Designing Immersive Virtual Environments for Cognitive Learning and Spatial Memory Tasks

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Dedication

I dedicate this to the One without whom I couldn't have made it this far, my mental support and source of strength, God!

Abstract

Virtual reality provides a realistic way to learn at a flexible progression and to develop skills that could be difficult to grasp in the real world. Our hypothesis is that there are certain VR affordances that educators and developers can leverage to build simulated learning experiences that can transform education and training activities. The immersive experience VR provides through real-time interaction, engagement, spatial awareness, visual representations, and media richness is useful for developing experiential learning environments. Watching a dinosaur egg hatch and the development of its complete life cycle in a virtual Jurassic world may provide more visual context than reading a textbook on the life cycle of the same dinosaur.

The goal of this study was to better understand which interaction mechanism may be better for the design of immersive virtual learning environments. We investigated the role that natural locomotion and teleportation may have on cognitive and spatial information processing in a virtual environment. The learning space is a virtual cemetery, and it consists of thirteen tombstones with stories about the lives of the residents of spoon river, a fictional town mentioned in Spoon River Anthology by Edgar Lee Masters. We conducted experiments by placing subjects in four different conditions: teleportation across long distances, walking across long distances, teleportation across short distances and walking across short distances. Our hypotheses are that shorter natural walking paths will produce better outcomes on the cognitive assessments and spatial memory assessments we conducted. Teleportation, while beneficial for navigating virtual reality from a small, confined physical space, may not provide enough continuous spatial updating and therefore may be somewhat detrimental for certain learning environments. We analyzed the results and built a linear regression model to find any association between input and output variables.

Our data analysis revealed that:

- For definite memory recall and proprioception of the spatial layout of a virtual space, it is better to walk than to teleport.
- To visually match objects to their spatial positions, a learning space that is logically investigated through shorter distance movements is better than longer paths.
- Strong cognitive understanding is achieved if the learning space properly balances exploration of the environment and discovery of information.

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1 Introduction

Virtual Reality (VR) successfully reproduces real-world scenarios and is a good technology to observe and improve the learning experience. Scenarios that are difficult to reproduce in the real world can be simulated and closely observed in VR, and users can interact naturally and perform complex tasks that may be impractical in the real world. VR is a beneficial technology to Education as it presents significant advantage over the traditional classroom experience through simulation of realistic scenarios. Also, trainers can obtain in-depth information about the user through a safe and controlled experience.

1.1 VR and Cognitive Learning

Knowledge acquisition is trending in education, manufacturing, engineering, business, finance, and construction as a critical task. A research study found that the Federal Government increased their spending budget on knowledge acquisition software from $850 million in 2004 to about $1.1 billion in 2008 [6]. A lot of sectors struggle with being unable to successfully transfer knowledge from one part of the organization to the other [9]. Experiential learning in virtual reality provides learners a hands-on, realistic learning strategy. We can adapt the conceptual knowledge framework to VR by providing cognitive motivators such as immersion, engagement, interaction and setting cognitive goals that can be perfected through a strategy.

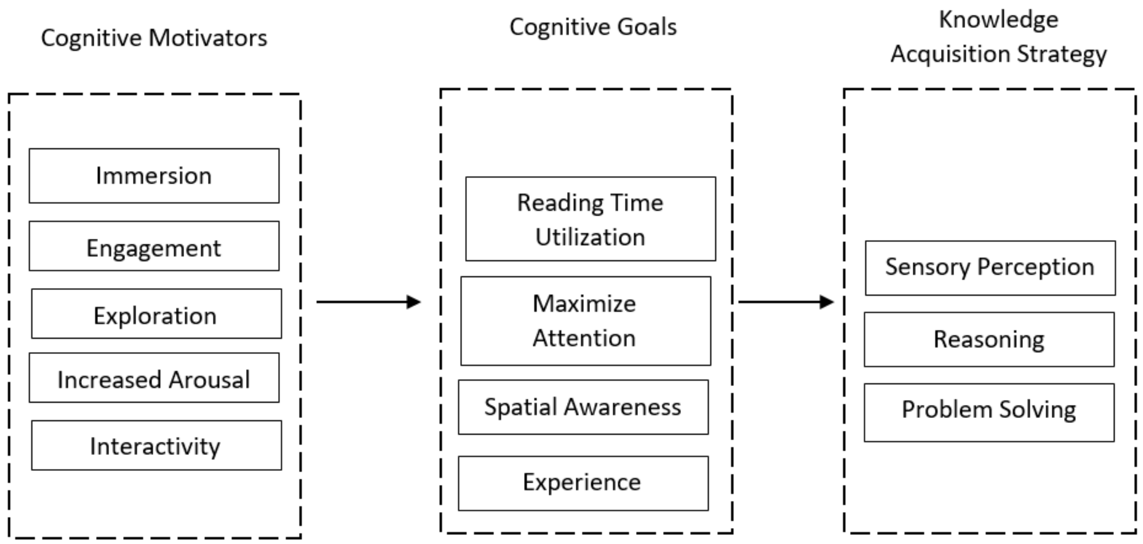


Figure 1.1: VR conceptual knowledge framework

1.2 Baddeley's model of working memory

The working memory capacity plays a significant role in cognition and spatial memory encoding. The cortical areas of the brain exhibit traits that affect low and high accuracy memory encoding, explained by Baddeleys working memory model [18]. Baddeley's model suggests that memory formation is achieved through three systems in the brain: Phonological Loop, Visuospatial Sketchpad and Episodic Buffer. The phonological loop is the part of the working memory that processes auditory information. It is composed of the phonological store which configures how information is assimilated, and the articulatory process which allows repetition. The visuospatial sketchpad provides the capacity to store, break down or modify visual information. Nonverbal intelligence can be measured through the use of the visuospatial sketchpad. Episodic buffer is capable of binding visual and auditory features from the working memory in a multidimensional code. The study by Teramoto et al. cited that spatial information stored in the episodic buffer can be accessed and retained for a longer period.

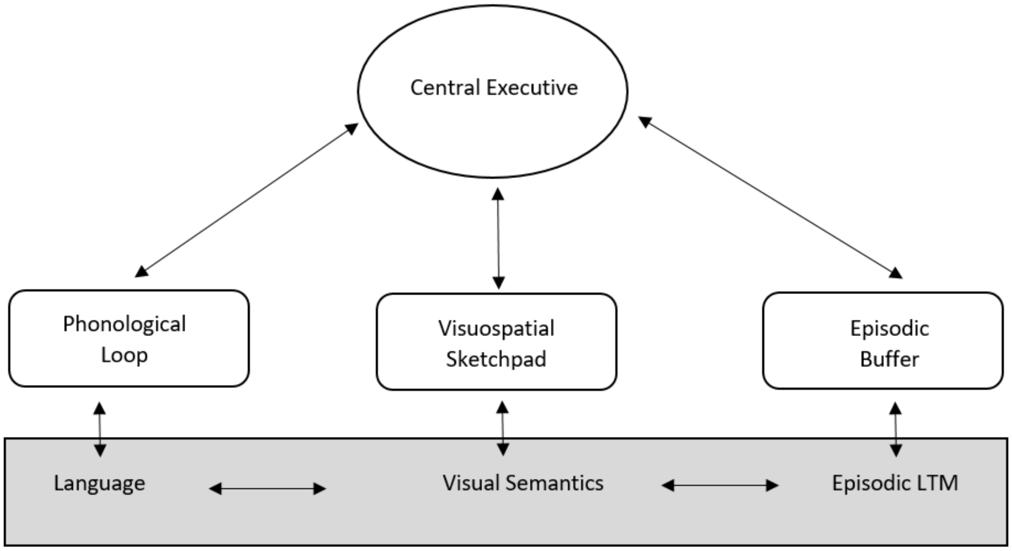


Figure 1.2: Baddeley's model of working memory

Some studies might exempt certain age group from VR related studies as improper memory encoding is linked to age-related diseases that affect one's ability to recollect information. Cognitive load is the mental load exerted on a subject while executing a task and is largely influenced by the capacity of the working memory to process information derived from the task. After a certain threshold, high cognitive load reduces learning performance and user effectiveness [5]. The subject's cognitive capacity affects their interaction hence measuring individual's cognitive loads helps to determine their effectiveness in a task. There are ways to go about measuring cognitive load: during or after task flow. Measuring the load after interaction is better than during interaction, as interruptions may occur that break the subject's focus.

Over-arousing or over-engaging virtual experiences can be used to get an idea of the user's level of cognitive load limit.

1.2.1 Dual-task design

The Dual-task design paradigm requires that two separate tasks are performed at the same time, and is used in Psychology to exert cognitive load. The high mental demand imposed is due to the limited capacity of the working memory and the load from focusing on one task and shifting to a different task, known as Interference.

Modality effect is seen in how secondary tasks are designed. If the cognitive load is more than the working memory can handle, learning is reduced. The bottleneck is the limitation of the working memory, and a productive learning approach involves mastering the bottleneck [5]. The Dual-task approach is used to measure cognitive load when in studies of Modality Effect.

Certain speech-based dual tasks prompt a speech pause, a useful indicator of high load versus low load scenario. A pause could be silent or filled, and it gives the subject more time to analyze, reflect and construct an appropriate response. The pause time is used to regulate information processing, and therefore, manage cognitive load [8].

1.3 Sustaining User's Attention

Emotional and mental states are important considerations in the learning process. According to Psychology, subjects may get to a level of attention known as flow state, a mental state in which one is fully focused, immersed and involved in the task, accompanied by loss of the sense of space and time. Not to be confused with hyperfocus which is an intense, conscious effort on a specific task, with the intent to remove every surrounding distraction, which in psychiatric cases, often results in an inability to mentally switch to a different task. The goal of a learning strategy should be to get the subject into a comfortable flow state.

2 Background

Virtual reality is going to keep changing as new technologies are developed and developers identify the improved affordances of VR that enhance virtual learning experiences. Virtual environments provide a realistic way to experience the world around us in natural progression and are created by applying dynamic/static variables to models that represent complex real-life processes. Recent research found that improving the user's level presence and engagement [3] improves the learning outcome. However, VR is not a perfect recreation of the real world, and comes with its own psychological and physiological shortcomings. Psychology studies have shown that humans learn in different ways from visual, aural, verbal, physical, logical or social cues. A study conducted years ago postulated that emotionality affects conceptual learning and that memorization can reflexively occur in a state of emotional arousal [14]. Our study focuses on learning in a virtual space that requires mental processing of cognitive information and the environment's spatial layout.

The Cognitive Learning process is a complex cycle of voluntary and involuntary actions that affect reasoning, experience and the sensory systems [4]. The practical applications of VR in experiential learning allows us to explore the complexity of the human memorization process and learning in general. The immersive experience it provides through real-time interaction, engagement, spatial awareness, visual representations, and media richness makes it a viable option for experiential learning.

2.1 Space Perception

Spatial cognition is defined by distance, depth and space perceived through visual and somatosensory information [17]. We orient ourselves relatively to objects or based on object-to-object layout. The first is referred to as egocentric orientation while the latter is allocentric orientation. Egocentric perception is how one perceives other objects with respect to one's position and orientation while allocentric perception of a space is the ability to find relative positions of objects to one another in space. In a study to assess egocentric spatial cognition in a VR Environment, no learning effect or short-term memory influence was found [2]. The experiment involved a symmetric, three storey virtual house with 24 windows, one of which is marked as the objective window through a pseudo-random sequence. The participants were tasked with walking the minimum possible distance to reach the targeted window. They found a linear trend between age and performance error, with younger participants performing better.

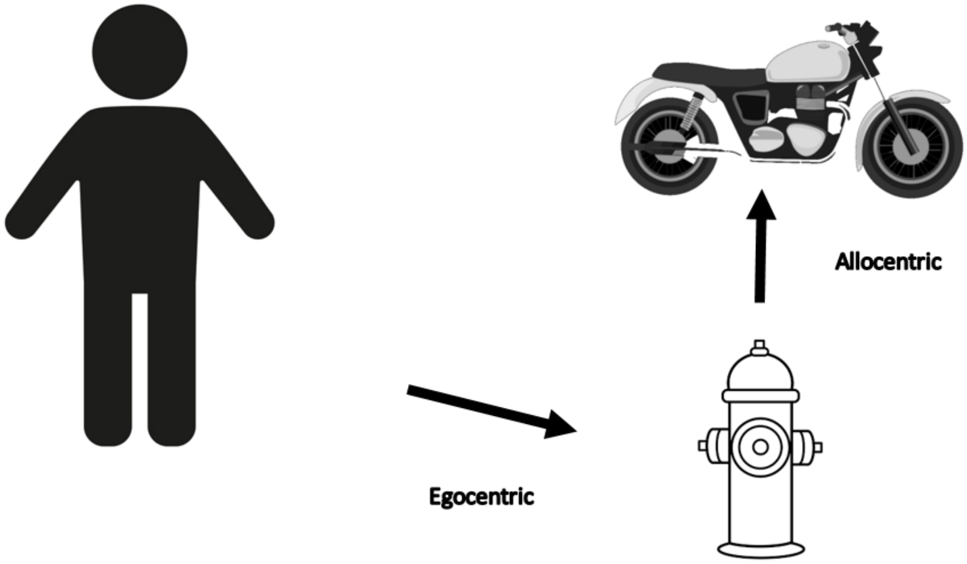


Figure 2.1: Space Perception in VR

2.2 Path Integration

VR simulations are known to cause mild to severe motion sickness and spatial disorientation [13]. Extensive pre-experiment training is often used to compensate for intuitive spatial reasoning. Riecke and Wiener proposed a rapid point-to-origin paradigm [15] in their study to reveal qualitative errors in visual path integration. They eliminated visual cues and navigation markers from the virtual environment and observed dependency solely on innate cues such as vestibular, proprioceptive and kinaesthetic cues. In their discussion, they referred to a previous study where head turn was expected to follow visual stimulus. Turners used an egocentric strategy while non-turners used an allocentric strategy. They asserted that when a physical response such as pointing, or movement is expected; visual cues or location markers should be provided in the virtual environment. Another approach to improve performance is to extensively train users on the task.

2.3 Navigation Locomotion

2.3.1 Natural Walking

Motion-based virtual systems seek to maximize naturalness to provide an optimal immersive experience. It's impossible to traverse an infinite virtual space in a finite physical space. A user responds naturally to locomotion in VR as in the real world, hence, if the virtual world mirrors the natural world, the user requires minimal training. The limitations of physical space has inspired hardware based movement devices for VR such as the Teleportation, Virtuix Omni treadmill, and hybrid control systems that mix natural movement in a confined space with virtual maneuvering. Human cognitive resources are finite and shared between perceptual tasks, which have different processing loads.

An experiment investigated the implication of simultaneous cognitive processing of spatial and verbal tasks with semi-natural virtual locomotion [11]. Participants were placed in one of three interfaces: using a Logitech Wingman gamepad, P2V interface, real walking movements around C6. Their results indicate that spatial and verbal tasks compete for the same cognitive resources.

Natural walking generally provides the most immersive experience in VR, although, it is not the most feasible way to explore virtual spaces. To that end, walking is one of the few natural interactions possible. In most cases, connecting the input mechanism to a specific sensory system can make an otherwise unnatural experience, immersive. A suspended hoverboard interface was designed for short and long distance exploration in virtual reality [16]. It provided the user with a corresponding proprioception that is consistent with the perceived movement. The key is to involve the users body in the interaction sequence, providing vestibular perception/feedback. Modern alternatives such as redirected walking, arm-swinging, and treadmills intuitively include the user's body in the experience.

2.3.2 Teleportation

One of the shortcomings of VR is the inability to explore the limitless virtual space in a limited walking space. Teleportation is a mechanism that allows a user to be transported from one position to another without the use of natural locomotion. When users do not ”own” their movement, their perception of the space is often off. This might be attributed to the illusionary nature of teleportation and for the same reason , users often report feeling motion sick. While an instant change in viewpoint without continuous optical flow might reduce the possibility of motion sickness, it limits the user's ability to integrate their path. The resulting spatial disorientation could be due to inability to estimate a relative distance from transitions or the realization that the experience is cognitively unrealistic [10]. Certain VR experiences might find a less realistic interaction desirable, in light of changing an event context e.g. driving a flying car. Simulating a realistic scenario on the other hand requires closely realistic interaction.

A study [12] focused on scene transitions in which users did not have control of their movement or view change. The goal was to find out which of three transition techniques users were more spatially aware or motion sick. The techniques were teleportation, animated interpolation, and pulsed interpolation. Teleportation involved an immediate change of position. Animated interpolation allowed users to observe their state change as it occurred, and the pulsed technique provided sequences of viewpoints during the transition from the start to target state. 50% of the participants in the first phase of the experiment preferred to teleport instantly. Animated interpolations was better for spatial awareness as participant could track their view changes but its downside was the unpleasant feeling of motion sickness.

When confronted with the precarious task of getting around a large virtual environment in a confined walking space, teleportation makes sense. But until spatial memory can keep up with the pace at which narratives occur during teleportation, without its lingering side effects, a safer alternative is to limit the spatial space to what the natural senses can explore and recall.

2.4 Time-Perception

Not much study has been done on time perception differences between VR and real life. Our research is not studying time perception in VR, but since we expect to see elapsed time difference in our between-subject conditions, we thought it might be interesting to understand how users perceive time VR. A study evaluated time perception during walking motions [1] and found that the discomfort and complexity of worn VR gears could influence time judgment. In a pilot study where subjects were tracked via a WorldViz PPT-X4 tracking system, and walked around at their own pace in the direction of a visual target, subjects were found to overestimate time by 4.2%.

The results show that how time is perceived in VR is connected to motion perception. Psychology experts would agree that tau and kappa effects[7] are phenomenons that occur through time and space perception.The brain estimates time based on internal biological, physiological events or external stimulus from the environment [7]. *Tau effect* affects spatial judgment of a layout due to time variation between spatial markers i.e. time it took to get to marker one is different from time it took to get to marker two. On the other hand, *kappa effect*, more pronounced through visual stimuli, is a temporal perception based on sequential sensory stimuli experienced at different location i.e. the experience at marker one was longer than the experience at marker two. More studies need to explore the area of time perceptionin VR to reach a cohesive conclusion.

2.5 Terminologies

2.5.1 Involvement

Ontologists describe involvement as mental participation [19] rather than inclusion i.e. being involved with the lecture rather than just staring at the Professor.

2.5.2 Engagement

Engagement is a voluntary choice to direct one's attention on a task e.g. engaged in a movie rather than just sitting in the audience. [19].

2.5.3 Immersion

Immersion is an experience provided through the stimulus modalities in a space. For example, someone watching a horror movie without sound and someone else watching the same movie with sound will be immersed differently.

3 Implementation

3.1 Study

The purpose of our study is to investigate how navigation and teleportation techniques affect a user's cognitive and spatial information processing ability in VR. Subjects are placed in one of four between-subjects conditions:

- Long Teleportation
- Long Walk
- Short Teleportation
- Short Walk

3.2 Setup

3.2.1 Oculus Rift S

The Head-mounted display is a sensorless PC-powered gaming oculus headset. It has a screen resolution of 2560 x 1440 and a refresh rate 80 Hz. It delivers high quality imagery and blocks see-through light.

Figure 3.1: Oculus Rift S Head Mounted Display and Controllers

3.2.2 VR Backpack PC

The CPU is a MSI VR One Backpack PC with Intel Core i7-7820HK and NVIDIA GeForce GTX 1070 graphics card.

3.2.3 Play Area

The play area is 18 by 13 feet of free walking space. The virtual cemetery perimeters correspond to the available space in the play area and the subjects in a locomotion condition can walk freely in the virtual space. The headset is calibrated with a forward direction and floor position. The native guardian system which draws the boundaries of the play area size is turned off so that the virtual gates of the cemetery serve as reference boundaries.

Figure 3.2: Experiment Play Area Size is equivalent to SIVE Lab Walking Space

3.3 Methodology

3.3.1 Navigation

There are two ways the environment can be navigated:

- Long path: the user is presented with a choice of two farthest markers from their position.
- Short path: the user is presented with a choice of two nearest markers from their position.

Long path

The position markers are placed farthest away from the subject's current position. Those in the teleportation condition make large random instant jumps around the virtual environment, while those in the walking condition take long walks around the environment.

Short path

The glowing blue markers that specify the next position are placed nearest to the subject's current position. The path is sequential so that the subject follows one round of continuous walking pattern.

3.3.2 Locomotion

Natural Walking

The subject has full mobility to walk around the training and experiment scenes. They can squat, bend or reorient themselves however they choose. Natural locomotion means one walk can naturally, unconstrained, at the same pace both in the virtual world and physical walking space.

Teleportation

Subjects can move from their current location to another, by pointing the Oculus touch controller at a glowing blue position marker, which changes to a glowing orange and pressing the A button (right controller) or the X button (left controller). The subject is not allowed to take more than two steps forward, backward or sideways, and they can turn, squat or bend.

