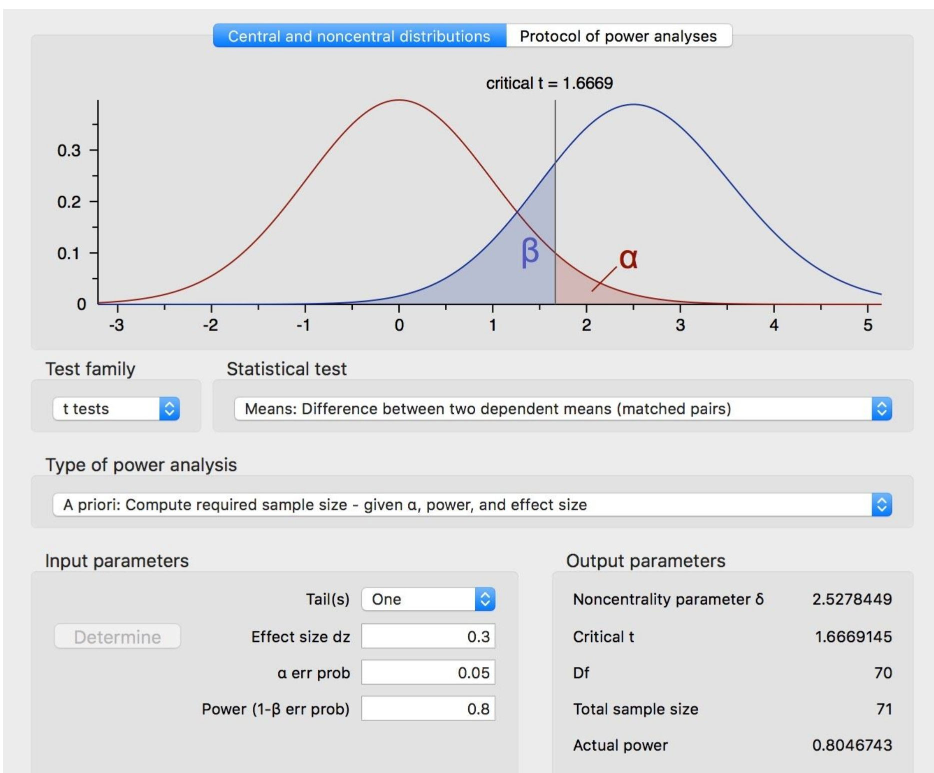
4 Data Analysis

4.1 Types of Statistical Analysis

We will conduct an ANOVA test on our data using order to determine if there is a significant decrease in memory ability from radiation therapy. We plan on using a paired t-test to compare the difference in means between groups within each block using an alpha level of 0.05 and power of 0.8. This will test if ability on the memory task is significantly lower after the use of radiation treatment. Our control group in this case is our subject before they are randomly assigned to a treatment group. We also are testing for interaction between age groups and improved memory status.

4.2 Sample Size Determination

We have a power of 0.8 and Alpha level of 0.05. The power is equal to 1- Beta, or one minus the probability of failing to reject a false H0. The alpha is the probability of rejecting a true H0. The sample size was determined using a G*power test. An effect size of 0.3 is used which is rather conservative considering the fact that there are not too many studies with conclusive data on the effects of radiation treatment on memory. The G*power test determined the sample size of 138 is appropriate. We will round that up to 144 so that we have equal group sizes. There will therefore be 8 people per treatment group, after blocking by age.



5 Results

5.1 ANOVA Analysis

	Df	Sum Sq	Mean Sq	F Value	Pr(>F)
Age	2	222.6	111.28	4.857	0.00917**
Treatment	1	107.4	107.43	4.689	0.03210*
Gender	2	67.4	33.68	1.470	0.23360
Age:Treatment	2	10.1	5.04	0.220	0.80283
Residuals	136	3116.0	22.91		

Table 1: Two Way Anova with Blocking and Interaction. Age is the most significant factor, with a p-value of 0.00917, telling us that age has an effect on cognitive memory. Treatment is also significant, with a p-value of 0.03210, meaning the amount of GY given has an effect on cognitive memory. Gender and the interaction between Age and Treatment do not have significant p-values, suggesting that our block was not necessary.