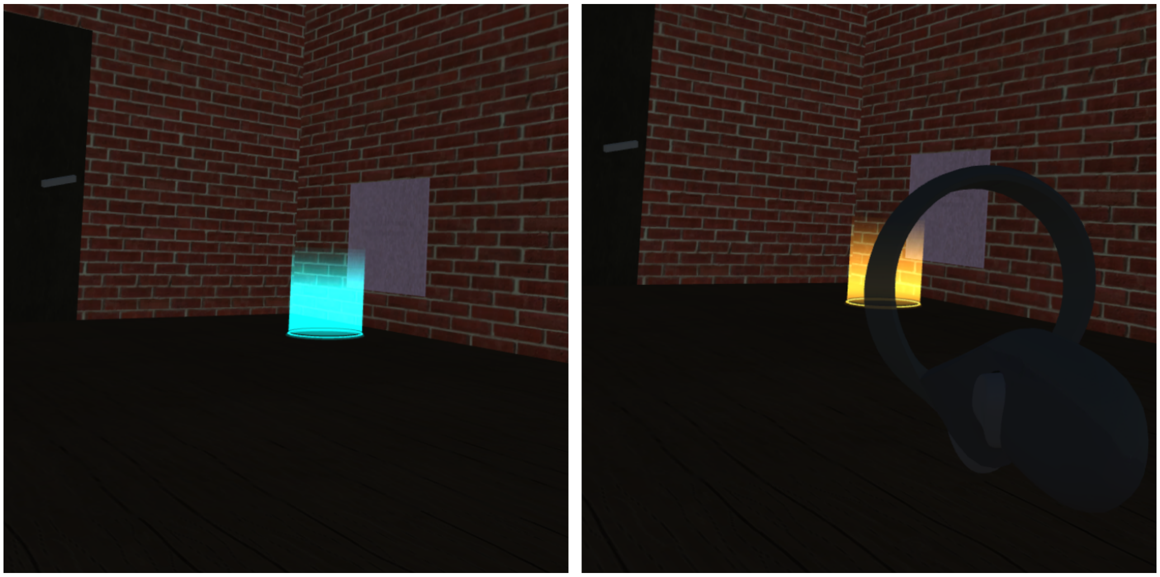


Figure 3.3: Teleport Marker changes from blue to glowing orange when controller is pointed at it

```
// Find closest tombstone
hitVec2.Set(hit.point.x, hit.point.z);
// checks if the tombstone hasn't been visited
// and location marker is turned on
if (tombPlanes[i].GetComponent<planeController>().visited == false &&
    tombPlanes[i].transform.GetChild(0).gameObject.activeSelf)
```

```
{
    // Highlight
    nearestMarker = tombPlanes[i].transform.GetChild(0).gameObject;
    nearestMarker.transform.GetChild(0).gameObject.GetComponent<Renderer
        >().material = halo.transform.GetChild(0).gameObject.
        GetComponent<Renderer>().material;
}


// To teleport
TeleportArea.transform.position = new Vector3(transformPos.x , 0.0f,
    transformPos.z); // This places HMD in front of Teleport Marker
```

3.4 Pilot Study

3.4.1 Subjects

We had 28 subjects in the pilot study with the age ranging between 20 - 53 years. Everyone reported feeling healthy before the experiment, and no one experienced motion sickness in the virtual environment.

3.4.2 Protocol

The subject is assigned a condition number drawn randomly from a deck of four cards. The random assignment is to reduce a cyclical selection bias which may arise from having subjects that arrive at a specific hour of the day e.g. morning, in a specific condition. An informed consent form is presented to the subject and a Pre-Experiment questionnaire. The training scene is run until the subject becomes comfortable navigating in the environment, and then, the experiment begins. When the experiment is over, the subject is provided with an environment cognitive assessment, and brought back into VR for a spatial recall test. After the recall, the subject does a recreation of the cemetery in a sandbox task. The final task is to complete a Presence and Experience questionnaire.

3.4.3 Training

The training procedure is similar to the experiment's for each condition. The training is designed to help the subject become familiar with the protocol of the experiment, whether it's walking or teleporting in short or long distances. It takes place in a virtual brick room with seven placards on the wall. When the unity scene starts, two blue glowing markers appear and subjects walk or teleport to one of them. The marker will disappear and in front of it is a placard with a block of text that becomes visible. Above the placard, a timer is displayed which counts down how many seconds is left until the block of text disappears. The subject reads out loud the text to the experimenter and continues on to the next placard until all placards have been visited.

3.4.4 Experiment

The experiment takes place in a virtual cemetery referred to as Spoon River. The cemetery is fenced and contains thirteen tombstones. Similar to the training scene procedure, the experiment starts with two blue glowing markers that light up in front of tombstones and the subjects chooses either one to go to. There is a character attached to each tombstone and when a subject walks up to one of the glowing markers, the character's name and story appears on the tombstone and a timer above

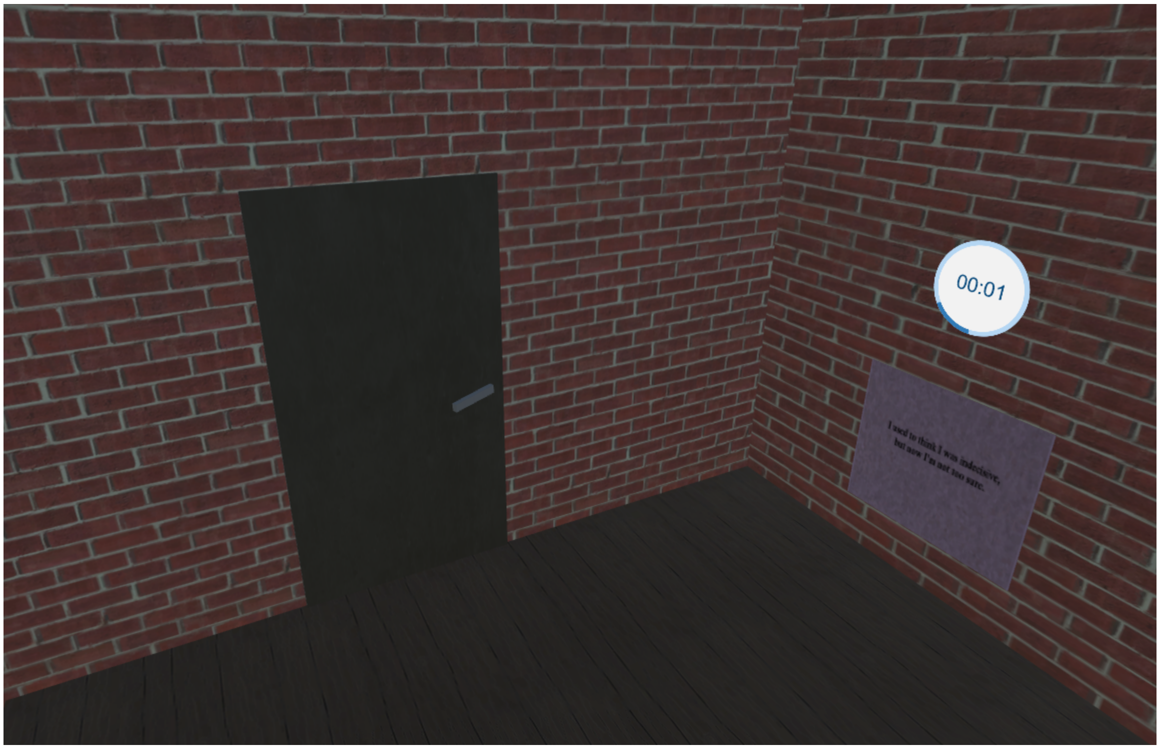


Figure 3.4: Training Scene with an activated countdown timer above a placard

it, with the time left until the text disappears. The subject is informed at the start of the experiment that they must pay attention to the environment and the story as they will be assessed after.

3.4.5 Spatial Test

A replicated scene of the experiment without any of the tombstones. Subjects are place in this environment to test their memory. They are asked recall from memory the position of the tombstones they had visited.

Figure 3.5: Experiment Scene - front view of Spoon River Cemetery

3.5 Subjective Variables

Some factors such as time spent or attention in the virtual environment are subjective and may or may not be due to the design of the environment. For analysis purposes, they will be measured and stored during the experiment.

3.5.1 Time Spent

Time spent is evaluated in minutes from the start of the experiment until the last tombstone is read.

3.5.2 Attention

Attention is a value evaluated for each tombstone visited by the subject. It is the percentage value of the ratio of time spent gazing directly at the current reading

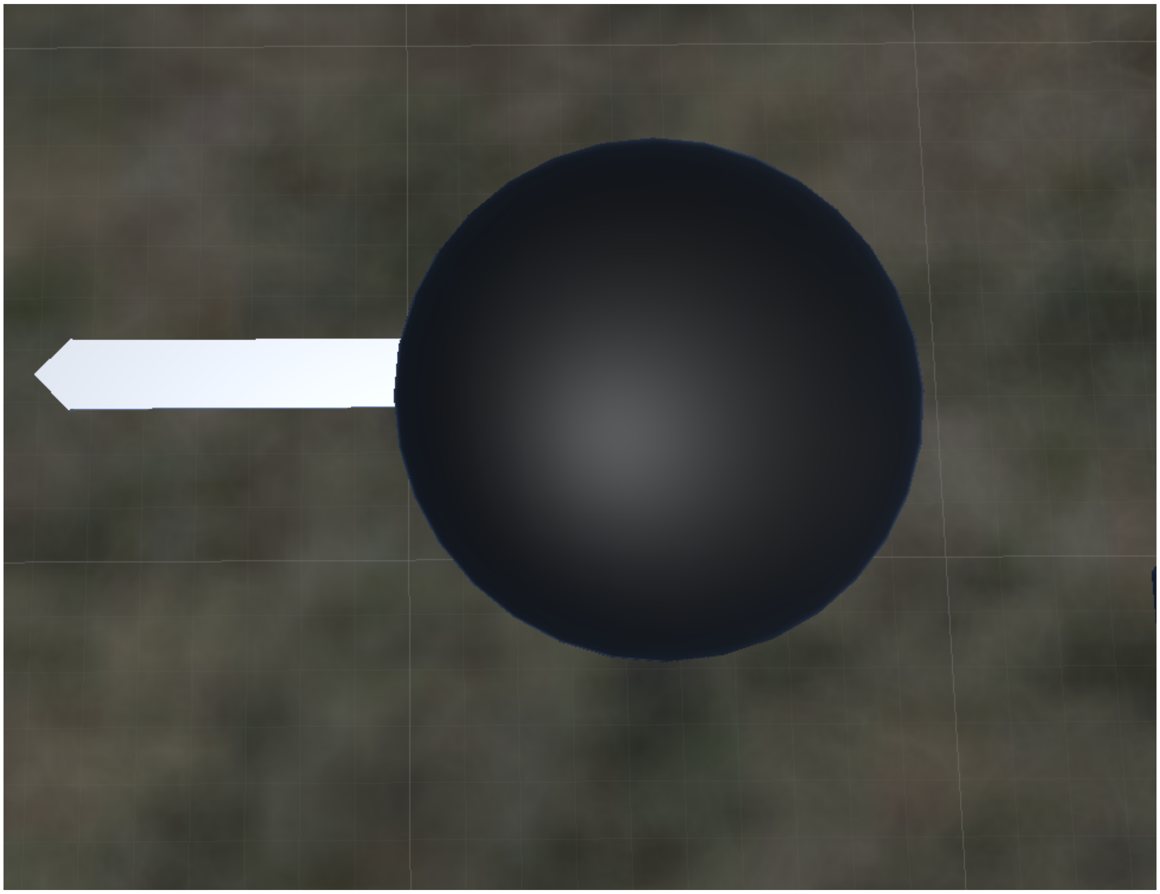


Figure 3.6: The compass arrow is rotated to point in a direction during the spatial test scene

tombstone divided by the total reading time.

attention = time eye gaze on current reading / total reading time * 100

```
void calculateAttention()
{
    frameCount = frameCount + 1; // updates frame count for as long as plane is active


    var camera = rails.GetComponent<RailsController>().player;
```

```

    ray = camera.ViewportPointToRay(new Vector3(0.5F, 0.5F, 0));
    if (Physics.Raycast(ray, out hit))
    {
        if (hit.transform.name == transform.parent.gameObject.transform.
           name) // checks if ray hits the current tombstone
        {
            hitCount = hitCount + 1;
        }
    }
    attention = hitCount / frameCount * 100;
}
```

3.5.3 Path Tracking

The path data is a 3D vector of the x,y,z-coordinate of the subject's position at every fixed update. It is segmented into thirteen start-to-end sequences for each tombstone in the experiment. When the experiment starts, the path data until the first tombstone has been read is recorded as the first sequence. The next sequence is from the first tombstone until the next tombstone is read. The data is used to evaluate the distance moved by subject between tombstones.

3.6 Qualitative Assessments

Each subject is required to answer multiple choice questions, a spatial pointing task and a sandbox recreation of the spatial layout of the cemetery.

3.6.1 Environment Cognitive Assessment

Twenty multiple choice questions are asked of the subjects after the experiment. The questions are the same for all subjects and graded on a scale of 0 or 1.

3.6.2 Spatial Memory Recall

A recall memory test in which subjects go back to the entrance of the cemetery and are presented with a controller to move an arrow in the direction of a tombstone. The angle at which the arrow is oriented is recorded for each tombstone that needs to be recalled.

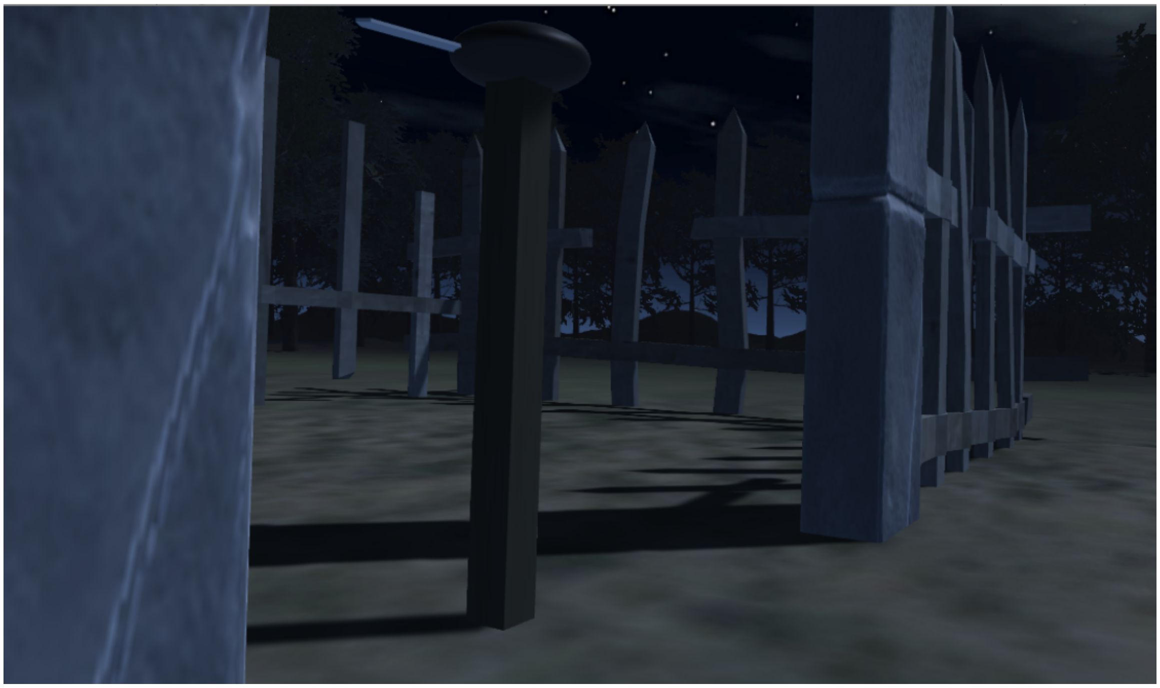


Figure 3.7: Using a controller, subjects perform a spatial recall test

3.6.3 Spatial Memory Recreation

Cardboard cutouts of the tombstones are presented and subjects recreate the spatial layout of the cemetery.

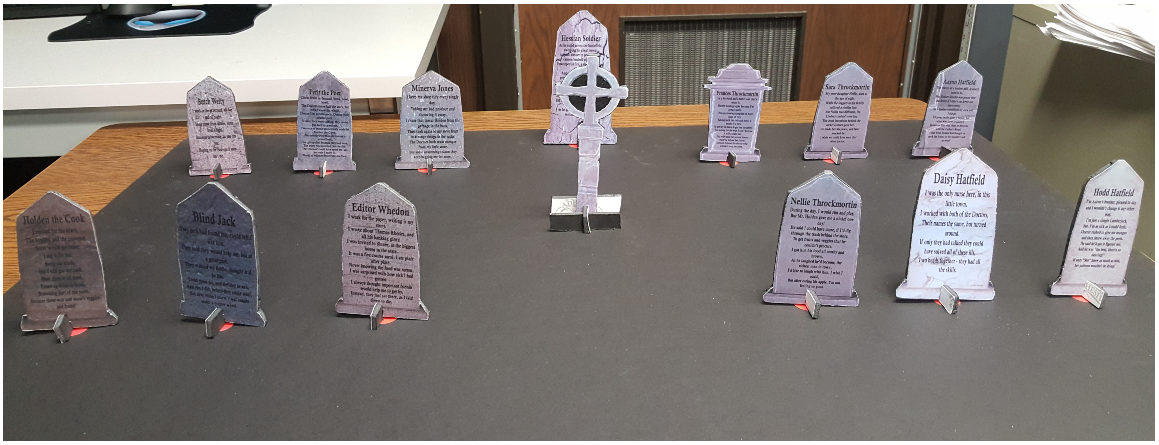


Figure 3.8: Sandbox measure is captured

4 Results

A total of 28 participant data was collected from the experiments. The first experiment data had some missing values that were excluded from some evaluations.

4.1 Environment Cognitive Assessment

The environment cognitive assessment is a set of twenty multiple choice questions asked of each participant after the experiment. The assessment is available in Appendix A. The breakdown of the average score in each condition is:

- Long teleportation : 11.63
- Long walking : 16.43
- Short teleportation : 15.43
- Short walking : 15.57

As expected, the long teleportation condition average score was the lowest. Most of the subjects in the condition scored below average. The other conditions have reasonably good performance with a number of long distance subjects scoring well above average. We analyzed the correlation between the assessment scores and other subjective variables that were recorded during the experiment.

Figure 4.1: Average scores in each condition

4.1.1 Performance and correlation to subjective variables

The r-value between the overall performance of subjects in the cognitive assessment and other variables are:

- Attention : 0.108

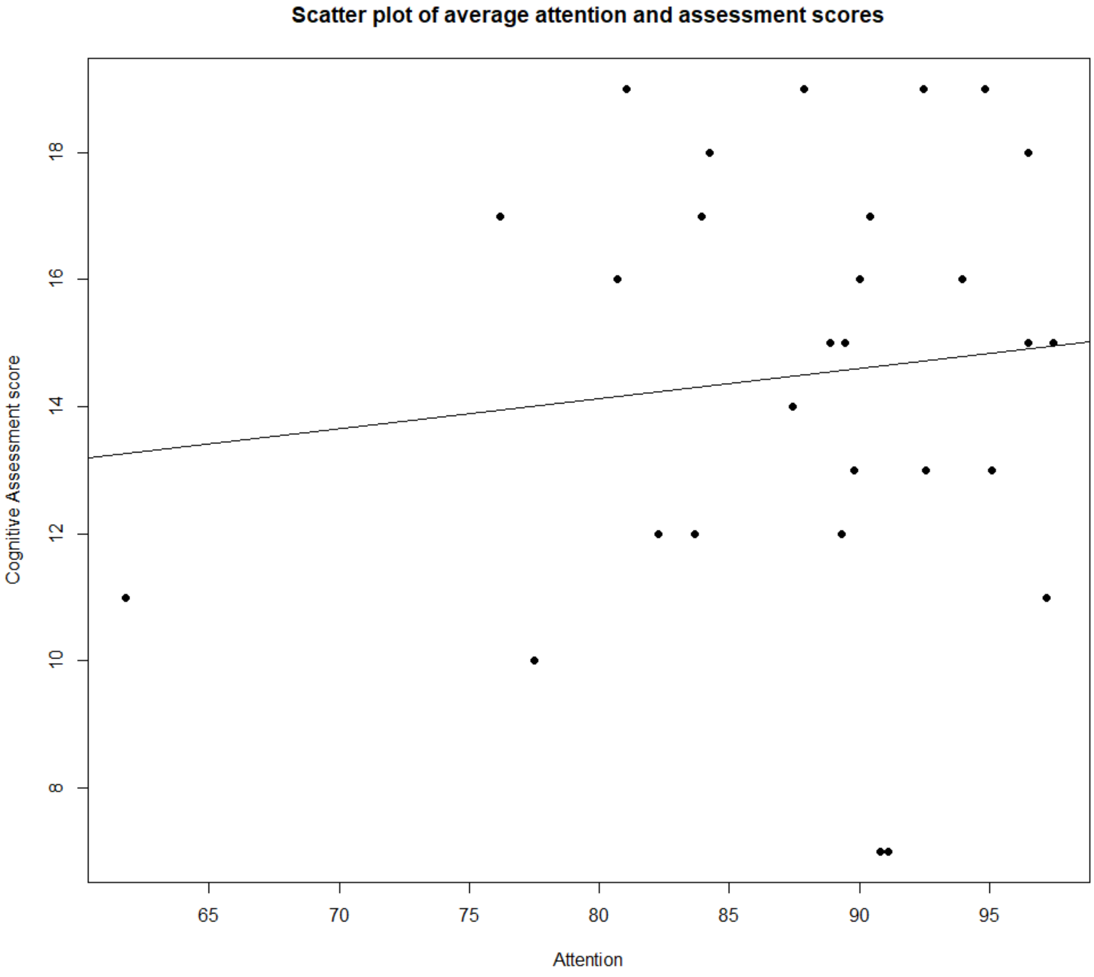


Figure 4.2: Correlation between Average Attention and Assessment Score

- Average distance : 0.118

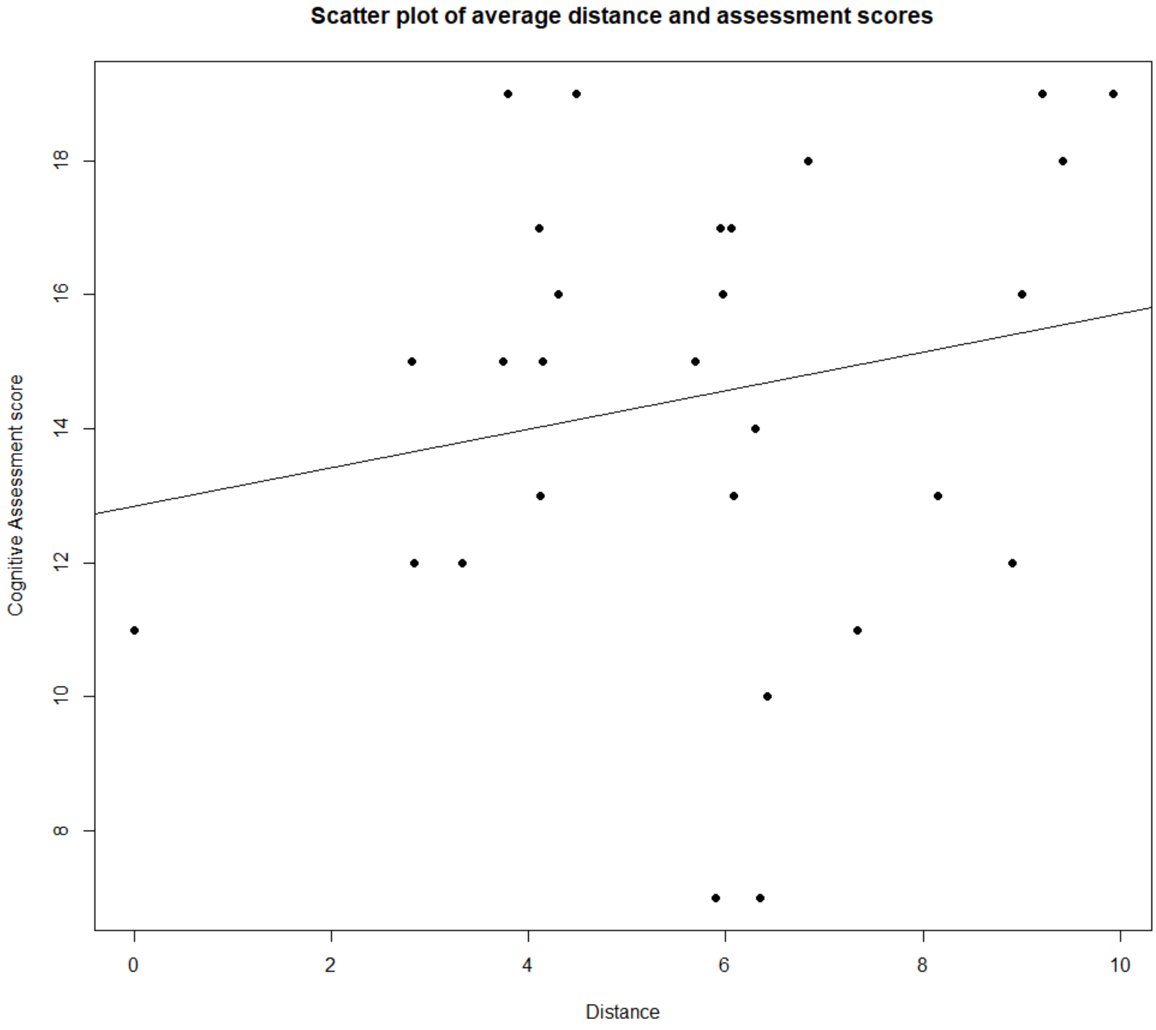


Figure 4.3: Correlation between Average Distance and Assessment Score

- Time spent : 0.212

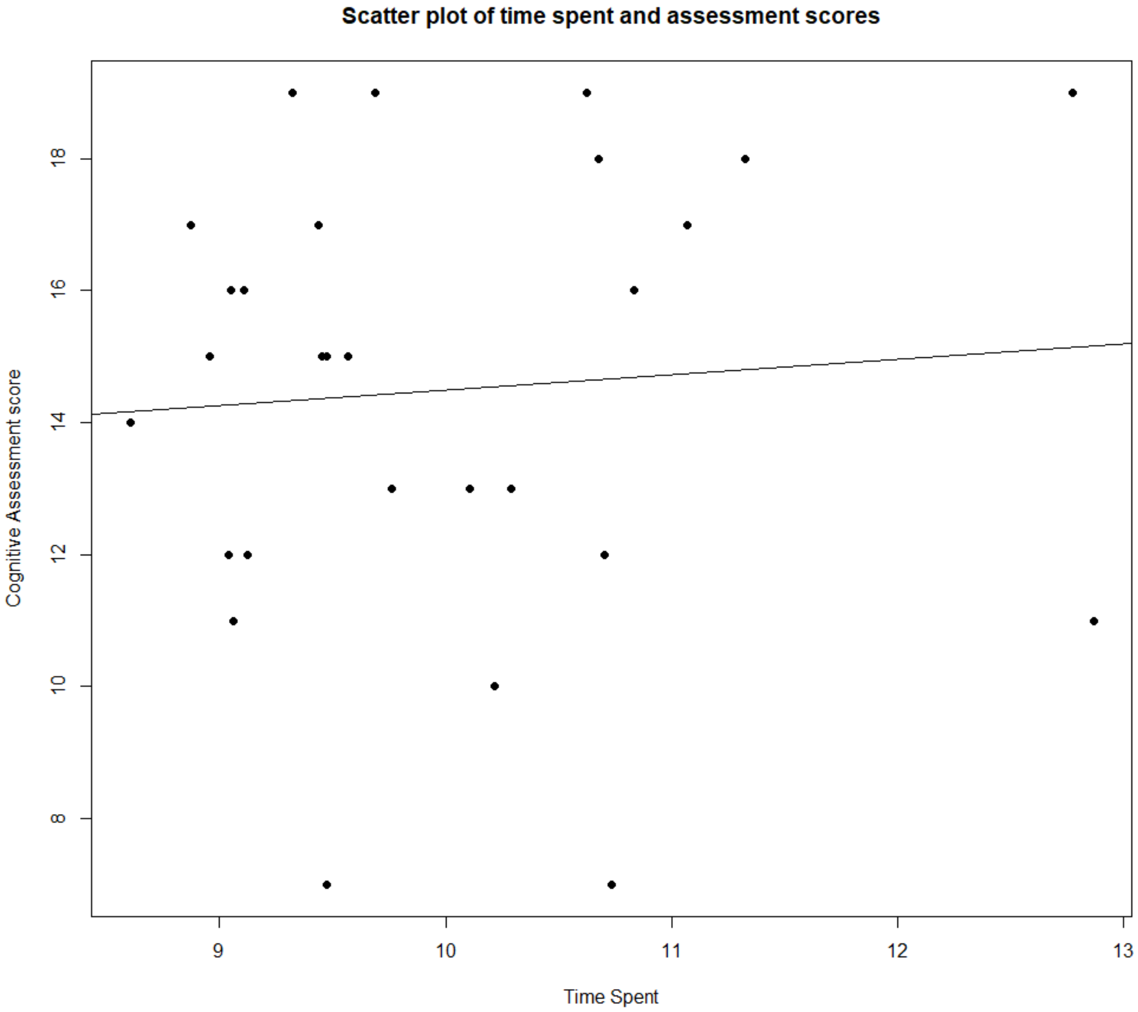


Figure 4.4: Correlation between Time Spent and Assessment Score

4.2 Spatial Recall Assessment

Subjects are asked to recall from memory the location of a tombstone in the cemetery. The name written on the tombstone is called, and the participant uses an Oculus touch controller to move an arrow in the direction of the tombstone with the

mentioned name on it. The error value is given by the difference between the angle of the subject's pointing direction and the actual direction of the tombstone from the default position. We calculated the sum of error difference for all tombstones visited by the participant and for each condition, we evaluated the spatial error percentage. The percentage accuracy is henceforth derived as:
spatial accuracy % = 100 - spatial error %

The breakdown of the average percentage accuracy in each condition is:

- long teleportation : 64.5%
- Long walking : 82.3%
- short teleportation : 73%
- Short walking : 80.2%

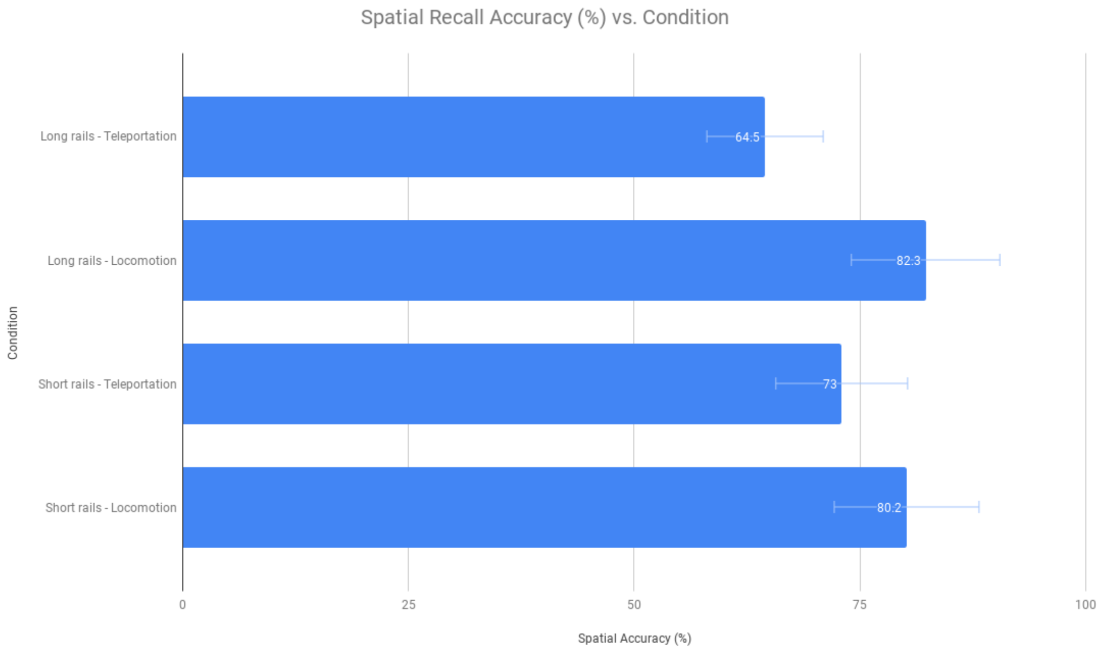


Figure 4.5: Percentage spatial recall accuracy in each condition

The long teleportation has the least accuracy and is again the condition with the worst performance. It's interesting to find that both locomotion conditions were the better performing conditions. The Long walking condition has the best accuracy for spatial recall.

4.2.1 Spatial recall error and correlation to subjective variables

The r-value between the overall spatial recall error of subjects and other variables are:

- Attention : 0.2

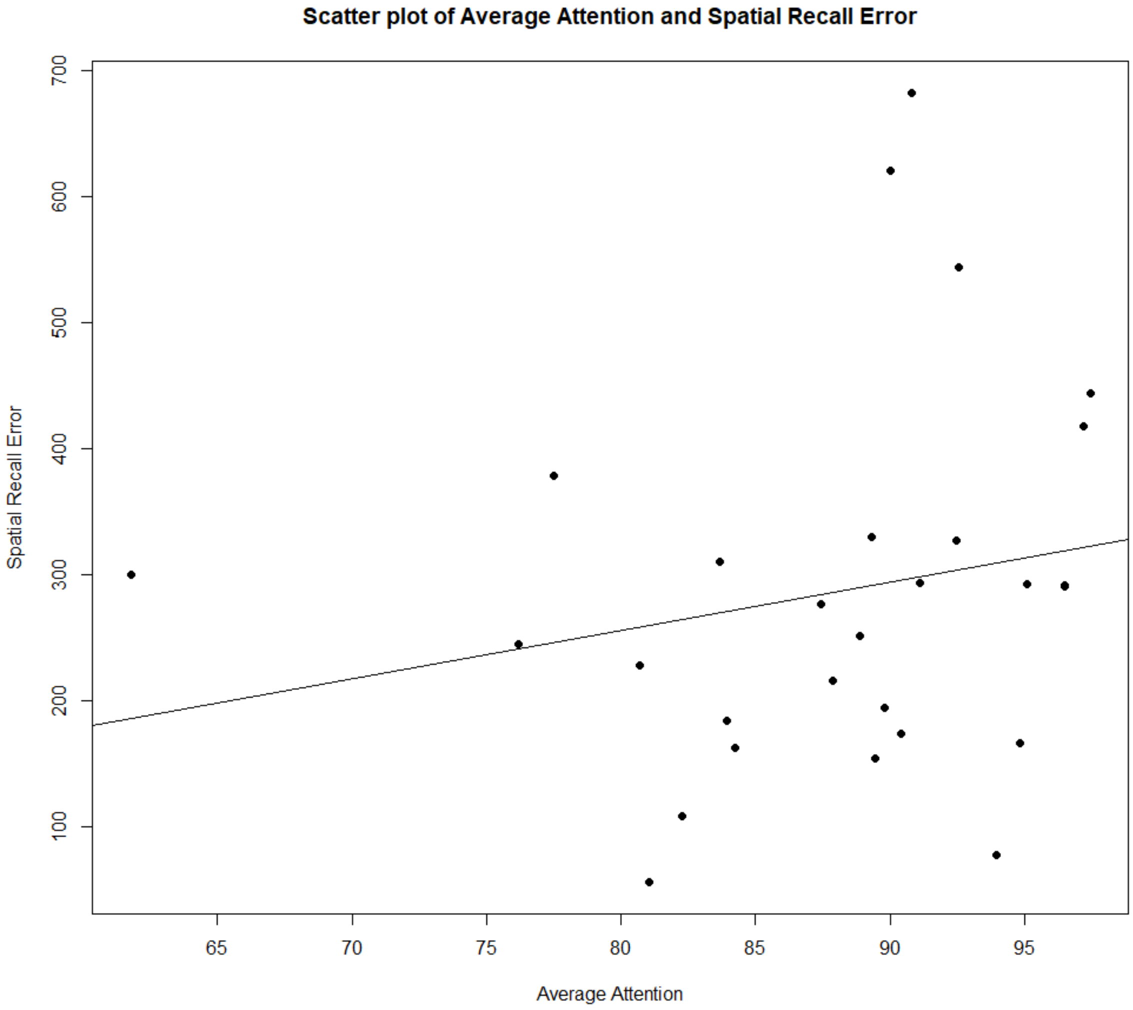


Figure 4.6: Correlation between Average Attention and spatial Recall Error

- Average distance : -0.234

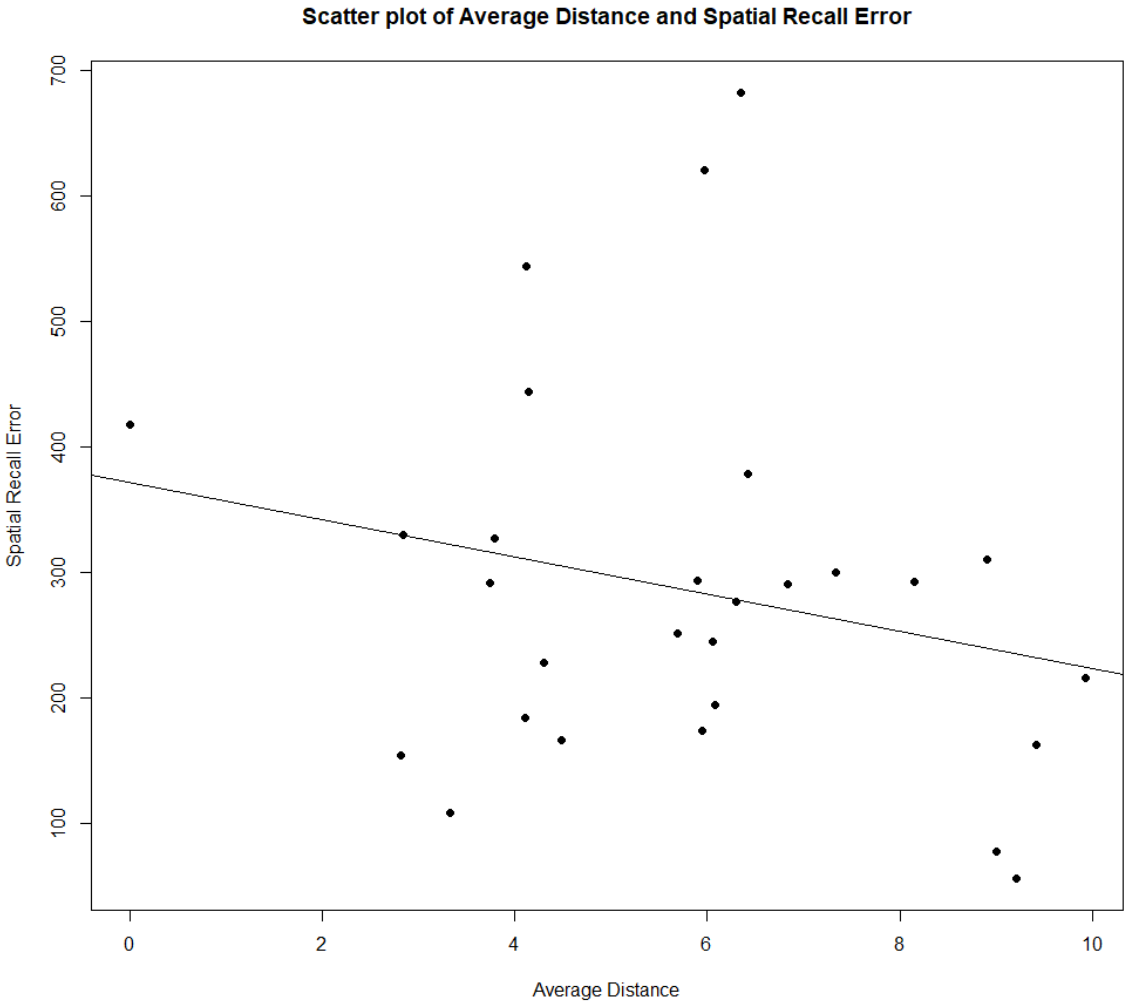


Figure 4.7: Correlation between Average Distance and spatial Recall Error

- Time Spent : -0.096

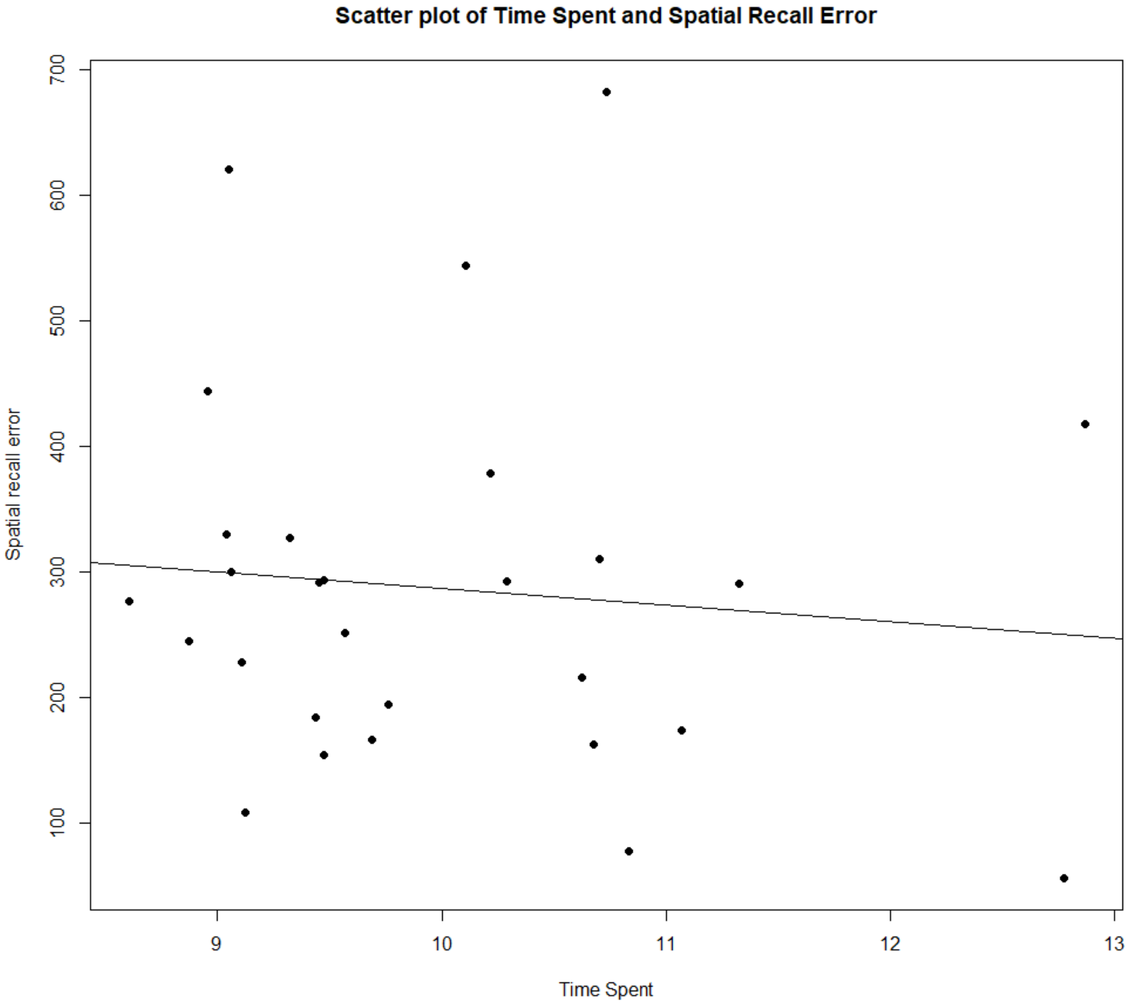


Figure 4.8: Correlation between Time Spent and spatial Recall Error

4.3 Spatial Sandbox Assessment

The assessment is an applied learning task in which participants are presented with a scaled cardboard cutout of the cemetery tombstones and asked to place them in their spatial positions marked by a red dot. If tombstone is placed in the right position, a value of 1 is given, otherwise the assigned value is 0.