5.2 Residual Diagnostics

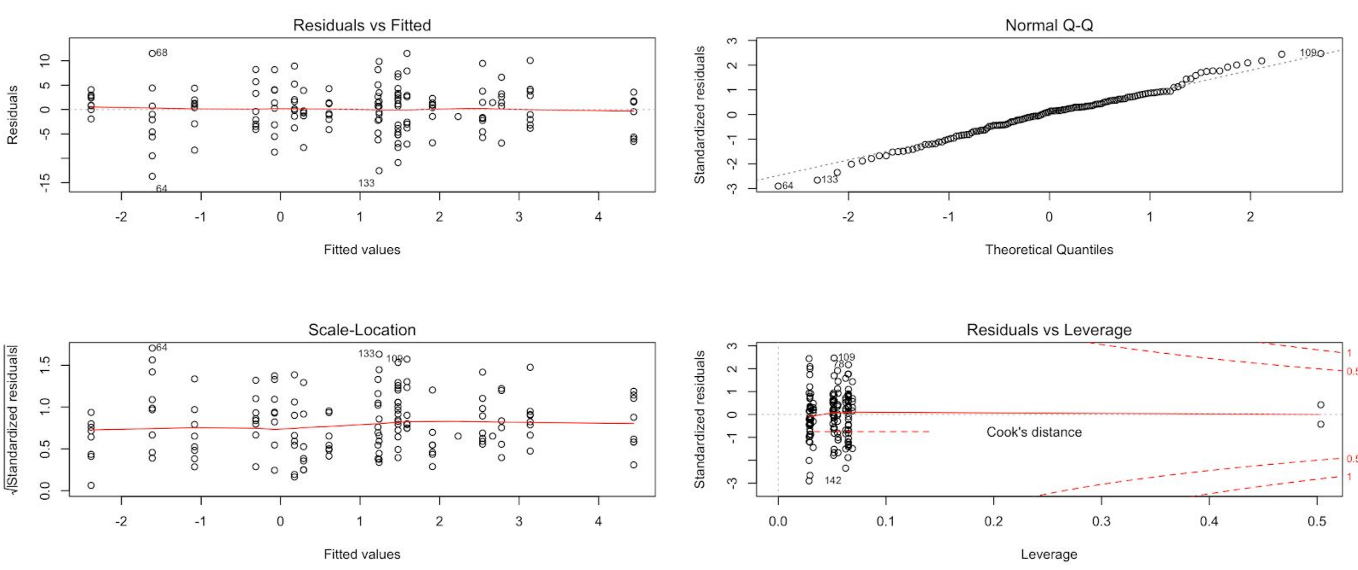


Figure 1: Residual Diagnostic Plots for ANOVA Summary. The Residuals vs Fitted Plot and Scale-Location Plot show no unusual pattern in the residuals, suggesting that the assumption of constant variance is maintained. The Normal Q-Q Plot shows a drift away from the normal line for values below -2 and above 1; however, since a majority of the values follow a straight line, we can assume normality for this large sample size. The Residuals vs Leverage Plot tells us that there are leverage points, which can be seen in Figure 2.

5.3 Box Plots

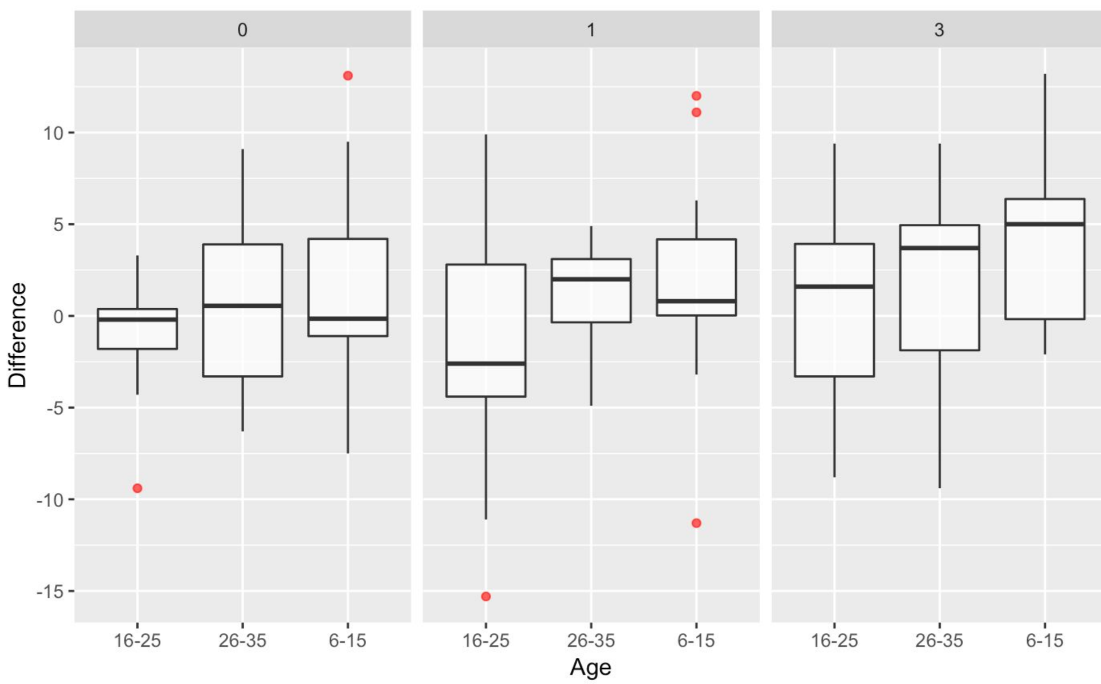


Figure 2: Box Plots Comparing Difference in Memory Scores between GY Amounts by Age. The side-by-side box plots suggest fluctuation between age groups within each GY level, but not a great amount of fluctuation between GY amounts. However, it should be noted that there was a major change in scores in the 6-15 age group that received 3 GY compared to the treatment group for that age level. The red dots in this figure represent outliers, suggesting that those subjects got significantly better or worse at the memory game on their second try due to individual intelligence, memory, and/or alertness.