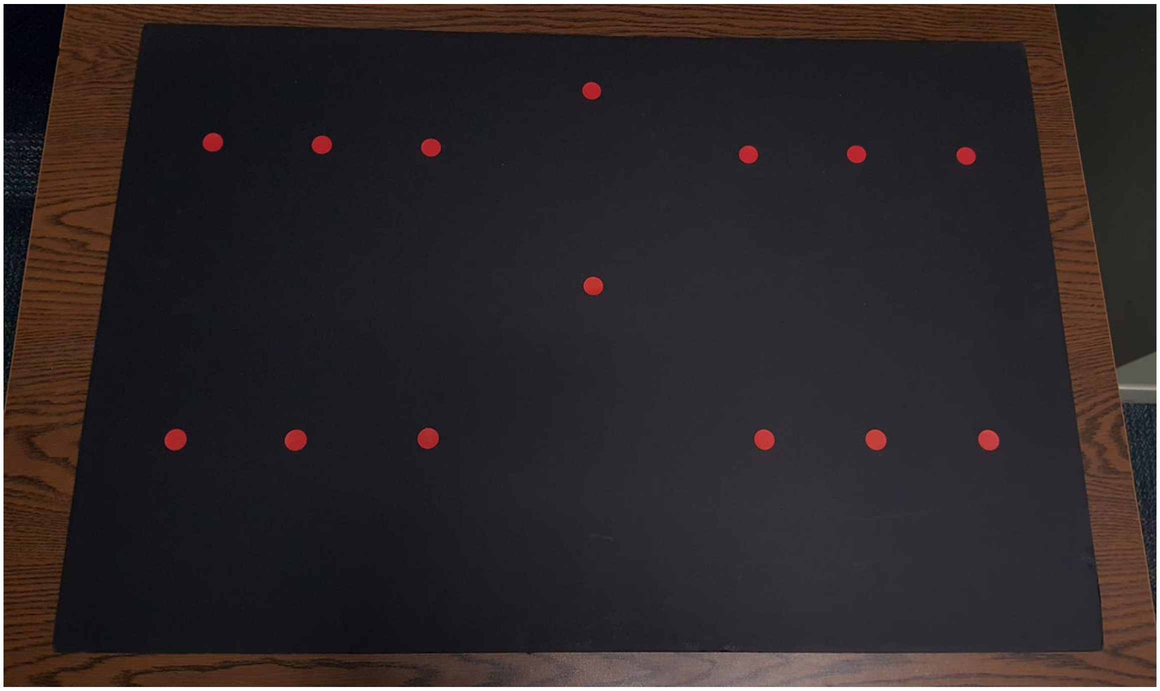


Figure 4.9: Participants place tombstone cardboard cutout on a red dot in sandbox task

The average scores of subjects from each conditions are:

- long teleportation : 4.29
- Long walking : 7
- short teleportation : 8.86
- Short walking : 7.14

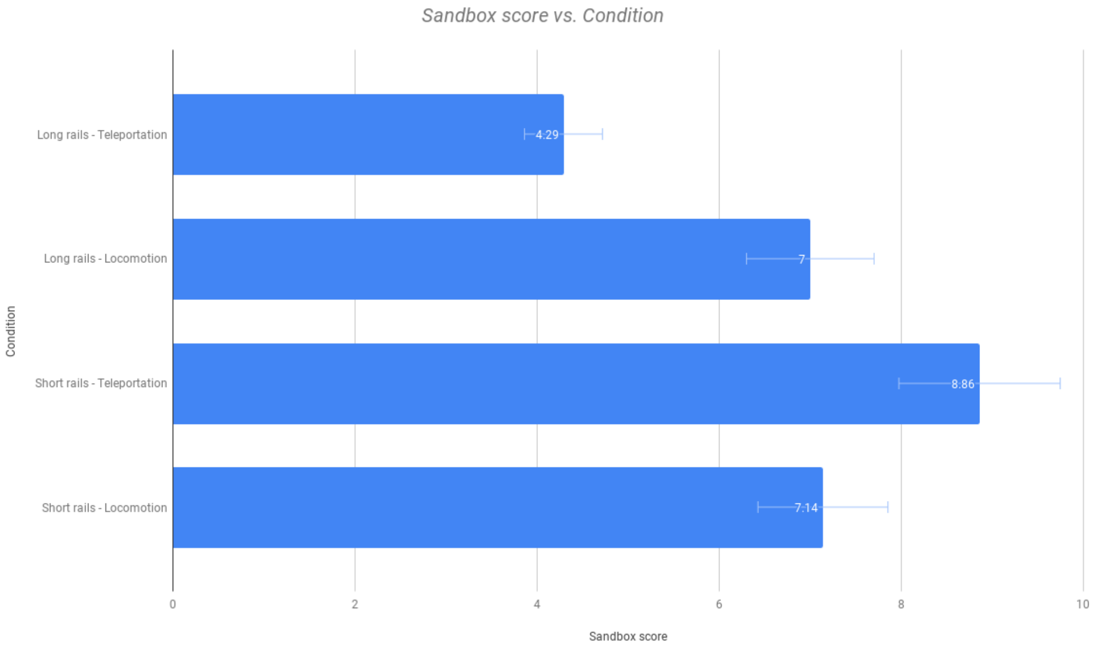


Figure 4.10: Average sandbox assessment score in each condition

It's not surprising that long teleportation condition once again has the worst average performance.

4.3.1 Spatial Sandbox scores and correlation to subjective variables

The r-value between the overall spatial sandbox scores of subjects and other variables are:

- Attention : 0.004

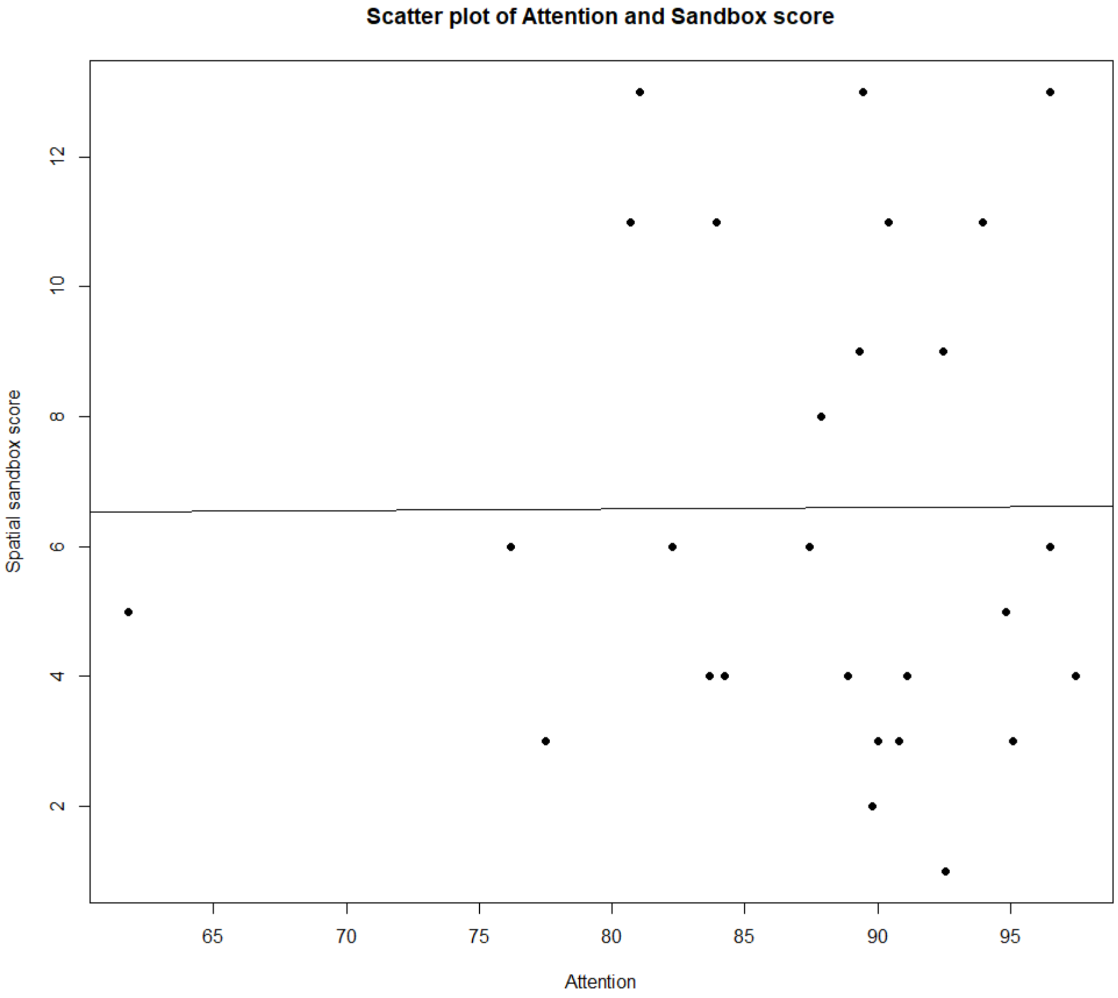


Figure 4.11: Correlation between Average Attention and sandbox score

- Average distance : -0.167

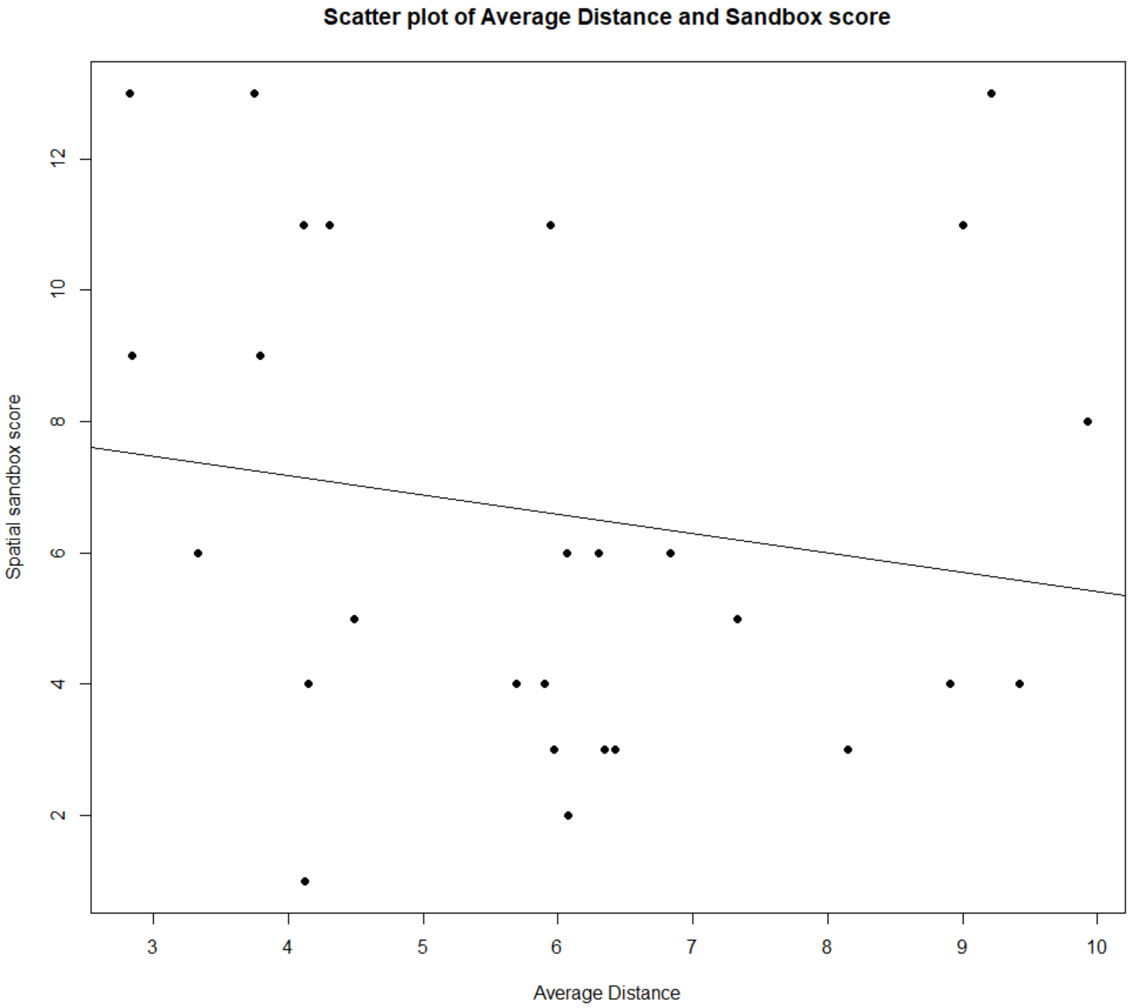


Figure 4.12: Correlation between Average Distance and sandbox score

- Time Spent : 0.153

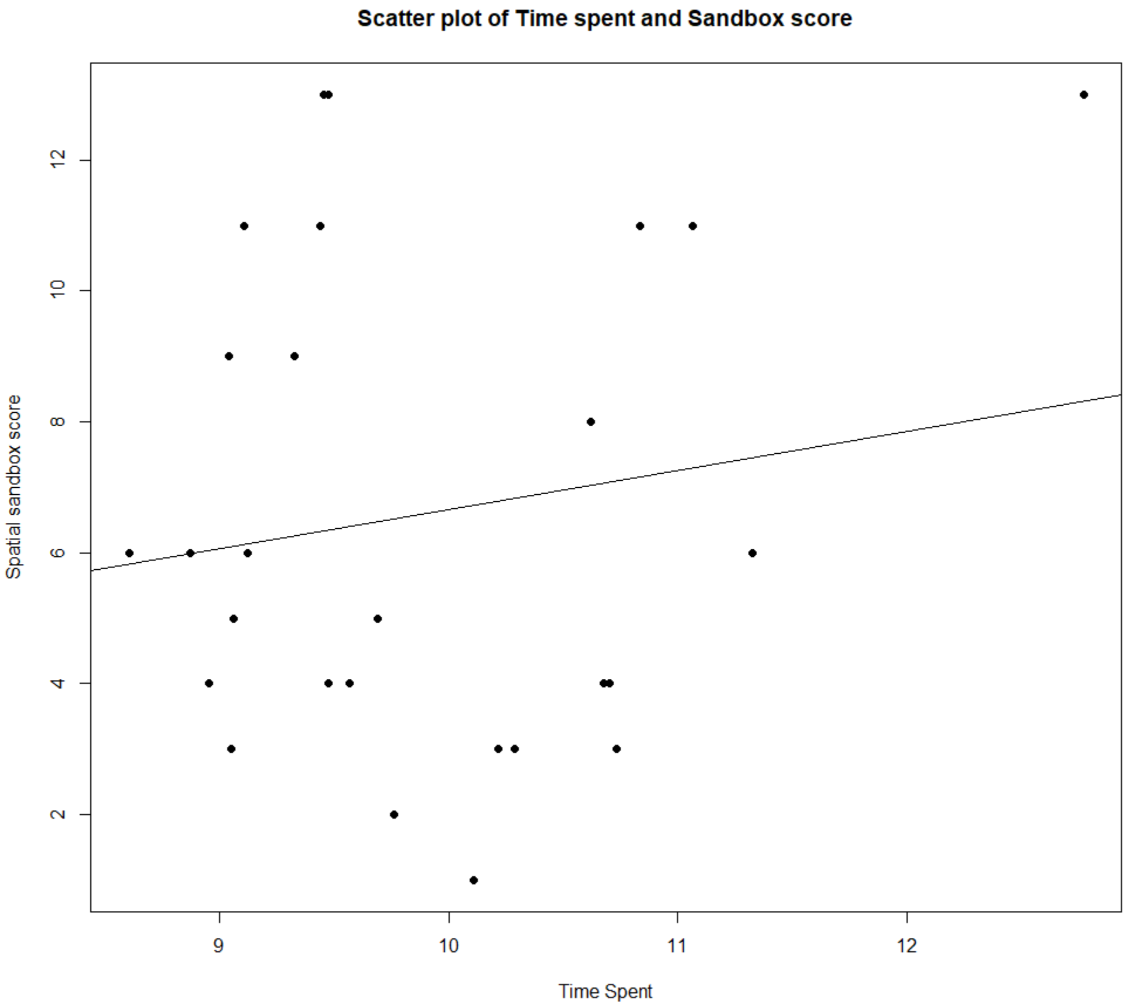


Figure 4.13: Correlation between Time spent and sandbox score

4.3.2 ANOVA : Single Factor between subjects analysis with repeated measures

The significance level (or alpha) is set to 0.05 for the ANOVA analysis and the factor is condition. There is no significant impact from the over average attention (SS = 184.55, df = 3, MS = 61.52, F = 1.02, P-value > .05, F crit = 3.01) but a very significant impact on the time spent in the environment (SS = 10.48, df = 3, MS = 3.49, F = 3.89, P-value = 0.021, F crit = 3.01) and distance (SS = 94.85, df = 3, MS = 31.62, F = 35.48, P-value = 8.49E-09, F crit = 3.03).

There is a significant effect of the condition on the cognitive assessment (SS = 100.86, df = 3, MS = 33.62, F = 3.77, P-value = 0.024, F crit = 3.01) and spatial accuracy (SS = 187332.30, df = 3, MS = 62444.10, F = 3.56, P-value = 0.029, F crit = 3.01), but no significant impact on the sandbox measure (SS = 55.4, df = 3, MS = 18.47, F = 1.4, P-value > .05, F crit = 3.03).

4.3.3 Other Correlation data

There were some missing pre-experiment data such as GPA, major, and academic year as some subjects weren't students. However, for the available data, we did some correlation tests and the results prove that there is no correlation whatsoever between the subject's age, GPA, VR experience, or gaming hours to their overall performance in the experiment.

4.4 Modeling Relationship between variables

An overview of the result from each assessment and other measures, is presented below:

Table 4.1: Overview of results between conditions

Path	Navigation Type	Cognitive Assessment	SR Accuracy	Sandbox	Avg. Attention	Avg. Distance	Time Spent
Long	Teleportation	11.63	64.5%	4.29	82.12	6.33	9.43
Long	Walk Locomotion	16.43	82.3%	7	88.92	8.78	11.03
Short	Teleportation	15.43	73%	8.86	90.52	3.99	9.68
Short	Walk Locomotion	15.57	80.2%	7.14	89.35	4.49	9.43

4.4.1 Estimated Marginal Means

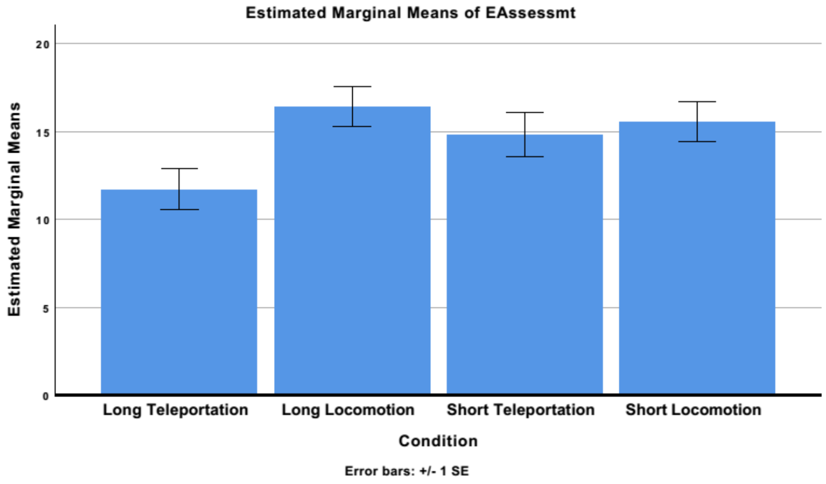


Figure 4.14: Estimated Marginal Means of Cognitive Assessment by condition

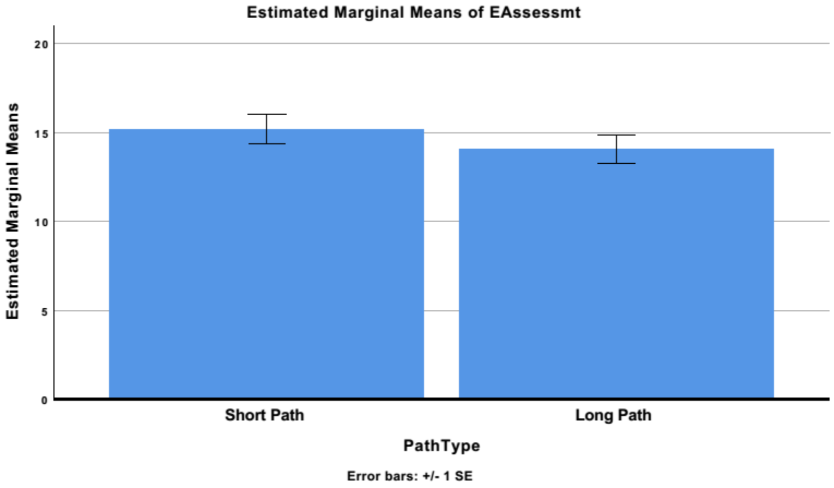


Figure 4.15: Estimated Marginal Means of Cognitive Assessment by path

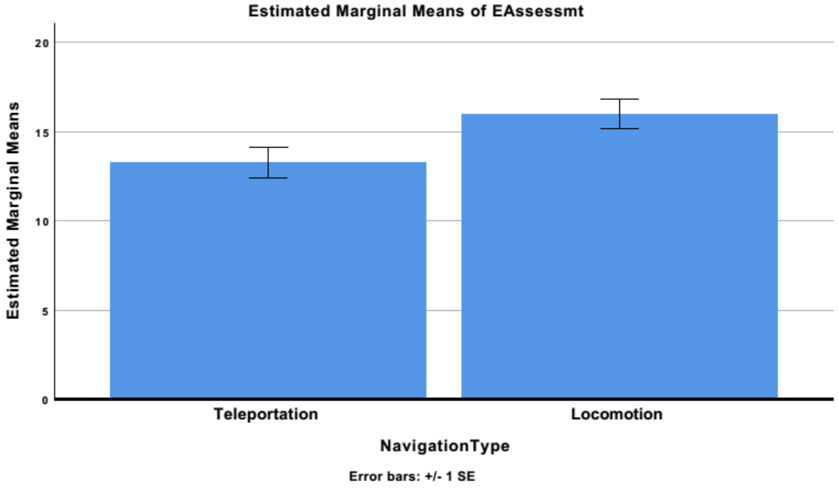


Figure 4.16: Estimated Marginal Means of Cognitive Assessment by navigation

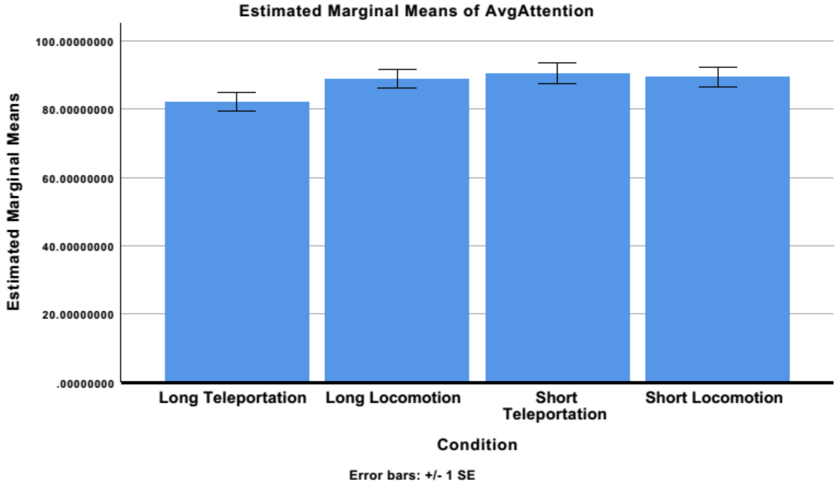


Figure 4.17: Estimated Marginal Means of Average attention by condition

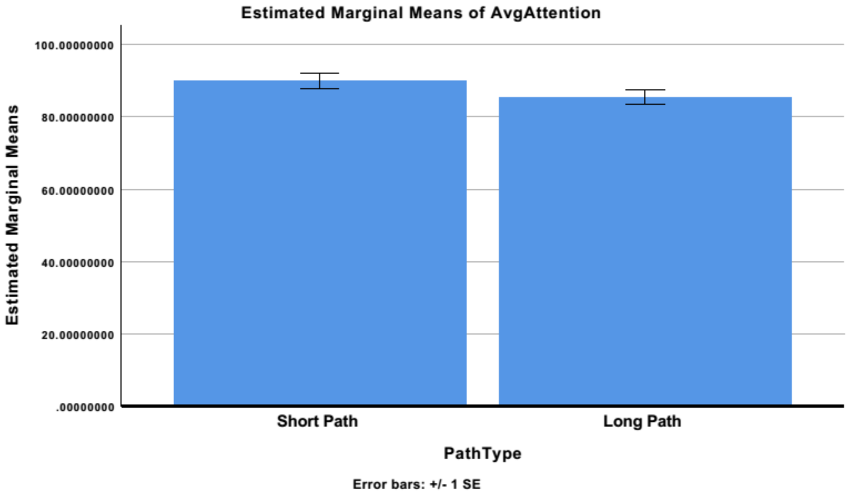


Figure 4.18: Estimated Marginal Means of Average attention by path

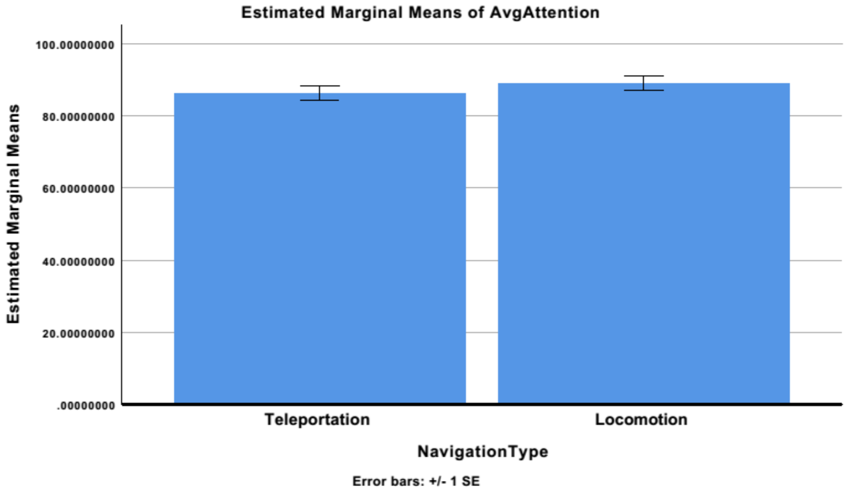


Figure 4.19: Estimated Marginal Means of Average attention by navigation

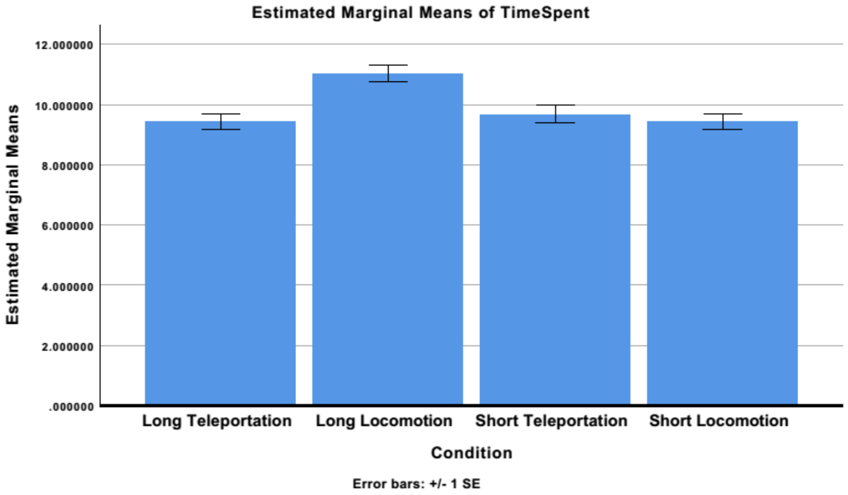


Figure 4.20: Estimated Marginal Means of Time spent by condition

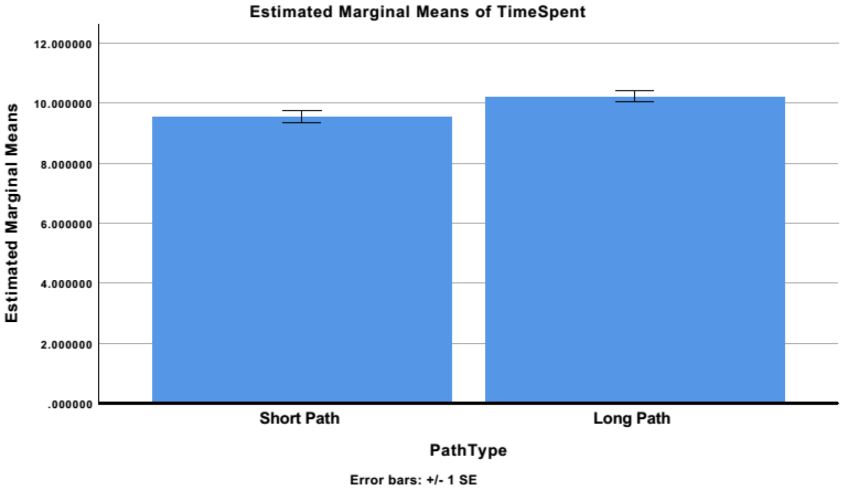


Figure 4.21: Estimated Marginal Means of Time spent by path

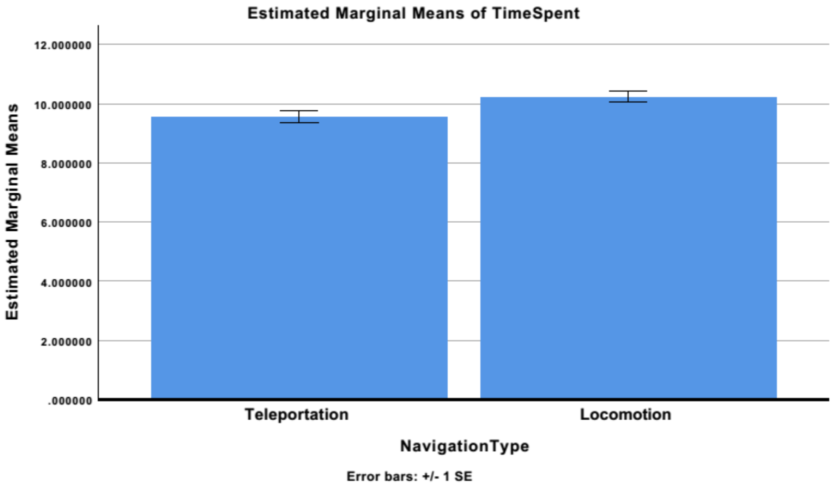


Figure 4.22: Estimated Marginal Means of Time spent by navigation

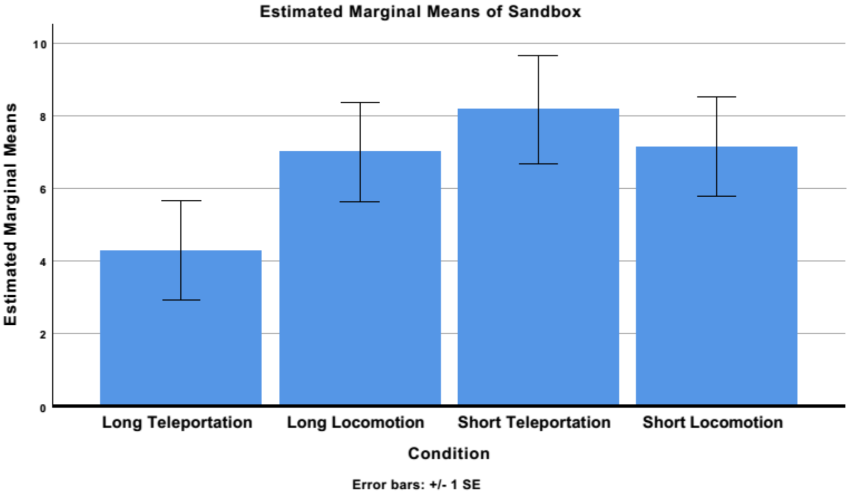


Figure 4.23: Estimated Marginal Means of sandbox score by condition

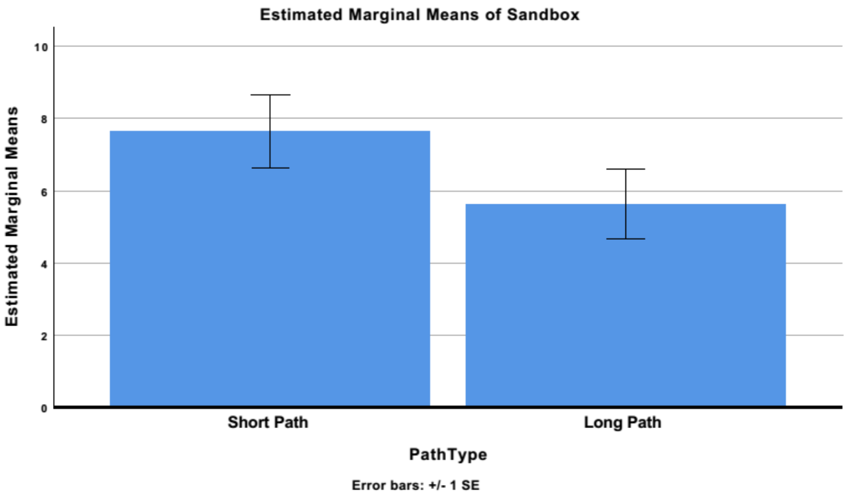


Figure 4.24: Estimated Marginal Means of sandbox score by path

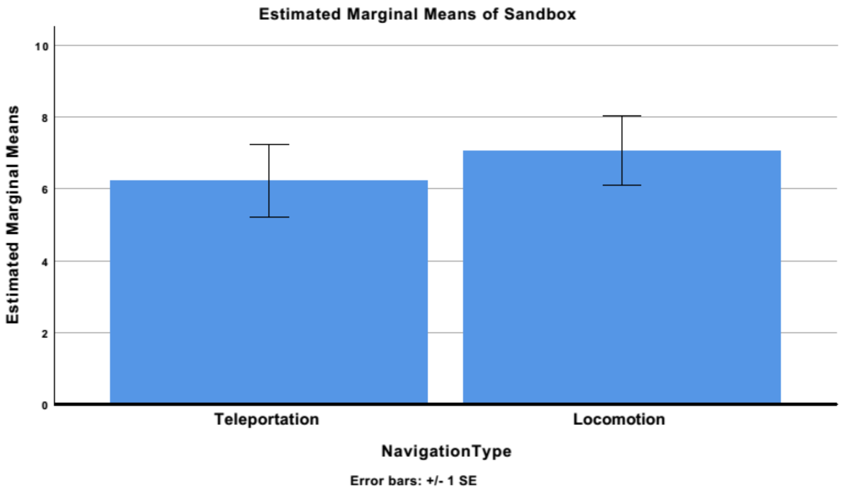


Figure 4.25: Estimated Marginal Means of sandbox score by navigation

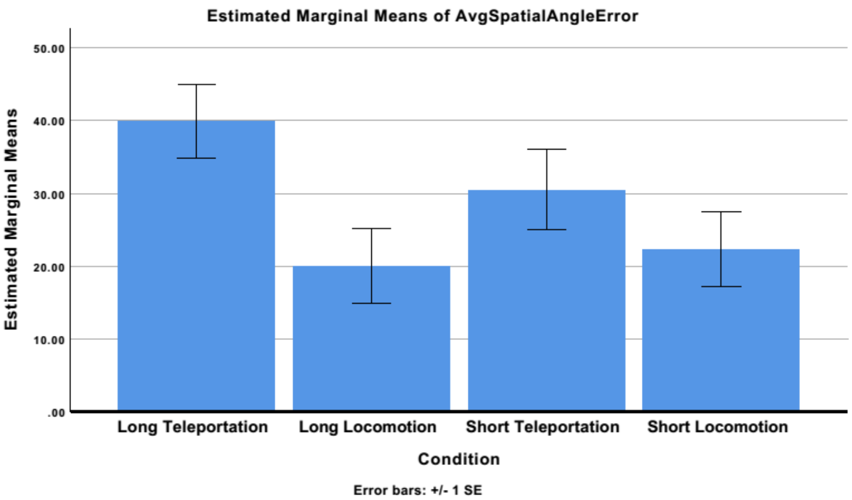


Figure 4.26: Estimated Marginal Means of spatial recall error by condition

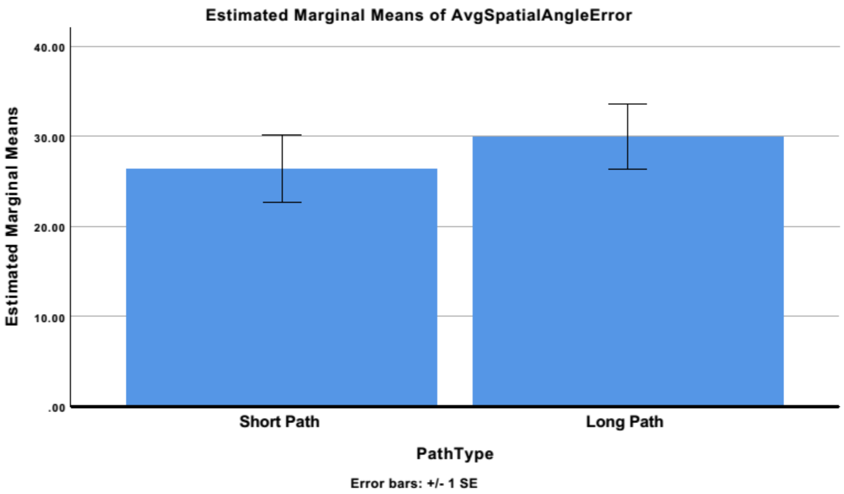


Figure 4.27: Estimated Marginal Means of spatial recall error by path

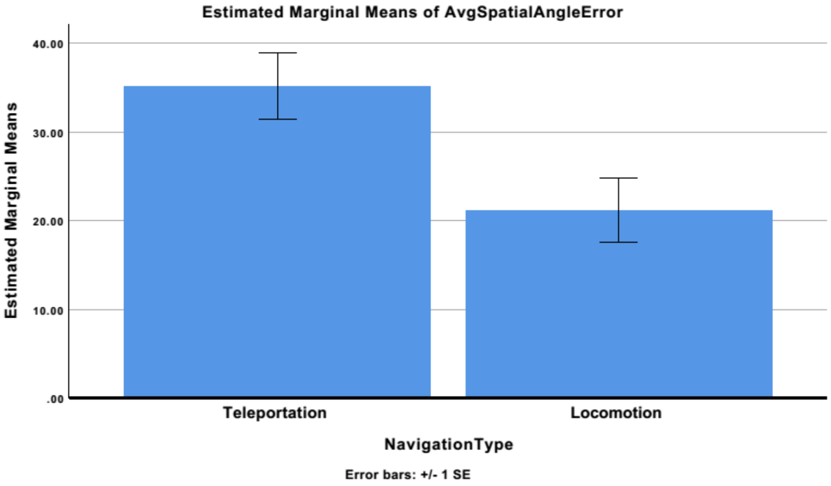


Figure 4.28: Estimated Marginal Means of spatial recall error by navigation

4.4.2 Cluster Analysis

Using a scatterplot, we evaluated association between input variables: navigation , locomotion, attention, average time spent and distance, and outputs: cognitive score, spatial error and spatial sandbox scores. Even though there are no strong direct correlation due to outliers in every variable, there are data aggregates that highlight clustering in the data.

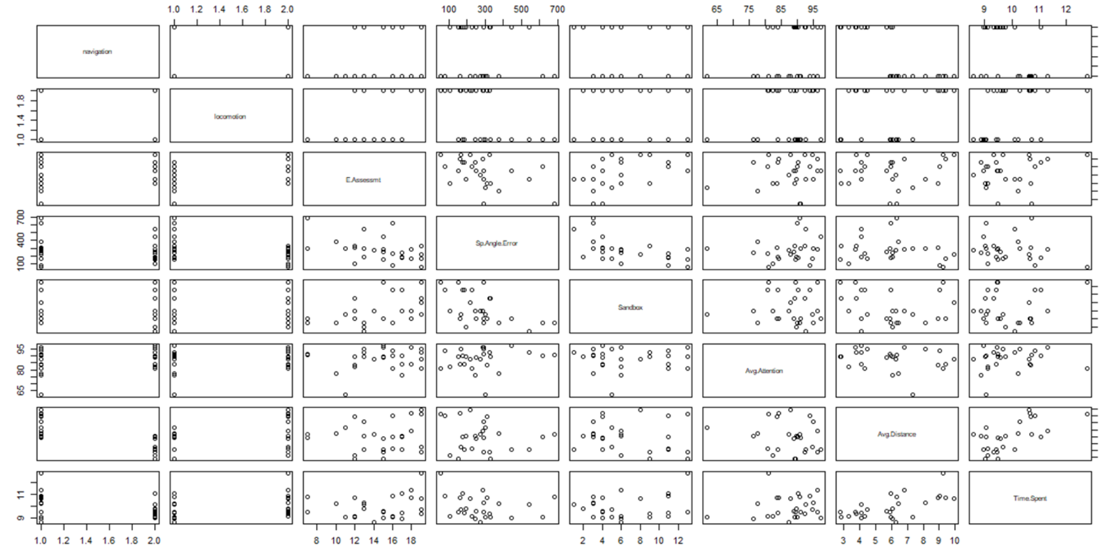


Figure 4.29: Clustering between variables

4.4.3 Best Model fit

With the exception of one or two outliers, subjects fall into two clusters. This is validated with a k-means clustering analysis.

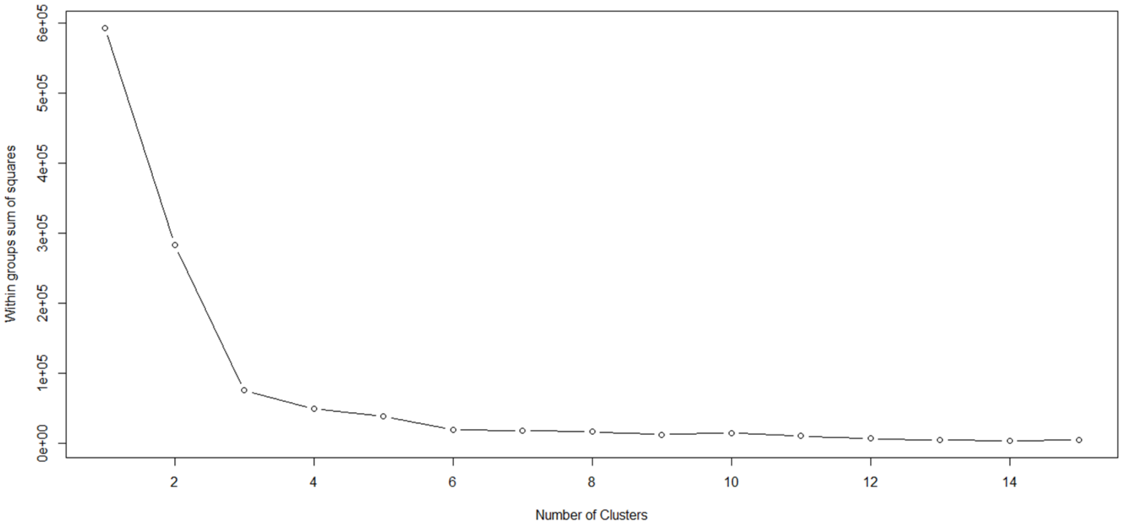


Figure 4.30: K-means shows ideal number of clusters in data set

One cluster shows that those who scored above average in the cognitive assessment and lower spatial recall error and high average attention. However, having high attention doesn't mean that the participant will score above average in the cognitive assessment or have low spatial recall error.