5.4 Interaction Plot

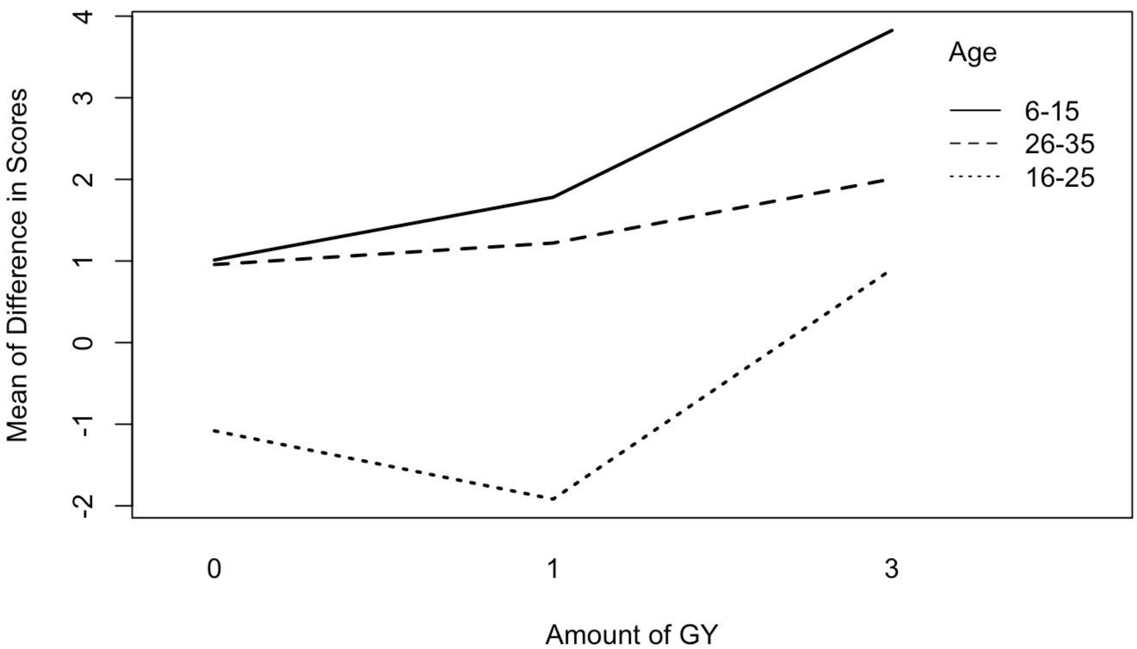


Figure 3: Interaction Plot between Age Groups and Amount of GY. This plot suggests that there is no interaction between age groups and treatment levels. The plot is backed up by a high p-value of 0.80283 for the interaction in the ANOVA analysis.

6 Discussion

The aim of this study was to determine the effect of varying levels of radiation on memory, as well as the impact of this based on differing age groups. As cancer is one of the most threatening medical conditions, and radiation plays a pivotal role in treating the condition, with our results, we aim to conclude the extent to which radiation affects memory, and whether this varies for different age groups.

A two-way ANOVA analysis was conducted in order to conclude the results of the study. The study was based on a sample of 144 people, with 0.8 power, and 0.3 effect size. After thorough analysis, our data revealed that radiation causes a significant difference in memorization game speeds when in comparison with our control. The interaction plot and ANOVA table indicate that there is insignificant interaction between our different treatments and age level. After also analyzing the boxplot, it's evident that while increased radiation levels affected all ages of islander's memorization speeds in relatively the same way (p-value = 0.009), it affected different ages to different extents (p-value = 0.802). For example, the youngest age level's (5-15) memorization game speeds were the most slowed down by increased radiation and the oldest age level's memorization game speeds were the least slowed down.

We acknowledge that there were some limitations to our experimental design which can be improved upon for any follow up studies. Blocking on gender had no significant effect on the results, despite prior research that suggested radiation may affect males and females in different ways. Though this may be a sample limitation, it may be worth investigating this further by repeating the experiment given that literature states that this is a significant factor. This results also suggests the possibility of utilizing an alternative blocking factor. For example, some uncontrollable factors included radiation received in the participant's lifetime (prior to the experiment), individual health conditions, food intake, sleep received, and physical activity levels. Therefore, if the design was conducted on a different medium, it may be more practical to block on these factors, though these factors would still be fairly difficult to measure. Additionally, it is possible that, as islanders play the memory game multiple times, their game speeds naturally increase. This may have affected post-radiation memorization game capabilities. Potential future paths to this study could involve examining islands outside of Macondo to see if the results are similar. Furthermore, since this study only examined islanders between the ages of 6 and 35, we could study how radiation affects islander's memory when they're over the age of 35.

7 References

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