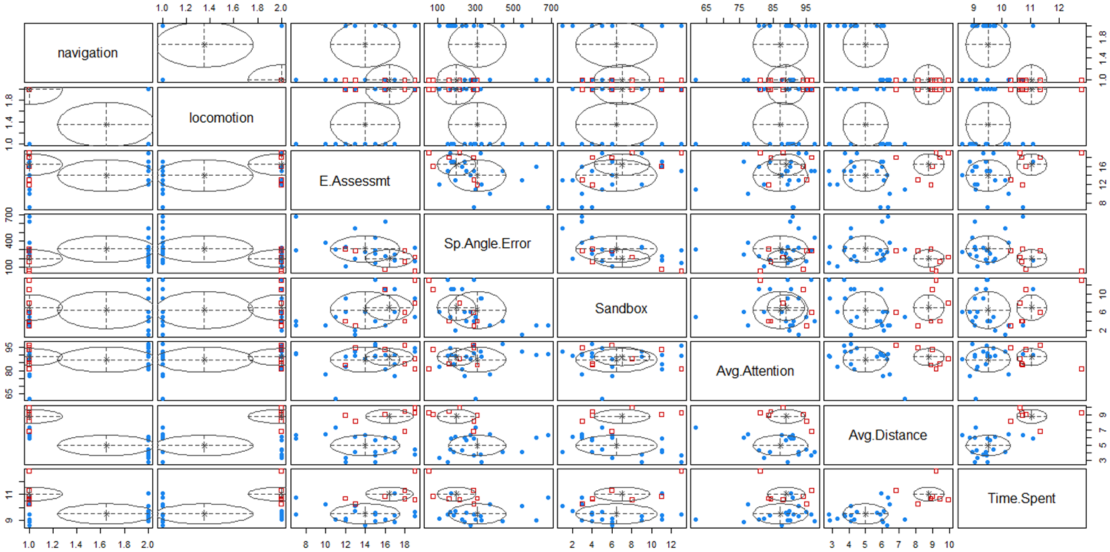
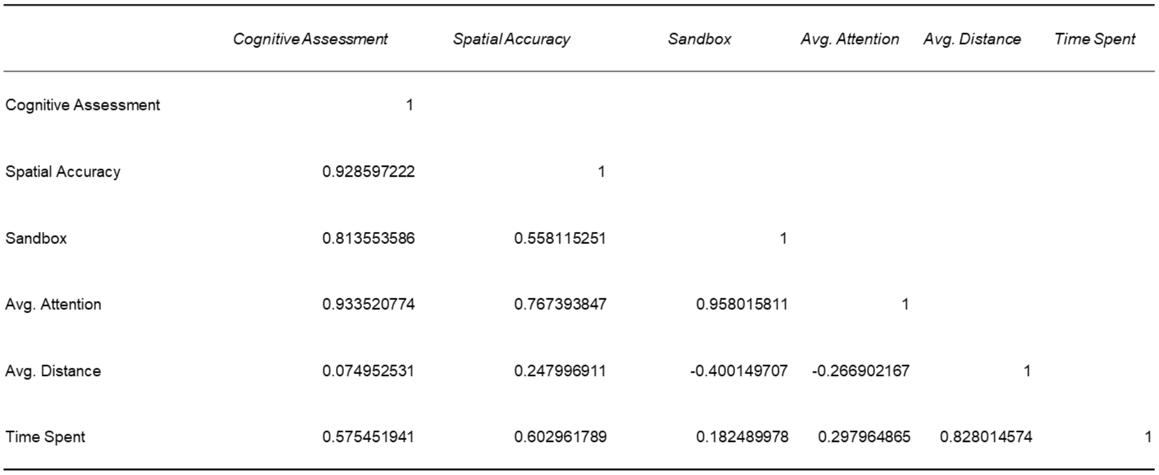


Figure 4.31: Model Based Clustering displays best model by classification

4.4.4 Correlation Matrix

There is significant correlation between average attention and cognitive assessment, spatial accuracy and sandbox. Average distance has a fairly negative correlation to the Sandbox i.e long distance jumps has a poor effect on egocentric perception encoding. And there's a positive effect between time spent on cognition and spatial recall but not on sandbox task.



	Cognitive Assessment	*Spatial Accuracy*	*Sandbox*	*Avg. Attention*	*Avg. Distance*	*Time Spent*
Cognitive Assessment	1					
Spatial Accuracy	0.928597222	1				
Sandbox	0.813553586	0.558115251	1			
Avg. Attention	0.933520774	0.767393847	0.958015811	1		
Avg. Distance	0.074952531	0.247996911	-0.400149707	-0.266902167	1	
Time Spent	0.575451941	0.602961789	0.182489978	0.297964865	0.828014574	1

Figure 4.32: Correlation Matrix

4.5 Discussion

Long teleportation is not the optimal learning condition for spatial or cognitive information processing. Our results revealed that egocentric perception i.e. perceiving space with respect to one's position, is best achieved by natural walking and not teleporting around a virtual space while allocentric perception, i.e. perceiving how objects relate to one another in space is best achieved through short distance movements.

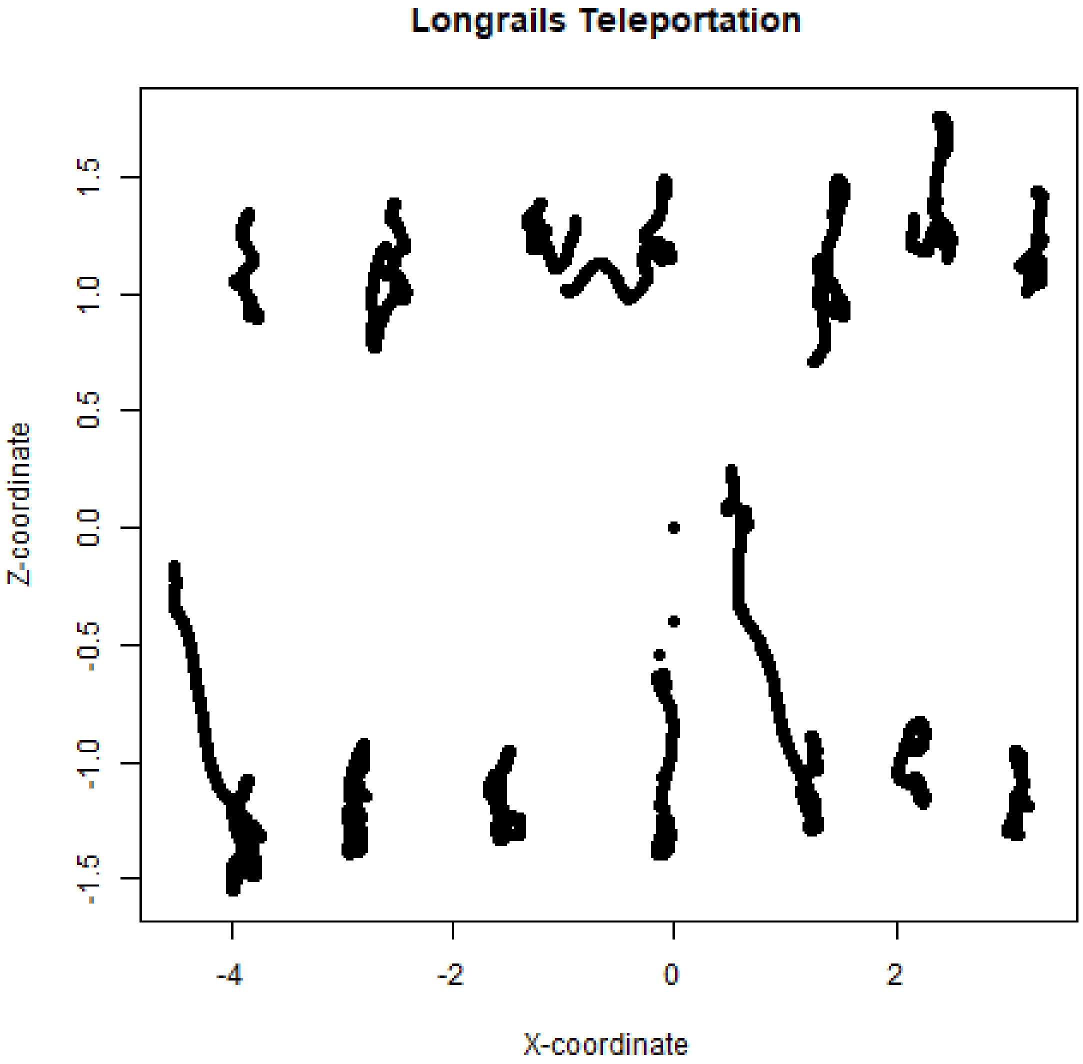


Figure 4.33: Plot of path data of subject in Long Teleport which depicts subject taking few steps forward, backward or sideways around the teleport area

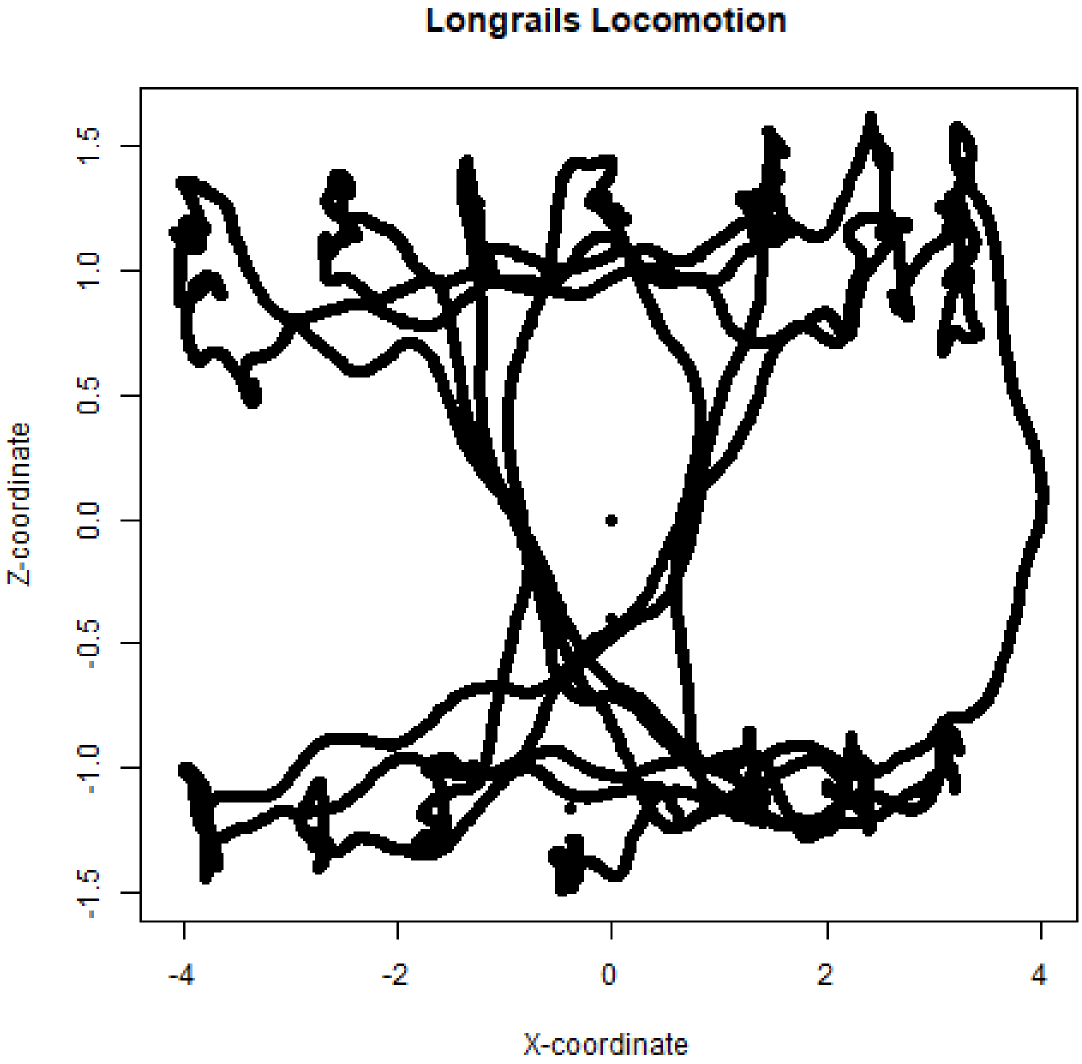


Figure 4.34: Plot of path data of subject in Long Walk Locomotion which depicts subject's long distance walks back and forth with several overlaps

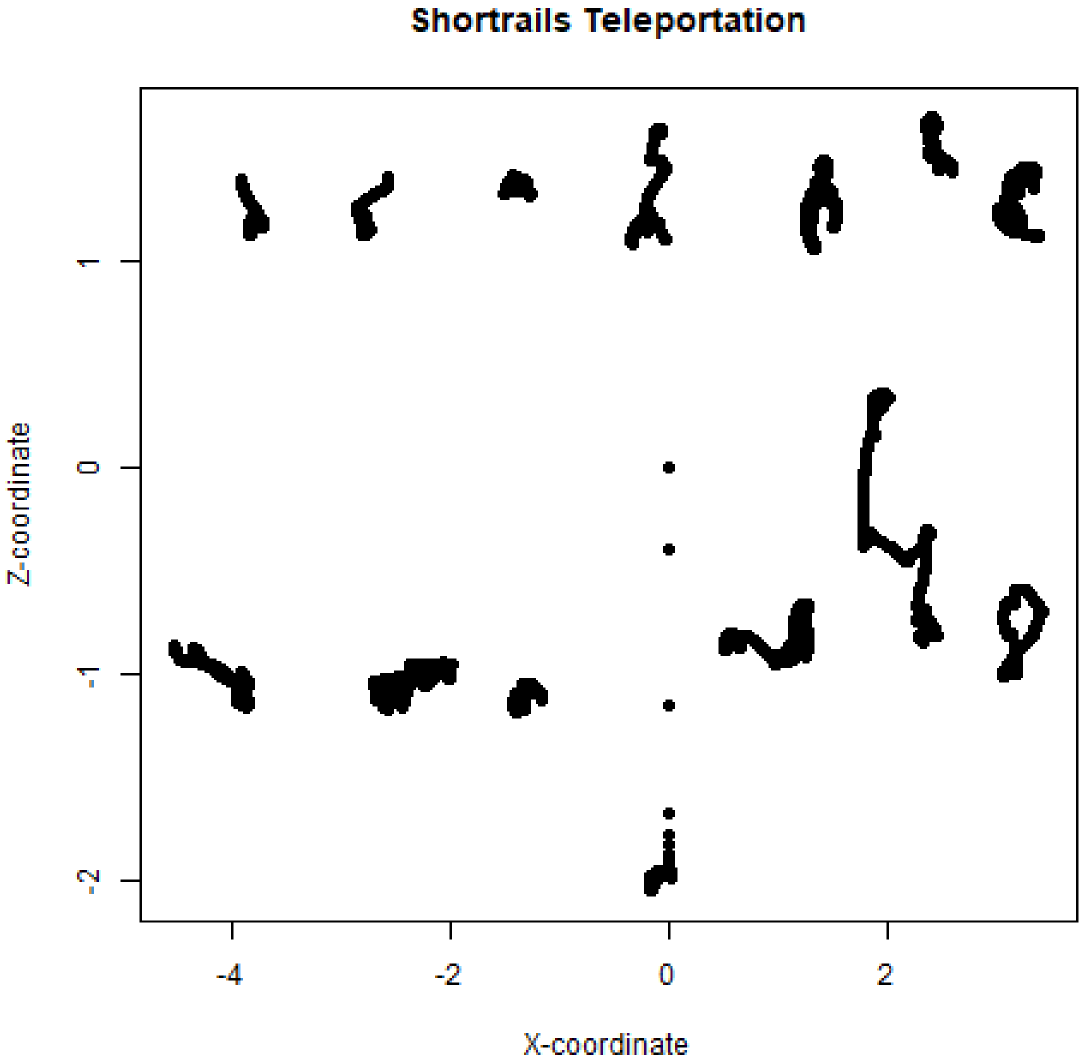


Figure 4.35: Plot of path data of subject in Short Teleport which depicts subject taking few steps forward, backward or sideways around the teleport area

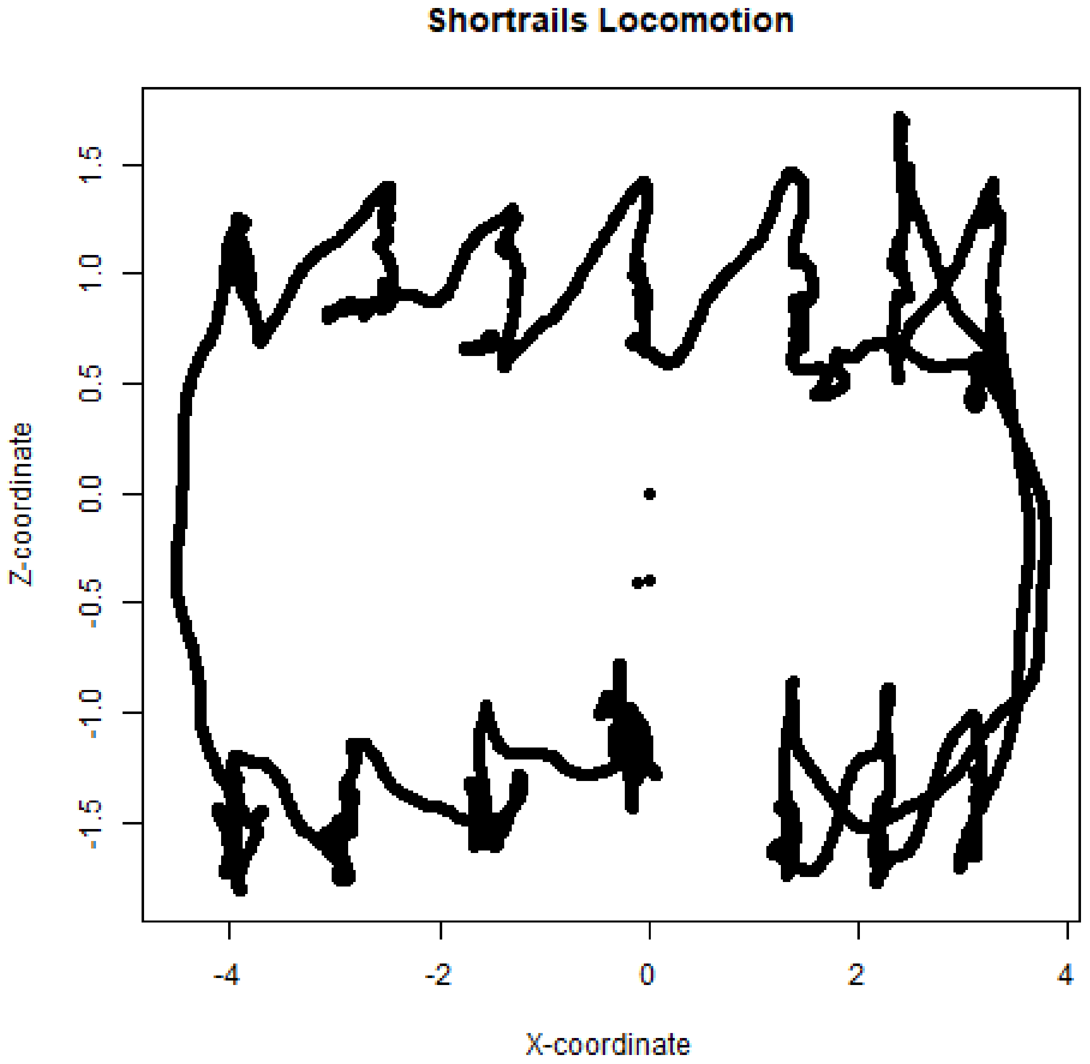


Figure 4.36: Plot of path data of subject in Short Walk Locomotion which depicts subject walking continuously from start to end marker with minor overlap from top to bottom right

Cognitive information processing is optimal if the space is balanced. The long walk condition allowed subjects to explore the space while walking around. Short walk/teleportation allowed subjects to explore and observe the space in close perimeters without drastic viewpoint changes. However, in long teleportation, subjects don't get to observe a gradual change as they're instantly transported to a different perimeter. Most got distracted by the new viewpoint and did not focus on the information presented on the tombstone. They took some time to observe their new area which in part explains why the attention values were low.

4.6 Presence and Experience

The presence and experience survey provides information about the involvement, engagement, immersion, and containment in the environment. A high percentage of subjects reported that the technology was new to them. Most subjects thought it was a fun, enjoyable, interactive and immersive experience and would do it again.The response survey is provided in the table below:

Table 4.2: Presence and Experience Survey

Question	Strongly Disgree(1)	2	3	4	5	6	Strongly Agree(7)
The experience I had today using this technology was a new one for me.	1	2	2	1	1	7	14
The experience I had today with this technology was very routine for me.	18	3	2	2	2		1
This was the first time I have used technology like this before.	8	2	1	2	1	4	10
I enjoyed the experimental task I participated in today.		1	1	2	5	19	
I thought that the task I participated in was frustrating.	15	6	3		2	2	
I had fun participating in the experiment today.			2		1	7	18
I was disappointed participating in the task today.	24	3	1				
I would like to have experiences like this again in the future.			1	2	5	5	15
I thought the task I participated in today was boring.	22	2	1	1	1		
My experience today was involving.				2	4	10	12
My experience was intense.	3	6	3	7	6	2	1
i felt like I was physically inside the task environment.			2	3	4	8	11
I felt immersed in the task environment.		1	1	4	3	7	12
I felt like I was surrounded by the task environment				1	6	6	15
The virtual world was responsive to actions that I initiated.					6	14	8
I was aware of events occurring in the lab space when i was in the virtual world.	2	10	3	7	2	2	2
It was easy to manipulate objects in the virtual environment.				1	5	15	7
The virtual environment made me feel disoriented.	9	10	3	3	3		
Using the control mechansims was intuitive.			1	3	4	13	7
I was proficient in moving around through the virtual environment.		1			3	9	15
The virtual display interfered with my ability to perform the required activities.	17	6	1	1	2	1	
I could concentrate on the assigned tasks in the virtual environment because the control mechanisms were easy to use.		1	1	3	10	13	
I felt nauseous when I was in the virtual environment.	23	4	1				
My eyes felt strained when I was in the virtual environment.	12	9	1	2	3	1	
The virtual environment gave me a headache.	21	4	1	2			
I had problems concentrating when I was in the virtual environment.	15	6	3	1	2	1	
The environment made me feel dizzy.	21	5		1	5		

5 Conclusions

Our results highlighted the negative effects of long teleportation on cognitive and spatial information processing. Natural walking is best for egocentric spatial encoding while short distance movement produces optimal allocentric spatial encoding. Because of walking limitation in physical spaces, short distance teleportation can replace waking. This is ideal for cognitive processing as well as progressive spatial updates are important for subjects in a virtual space. When subjects teleported in long distance, a fraction of the time when the text was displayed was spent looking around at the virtual environment as they didn't get to observe a gradual change in their viewpoint during teleportation.

5.1 Limitations

The main limitation of this pilot study is the number of participants. The experiment was conducted during the summer, a time when there are fewer students on campus. More experiments will be conducted over the next semester.

5.2 Future Work

It would be interesting to explore the effects of other factors, emotional response to stimulus induced by excitement or fear in the environment e.g. a walking skeleton or flying bats, visual or audio cues e.g. animated character images, an introductory message with a mention of the subject's name. Yerkes Dodson theory postulates that there is a curvilinear relationship between performance and arousal in a complex task situation. Flashbulb Memory experiences, social presence, co-presence are exciting ideas to explore. Trying out other natural locomotion techniques such as arm swing and walk-in-place mode instead of teleportation would provide insights into ways to avoid teleportation in limited physical walking spaces.

References

[1] G. Bruder and F. Steinicke. “Time perception during walking in virtual environments”. In: *2014 IEEE Virtual Reality (VR)* (2014). DOI: `10.1109/vr.2014.6802054` (cit. on p. 11).

[2] A. Byagowi and Z. Moussavi. “Design of a Virtual Reality Navigational (VRN) experiment for assessment of egocentric spatial cognition”. In: *2012 Annual International Conference of the IEEE Engineering in Medicine and Biology Society*. Aug. 2012, pp. 4812–4815. DOI: `10.1109/EMBC.2012.6347070` (cit. on p. 7).

[3] N. Collins, B. Vaughan, K. Gardiner, and C. Cullen. “Towards a Conceptual Framework for the Development of Immersive Experiences to Negotiate Meaning and Identity in Irish Language Learning”. In: *2018 IEEE Games, Entertainment, Media Conference (GEM)*. Aug. 2018, pp. 1–9. DOI: `10.1109/GEM.2018.8516523` (cit. on p. 6).

[4] H. Daniels. “Educational Theories, Cultures and Learning”. In: (2012). DOI: `10.4324/9780203379417` (cit. on p. 6).

[5] D. M. Diamond, A. M. Campbell, C. R. Park, J. Halonen, and P. R. Zoladz. “The Temporal Dynamics Model of Emotional Memory Processing: A Synthesis on the Neurobiological Basis of Stress-Induced Amnesia, Flashbulb and

Traumatic Memories, and the Yerkes-Dodson Law". In: *Neural Plasticity* 2007 (2007), 1fffdfffdfffd33. DOI: 10.1155/2007/60803 (cit. on pp. 3, 4).

[6] "Federal Knowledge Management MarketView Report". In: *INPUT* (2008) (cit. on p. 1).

[7] S. Grondin. "Pyschology of Time". In: *Emerald Group Publishing* (2008) (cit. on pp. 11, 12).

[8] M. A. Khawaja, N. Ruiz, and F. Chen. "Think Before You Talk: An Empirical Study of Relationship Between Speech Pauses and Cognitive Load". In: *Proceedings of the 20th Australasian Conference on Computer-Human Interaction: Designing for Habitus and Habitat*. OZCHI '08. Cairns, Australia: ACM, 2008, pp. 335–338. ISBN: 0-9803063-4-5. DOI: 10.1145/1517744.1517814. URL: http://doi.acm.org/10.1145/1517744.1517814 (cit. on p. 4).

[9] J. Kim, J. Song, and D. R. Jones. "The Cognitive Selection Framework of Knowledge Acquisition Strategy in Virtual Communities". In: *2010 43rd Hawaii International Conference on System Sciences*. Jan. 2010, pp. 1–10. DOI: 10.1109/HICSS.2010.368 (cit. on p. 1).

[10] J. Liu, H. Parekh, M. Al-Zayer, and E. Folmer. "Increasing Walking in VR using Redirected Teleportation". In: *The 31st Annual ACM Symposium on User Interface Software and Technology - UIST 18* (2018). DOI: 10.1145/3242587.3242601 (cit. on p. 10).

[11] W. E. Marsh, M. Putnam, J. W. Kelly, V. J. Dark, and J. H. Oliver. "The cognitive implications of semi-natural virtual locomotion". In: *2012 IEEE Virtual Reality (VR)* (2012). DOI: 10.1109/vr.2012.6180878 (cit. on p. 9).

[12] K. R. Moghadam, C. Banigan, and E. D. Ragan. “Scene Transitions and Teleportation in Virtual Reality and the Implications for Spatial Awareness and Sickness”. In: *IEEE Transactions on Visualization and Computer Graphics* (2018), 1fffdfffdfffd1. DOI: `10.1109/tvcg.2018.2884468` (cit. on p. 10).

[13] “Motion Sickness”. In: *The VR Book* (2015), p. 163. DOI: `10.1145/2792790.2792806` (cit. on p. 8).

[14] E. D. Ragan. “The Effects of Higher Levels of Immersion on Procedure Memorization Performance and Implications for Educational Virtual Environments”. In: *Presence: Teleoperators and Virtual Environments* 19.6 (2010), 527fffdfffdfffd543. DOI: `10.1162/pres_a_00016` (cit. on p. 6).

[15] B. E. Riecke and J. M. Wiener. “Can People Not Tell Left from Right in VR? Point-to-origin Studies Revealed Qualitative Errors in Visual Path Integration”. In: *2007 IEEE Virtual Reality Conference*. Mar. 2007, pp. 3–10. DOI: `10.1109/VR.2007.352457` (cit. on p. 8).

[16] J. Smeddinck, D. Alexandrovsky, D. Wenig, M. Zimmer, W. Wegele, S. Juergens, and R. Malaka. “Hoverboard: A Leap to the Future of Locomotion in VR!?” In: *Entertainment Computing – ICEC 2017*. Ed. by N. Munekata, I. Kunita, and J. Hoshino. Cham: Springer International Publishing, 2017, pp. 218–225. ISBN: 978-3-319-66715-7 (cit. on p. 10).

[17] “Spatial Cognition in a Multimedia and Intercultural World Proceedings of the 7th International Conference on Spatial Cognition (ICSC 2018)”. In: *Cognitive Processing* 19.S1 (2018), 1fffdfffdfffd76. DOI: `10.1007/s10339-018-0884-3` (cit. on p. 7).

[18] S. Teramoto, T. Inaoka, and Y. Ono. “Regional brain activity that determines successful and unsuccessful working memory formation”. In: *2016 38th Annual*

International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC). Aug. 2016, pp. 5550–5553. DOI: 10.1109/EMBC.2016.7591984 (cit. on p. 2).

[19] P. Turner and S. Turner. “Triangulation in practice”. In: *Virtual Reality* 13.3 (Sept. 2009), pp. 171–181. ISSN: 1434-9957. DOI: 10.1007/s10055-009-0117-2. URL: https://doi.org/10.1007/s10055-009-0117-2 (cit. on p. 12).

A Appendix A

The Appendix includes the following items:

- Instruction Script
- Pre Experiment Questionnaire
- Environment Assessment
- Spatial Layout Questionnaire
- ANOVA Multivariate Analysis
- Unity railscontroller script

SPOON RIVER INSTRUCTION SCRIPT

Standard Procedures

Standard response if question(s) would compromise the experiment:

- *“I cannot answer this question until the end of the experiment”*

Emergency Procedures

- Person is the priority if a dangerous situation would arise

Hello, my name is __________ and thank you for agreeing to participate in our study. First, we’d like you to read and sign this informed consent form. Please, let me know if you have any questions.
[*Wait for them to read the form and see if they have any question*]

All information will be kept confidential and your name will not be associated with any data collected during the experiment nor with any publication of research findings.

1. **Informed Consent Form**
2. **Pre-experiment Questionnaire**

Introduction to Technology

Today, you will be putting on the Oculus Rift S Headset and wearing a backpack. First, we want you to wear a VR protective mask. There’s a knob at the back of the HMD that lets you adjust it to fit your head and a strap on top which you can tighten accordingly. You will be put in a virtual training environment to get used to the technology, and after the trainining, we will proceed with the actual experiment.

Training

You will find yourself in a brick room. Look around you and there will be purple boards on the walls and a couple of them will have blue glowing markers. Your task is to go to one of the two markers and stand directly inside. A text will appear on the board and we want you to read it out loud to us so we can confirm what you’re seeing. At the same time the text appears on the board, a countdown timer will come up above with displaying how many seconds is left before the text disappears. After the text disappears, you will look around and a pair of new markers will appear and you will repeat the procedure.

[***For Participants in Teleport condition only***

[*Tell them to put on the VR headset, and hold the touch controller. Ask if they're comfortable and confirm that they see the blue markers.]*

If you point the controller at one of the glowing markers, the color should change from blue to orange. [*Confirm that the color of the marker changes.*] Good! Decide which one of the markers you want to go by pointing the controller at it, and teleport by pressing the A button (right controller) or X button (left controller).

Experiment

Now that you're comfortable with moving around in the virtual space, we're going to start the experiment. The environment is different from the training but the interaction is going to be just the same. You will find yourself in at the entrance of a cemetery. We want you to go/teleport to each marker and read the text on the tombstone to yourself. Pay attention to the environment you're in and the stories you read as you'll answer some questions at the end of the experiment.

3. Environment Cognitive Assessment
4. Spatial Pointing Task
5. Sandbox Task
6. Presence and Experience

Pre-Experiment Questionnaire Subject

Please answer these questions to the best of your ability. If you do not feel like answering a question, leave it blank.

Please state your relationship with the University:
- Student
- Staff
- Faculty
- Duluth Community Member
- Other

If you are a student, what is your major? _________________

Age _____ Gender _________

How are you feeling today?

1=Not Well, Very Sick 2 3 4=OK 5 6 7=Great! Very Healthy

To what extent have you experienced motion sickness? _____________________

Have you ever been diagnosed with any brain-related condition or disease: recent concussions, meningitis, spinal cord injury, Parkinson's, Alzheimer's, dementia, encephalitis, epilepsy, and/or restless leg syndrome? Y N

Approximately how many hours in the last month have you used virtual reality systems? _____________________

How much **total** experience do you have with virtual reality systems. Please select one option:
- 0-5 hours
- 5-30 hours
- 30-60 hours
- 60-100 hours
- 100+ hours

If you have had used virtual reality, please describe the types of experiences (such as games, simulations, movies or other immersive activities) that you have participated in including how you interacted with the virtual objects and environment.

If you have had experience with virtual reality, please indicate which virtual reality systems you regularly use:

Oculus Rift
HTC VIVE
PlayStation VR
Samsung Gear VR
Google Cardboard
Other ___________________________________

Approximately how many hours each week do you play video games (on phones, consoles, digital media, web pages, etc…) _________________

Current Overall College GPA _____ (Mark here if you are a freshman and do not have a GPA yet _________)

Academic Year: Freshman_____ Sophomore_____ Junior_____ Senior ____ Senior+ ____ Grad ____

What college are you affiliated with?

a. _______College of Liberal Arts
b. _______Labovitz School of Business & Economics c. _______School of Fine Arts
d. _______Swenson College of Science & Engineering e. _______CEHSP
f. Other(specify) _____________________________

Environment Assessment

Participant #: __________________________ Condition: _____________

1. Who is responsible for most of the deaths in Spoon River?
    - Holden the Cook
    - Petrus Van Tassel
    - Hessian Soldier
    - Aaron Hatfield
2. Who was the little girl in the story that died after the cook tricked her into getting spoiled fruits and vegetables from the trash behind the store?
    - Minerva Jones
    - Daisy Hatfield
    - Nellie Throckmortin
    - Marie Rhodes
3. Which of the following residents worked for Spoon River Cemetery?
    - Silas Rhodes
    - Butch Welty
    - Blind Jack
    - Peter Hatfield
4. Who owned a Lumber mill?
    - Aaron Hatfield
    - Hodd Hatfield
    - Rolf Rhodes
    - Petrus Van Tassel
5. Who owned a general store?
    - James Lindsay
    - Minerva Jones
    - Justice Rhodes
    - Marie Rhodes

6. Which of the following people were not married?
    - Petit the Poet

Daisy Hatfield
Katrina Ecker Van Tassel
Hodd Hatfield

7. Who was the nurse in town?
    Minerva Jones
    Daisy Hatfield
    Nellie Throckmortin
    None of the above

8. Among these people, who has a wooden grave marker?
    Blind Jack
    Hessian Soldier
    Petit the Poet
    Holden the Cook

9. Who could barely hold a job because he was always unfit?
    Editor Whedon
    Frances Throckmortin
    Blind Jack
    Petit the Poet

10. Who got caught under a wagon wheel?
    Hessian Soldier
    Blind Jack
    Butch Welty
    Aaron Hatfield

11. Who had rich, important friends?
    Lindsey Jones
    Frances Throckmortin
    Editor Whedon
    Aaron Hatfield

12. Whose business was booming?
    Minerva Jones
    Butch Welty
    Holden the Cook

Editor Whedon

13. Who'd become the richest man in town?
    Minerva Jones
    Butch Welty
    Holden the Cook
    Editor Whedon
14. Who knew the whole story?
    Butch Welty
    Petit the Poet
    Editor Whedon
    Daisy Hatfield
15. Which of the residents died after eating an apple?
    Daisy Hatfield
    Nellie Throckmortin
    Butch Welty
    None of the above
16. Who killed the Hessian Soldier?
    Frances Throckmortin
    Holden the Cook
    Butch Welty
    None of the above
17. How many tombstones belonged to the Throckmortin family?
    One (1)
    Two (2)
    Three (3)
    Four (4)

18. How many families (of more than one person with the same last name) were in the cemetery?
    One (1)
    Two (2)
    Three (3)
    Four (4)
19. Which of the following adjectives best describes the Holden the Cook:

Hero
Villain
Hard-worker
Father

20. What was Hodd Hatfield’s profession:

Lumberjack
Newspaper Editor
Doctor
Grave digger

Spatial Layout Questionnaire

Participant #: __________________________ Condition: _____________

[*Note: All participants get asked these questions and use a joystick controller they are holding to point in the direction where they believe the landmark is located. This is done outside of virtual reality in the lab environment.*]

1. Point to the location of Hessian Soldier’s tombstone from your current position.
2. Point to the location of Editor Whedon’s tombstone from your current position.
3. Point to the location of Hodd Hatfield’s tombstone from your current position.
4. Point to the location of Minerva Jones’s tombstone from your current position.
5. Point to the location of Blind Jack’s tombstone from your current position.
6. Point to the location of Nellie Throckmortin’s tombstone from your current position.
7. Point to the location of Butch Welty’s tombstone from your current position.
8. Point to the location of Daisy Hatfield’s tombstone from your current position.
9. Point to the location of Frances Throckmortin’s tombstone from your current position.
10. Point to the location of Sara Throckmortin’s tombstone from your current position.

```
GLM AvgAttention TimeSpent AvgDistance Sandbox CognitiveAssessmentAvgSpatialA
ngleError BY
    Condition PathType NavigationType
  /CONTRAST(NavigationType)=Repeated
  /METHOD=SSTYPE(3)
  /INTERCEPT=INCLUDE
  /POSTHOC=Condition(BONFERRONI)
  /PLOT=PROFILE(Condition PathType NavigationType) TYPE=BAR ERRORBAR=SE(1) MEA
NREFERENCE=NO
  /PRINT=DESCRIPTIVE ETASQ OPOWER HOMOGENEITY
  /CRITERIA=ALPHA(.05)
  /DESIGN= Condition PathType NavigationType Condition*PathType Condition*Navi
gationType
    PathType*NavigationType Condition*PathType*NavigationType
```

General Linear Model

Notes

Output Created		**24-JUN-2019 11:47:43**
Comments		
Input	**Data**	**/Users/willemsn/NavigationLearning_2019_Analysis/data_AsOf_06232019_1546.sav**
	Active Dataset	**DataSet1**
	Filter	**<none>**
	Weight	**<none>**
	Split File	**<none>**
	N of Rows in Working Data File	**28**
Missing Value Handling	**Definition of Missing**	**User-defined missing values are treated as missing.**
	Cases Used	**Statistics are based on all cases with valid data for all variables in the model.**

Notes

Syntax

```
GLM AvgAttention
TimeSpent AvgDistance
Sandbox
CognitiveAssessment
AvgSpatialAngleError BY
    Condition PathType
NavigationType
  /CONTRAST
(NavigationType)
=Repeated
  /METHOD=SSTYPE(3)
  /INTERCEPT=INCLUDE
  /POSTHOC=Condition
(BONFERRONI)
  /PLOT=PROFILE
(Condition PathType
NavigationType)
TYPE=BAR
ERRORBAR=SE(1)
MEANREFERENCE=NO
  /PRINT=DESCRIPTIVE
ETASQ OPOWER
HOMOGENEITY
  /CRITERIA=ALPHA(.05)
  /DESIGN= Condition
PathType
NavigationType
Condition*PathType
Condition*NavigationTyp
e

PathType*NavigationTyp
e
Condition*PathType*Nav
igationType.
```

Resources	**Processor Time**	00:00:02.17
	Elapsed Time	00:00:02.00

Between-Subjects Factors

		Value Label	N
Condition	1	Long Teleportation	7
	2	Long Locomotion	7
	3	Short Teleportation	6
	4	Short Locomotion	7
PathType	0	Short Path	13
	1	Long Path	14
NavigationType	0	Teleportation	13
	1	Locomotion	14

Descriptive Statistics

	Condition	PathType	NavigationType	Mean
AvgAttention	Long Teleportation	Long Path	Teleportation	82.1159600
			Total	82.1159600
		Total	Teleportation	82.1159600
			Total	82.1159600
	Long Locomotion	Long Path	Locomotion	88.9161695
			Total	88.9161695
		Total	Locomotion	88.9161695
			Total	88.9161695
	Short Teleportation	Short Path	Teleportation	90.5155781
			Total	90.5155781
		Total	Teleportation	90.5155781
			Total	90.5155781
	Short Locomotion	Short Path	Locomotion	89.3542836
			Total	89.3542836
		Total	Locomotion	89.3542836
			Total	89.3542836
	Total	Short Path	Teleportation	90.5155781
			Locomotion	89.3542836
			Total	89.8902657
		Long Path	Teleportation	82.1159600
			Locomotion	88.9161695
			Total	85.5160647

Descriptive Statistics

	Condition	PathType	NavigationType	Std. Deviation	N
AvgAttention	**Long Teleportation**	**Long Path**	**Teleportation**	10.9271800	7
			Total	10.9271800	7
		Total	**Teleportation**	10.9271800	7
			Total	10.9271800	7
	Long Locomotion	**Long Path**	**Locomotion**	6.23625680	7
			Total	6.23625680	7
		Total	**Locomotion**	6.23625680	7
			Total	6.23625680	7
	Short Teleportation	**Short Path**	**Teleportation**	4.43157226	6
			Total	4.43157226	6
		Total	**Teleportation**	4.43157226	6
			Total	4.43157226	6
	Short Locomotion	**Short Path**	**Locomotion**	5.99865395	7
			Total	5.99865395	7
		Total	**Locomotion**	5.99865395	7
			Total	5.99865395	7
	Total	**Short Path**	**Teleportation**	4.43157226	6
			Locomotion	5.99865395	7
			Total	5.15149080	13
		Long Path	**Teleportation**	10.9271800	7
			Locomotion	6.23625680	7
			Total	9.24709906	14

Descriptive Statistics

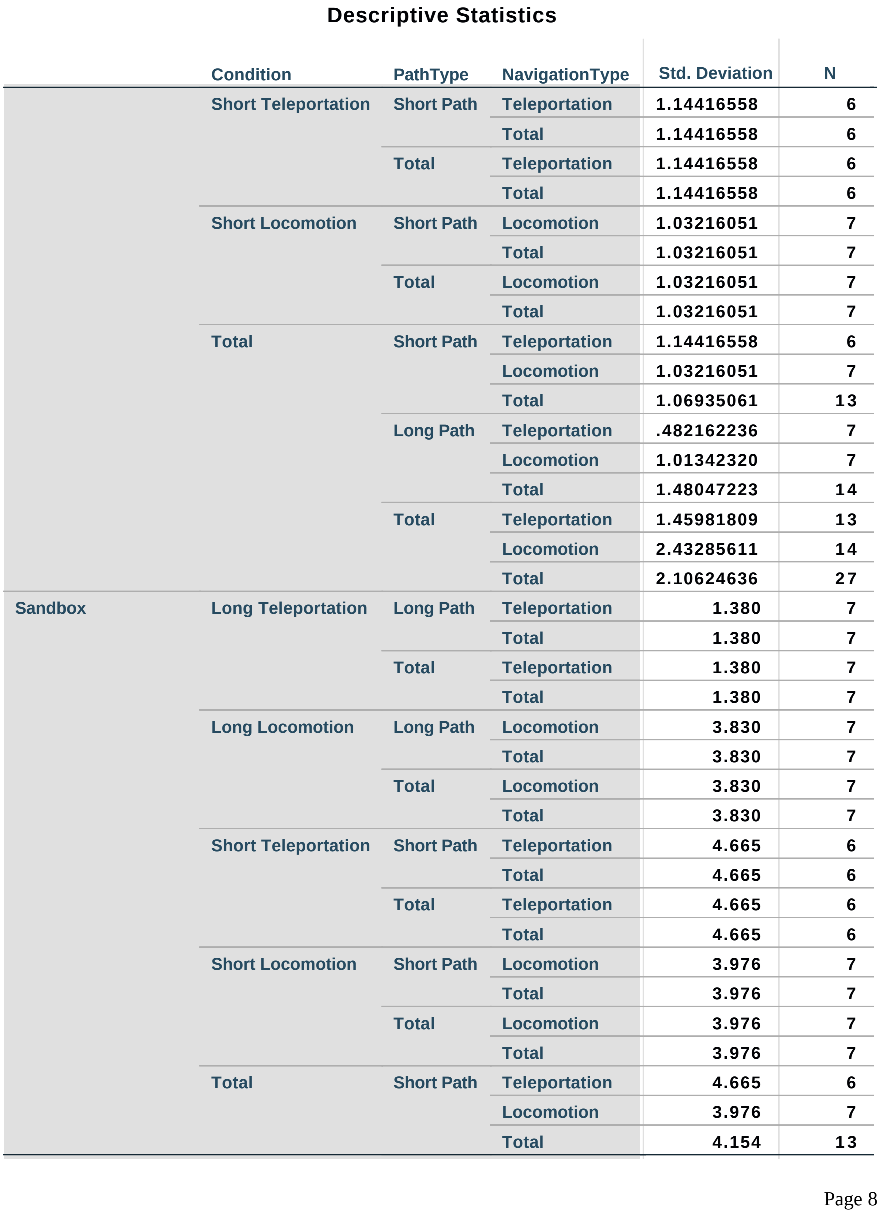
	Condition	PathType	NavigationType	Mean
		Total	Teleportation	85.9927068
			Locomotion	89.1352265
			Total	87.6221615
TimeSpent	Long Teleportation	Long Path	Teleportation	9.43047700
			Total	9.43047700
		Total	Teleportation	9.43047700
			Total	9.43047700
	Long Locomotion	Long Path	Locomotion	11.0323343
			Total	11.0323343
		Total	Locomotion	11.0323343
			Total	11.0323343
	Short Teleportation	Short Path	Teleportation	9.68077683
			Total	9.68077683
		Total	Teleportation	9.68077683
			Total	9.68077683
	Short Locomotion	Short Path	Locomotion	9.43290457
			Total	9.43290457
		Total	Locomotion	9.43290457
			Total	9.43290457
	Total	Short Path	Teleportation	9.68077683
			Locomotion	9.43290457
			Total	9.54730715
		Long Path	Teleportation	9.43047700
			Locomotion	11.0323343
			Total	10.2314056
		Total	Teleportation	9.54600000
			Locomotion	10.2326194
			Total	9.90202489
AvgDistance	Long Teleportation	Long Path	Teleportation	6.33318107
			Total	6.33318107
		Total	Teleportation	6.33318107
			Total	6.33318107
	Long Locomotion	Long Path	Locomotion	8.77895482
			Total	8.77895482
		Total	Locomotion	8.77895482
			Total	8.77895482

Descriptive Statistics

	Condition	PathType	NavigationType	Std. Deviation	N
		Total	Teleportation	9.32092664	13
			Locomotion	5.88296297	14
			Total	7.74359311	27
TimeSpent	Long Teleportation	Long Path	Teleportation	.773646879	7
			Total	.773646879	7
		Total	Teleportation	.773646879	7
			Total	.773646879	7
	Long Locomotion	Long Path	Locomotion	.826864478	7
			Total	.826864478	7
		Total	Locomotion	.826864478	7
			Total	.826864478	7
	Short Teleportation	Short Path	Teleportation	.792646020	6
			Total	.792646020	6
		Total	Teleportation	.792646020	6
			Total	.792646020	6
	Short Locomotion	Short Path	Locomotion	.259703496	7
			Total	.259703496	7
		Total	Locomotion	.259703496	7
			Total	.259703496	7
	Total	Short Path	Teleportation	.792646020	6
			Locomotion	.259703496	7
			Total	.558615445	13
		Long Path	Teleportation	.773646879	7
			Locomotion	.826864478	7
			Total	1.13253357	14
		Total	Teleportation	.760209579	13
			Locomotion	1.01755811	14
			Total	.952192585	27
AvgDistance	Long Teleportation	Long Path	Teleportation	.482162236	7
			Total	.482162236	7
		Total	Teleportation	.482162236	7
			Total	.482162236	7
	Long Locomotion	Long Path	Locomotion	1.01342320	7
			Total	1.01342320	7
		Total	Locomotion	1.01342320	7
			Total	1.01342320	7

Descriptive Statistics

	Condition	PathType	NavigationType	Mean
	Short Teleportation	Short Path	Teleportation	3.99702223
			Total	3.99702223
		Total	Teleportation	3.99702223
			Total	3.99702223
	Short Locomotion	Short Path	Locomotion	4.48976697
			Total	4.48976697
		Total	Locomotion	4.48976697
			Total	4.48976697
	Total	Short Path	Teleportation	3.99702223
			Locomotion	4.48976697
			Total	4.26234632
		Long Path	Teleportation	6.33318107
			Locomotion	8.77895482
			Total	7.55606794
		Total	Teleportation	5.25495391
			Locomotion	6.63436090
			Total	5.97020198
Sandbox	Long Teleportation	Long Path	Teleportation	4.29
			Total	4.29
		Total	Teleportation	4.29
			Total	4.29
	Long Locomotion	Long Path	Locomotion	7.00
			Total	7.00
		Total	Locomotion	7.00
			Total	7.00
	Short Teleportation	Short Path	Teleportation	8.17
			Total	8.17
		Total	Teleportation	8.17
			Total	8.17
	Short Locomotion	Short Path	Locomotion	7.14
			Total	7.14
		Total	Locomotion	7.14
			Total	7.14
	Total	Short Path	Teleportation	8.17
			Locomotion	7.14
			Total	7.62

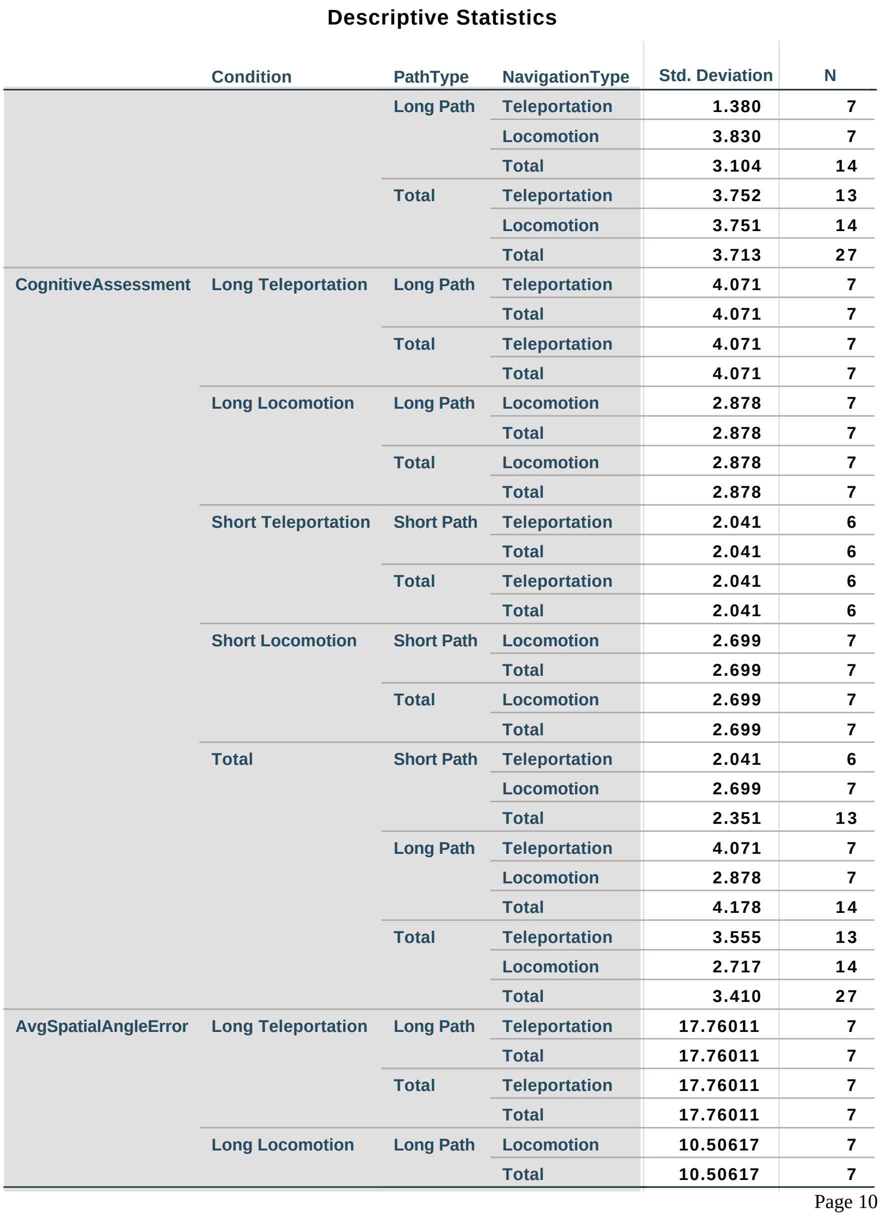


Descriptive Statistics

	Condition	PathType	NavigationType	Std. Deviation	N
	Short Teleportation	Short Path	Teleportation	1.14416558	6
			Total	1.14416558	6
		Total	Teleportation	1.14416558	6
			Total	1.14416558	6
	Short Locomotion	Short Path	Locomotion	1.03216051	7
			Total	1.03216051	7
		Total	Locomotion	1.03216051	7
			Total	1.03216051	7
	Total	Short Path	Teleportation	1.14416558	6
			Locomotion	1.03216051	7
			Total	1.06935061	13
		Long Path	Teleportation	.482162236	7
			Locomotion	1.01342320	7
			Total	1.48047223	14
		Total	Teleportation	1.45981809	13
			Locomotion	2.43285611	14
			Total	2.10624636	27
Sandbox	Long Teleportation	Long Path	Teleportation	1.380	7
			Total	1.380	7
		Total	Teleportation	1.380	7
			Total	1.380	7
	Long Locomotion	Long Path	Locomotion	3.830	7
			Total	3.830	7
		Total	Locomotion	3.830	7
			Total	3.830	7
	Short Teleportation	Short Path	Teleportation	4.665	6
			Total	4.665	6
		Total	Teleportation	4.665	6
			Total	4.665	6
	Short Locomotion	Short Path	Locomotion	3.976	7
			Total	3.976	7
		Total	Locomotion	3.976	7
			Total	3.976	7
	Total	Short Path	Teleportation	4.665	6
			Locomotion	3.976	7
			Total	4.154	13

Descriptive Statistics

	Condition	PathType	NavigationType	Mean
		Long Path	Teleportation	4.29
			Locomotion	7.00
			Total	5.64
		Total	Teleportation	6.08
			Locomotion	7.07
			Total	6.59
CognitiveAssessment	Long Teleportation	Long Path	Teleportation	11.71
			Total	11.71
		Total	Teleportation	11.71
			Total	11.71
	Long Locomotion	Long Path	Locomotion	16.43
			Total	16.43
		Total	Locomotion	16.43
			Total	16.43
	Short Teleportation	Short Path	Teleportation	14.83
			Total	14.83
		Total	Teleportation	14.83
			Total	14.83
	Short Locomotion	Short Path	Locomotion	15.57
			Total	15.57
		Total	Locomotion	15.57
			Total	15.57
	Total	Short Path	Teleportation	14.83
			Locomotion	15.57
			Total	15.23
		Long Path	Teleportation	11.71
			Locomotion	16.43
			Total	14.07
		Total	Teleportation	13.15
			Locomotion	16.00
			Total	14.63
AvgSpatialAngleError	Long Teleportation	Long Path	Teleportation	39.9143
			Total	39.9143
		Total	Teleportation	39.9143
			Total	39.9143
	Long Locomotion	Long Path	Locomotion	20.0429
			Total	20.0429



Descriptive Statistics

	Condition	PathType	NavigationType	Std. Deviation	N
		Long Path	Teleportation	1.380	7
			Locomotion	3.830	7
			Total	3.104	14
		Total	Teleportation	3.752	13
			Locomotion	3.751	14
			Total	3.713	27
CognitiveAssessment	Long Teleportation	Long Path	Teleportation	4.071	7
			Total	4.071	7
		Total	Teleportation	4.071	7
			Total	4.071	7
	Long Locomotion	Long Path	Locomotion	2.878	7
			Total	2.878	7
		Total	Locomotion	2.878	7
			Total	2.878	7
	Short Teleportation	Short Path	Teleportation	2.041	6
			Total	2.041	6
		Total	Teleportation	2.041	6
			Total	2.041	6
	Short Locomotion	Short Path	Locomotion	2.699	7
			Total	2.699	7
		Total	Locomotion	2.699	7
			Total	2.699	7
	Total	Short Path	Teleportation	2.041	6
			Locomotion	2.699	7
			Total	2.351	13
		Long Path	Teleportation	4.071	7
			Locomotion	2.878	7
			Total	4.178	14
		Total	Teleportation	3.555	13
			Locomotion	2.717	14
			Total	3.410	27
AvgSpatialAngleError	Long Teleportation	Long Path	Teleportation	17.76011	7
			Total	17.76011	7
		Total	Teleportation	17.76011	7
			Total	17.76011	7
	Long Locomotion	Long Path	Locomotion	10.50617	7
			Total	10.50617	7

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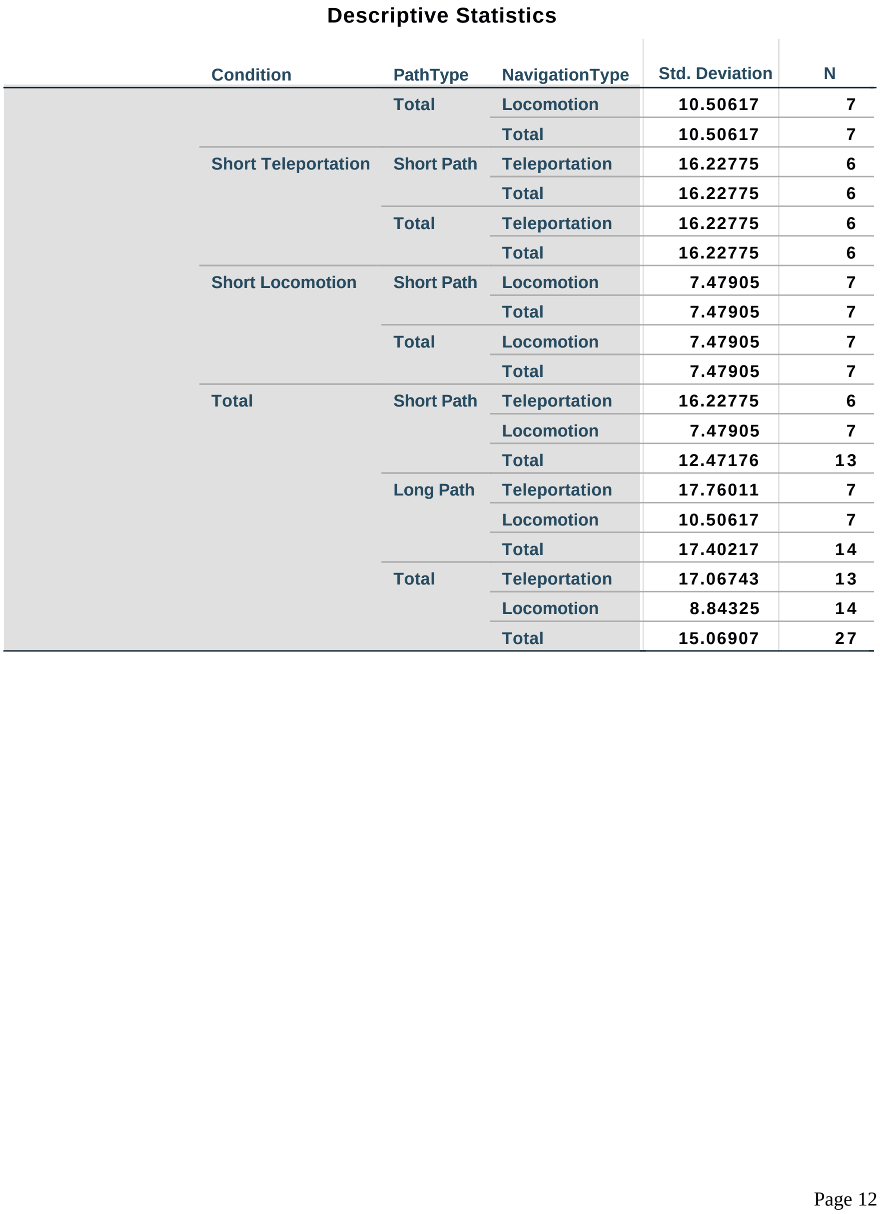
Descriptive Statistics

	Condition	PathType	NavigationType	Mean
		Total	Locomotion	20.0429
			Total	20.0429
	Short Teleportation	Short Path	Teleportation	30.5000
			Total	30.5000
		Total	Teleportation	30.5000
			Total	30.5000
	Short Locomotion	Short Path	Locomotion	22.3571
			Total	22.3571
		Total	Locomotion	22.3571
			Total	22.3571
	Total	Short Path	Teleportation	30.5000
			Locomotion	22.3571
			Total	26.1154
		Long Path	Teleportation	39.9143
			Locomotion	20.0429
			Total	29.9786
		Total	Teleportation	35.5692
			Locomotion	21.2000
			Total	28.1185



Descriptive Statistics

	Condition	PathType	NavigationType	Std. Deviation	N
		Total	Locomotion	10.50617	7
			Total	10.50617	7
	Short Teleportation	Short Path	Teleportation	16.22775	6
			Total	16.22775	6
		Total	Teleportation	16.22775	6
			Total	16.22775	6
	Short Locomotion	Short Path	Locomotion	7.47905	7
			Total	7.47905	7
		Total	Locomotion	7.47905	7
			Total	7.47905	7
	Total	Short Path	Teleportation	16.22775	6
			Locomotion	7.47905	7
			Total	12.47176	13
		Long Path	Teleportation	17.76011	7
			Locomotion	10.50617	7
			Total	17.40217	14
		Total	Teleportation	17.06743	13
			Locomotion	8.84325	14
			Total	15.06907	27

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Box's Test of Equality of Covariance Matrices[a]

Box's M	130.031
F	1.503
df1	42
df2	961.887
Sig.	.022

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.

a. Design: Intercept + Condition + PathType + NavigationType + Condition * PathType + Condition * NavigationType + PathType * NavigationType + Condition * PathType * NavigationType

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df
Intercept	Pillai's Trace	.998	1426.092[b]	6.000	18.000
	Wilks' Lambda	.002	1426.092[b]	6.000	18.000
	Hotelling's Trace	475.364	1426.092[b]	6.000	18.000
	Roy's Largest Root	475.364	1426.092[b]	6.000	18.000
Condition	Pillai's Trace	.000	.[b]	.000	.000
	Wilks' Lambda	1.000	.[b]	.000	20.500
	Hotelling's Trace	.000	.[b]	.000	2.000
	Roy's Largest Root	.000	.000[b]	6.000	17.000
PathType	Pillai's Trace	.000	.[b]	.000	.000
	Wilks' Lambda	1.000	.[b]	.000	20.500
	Hotelling's Trace	.000	.[b]	.000	2.000
	Roy's Largest Root	.000	.000[b]	6.000	17.000
NavigationType	Pillai's Trace	.000	.[b]	.000	.000
	Wilks' Lambda	1.000	.[b]	.000	20.500
	Hotelling's Trace	.000	.[b]	.000	2.000
	Roy's Largest Root	.000	.000[b]	6.000	17.000
Condition * PathType	Pillai's Trace	.000	.[b]	.000	.000
	Wilks' Lambda	1.000	.[b]	.000	20.500
	Hotelling's Trace	.000	.[b]	.000	2.000
	Roy's Largest Root	.000	.000[b]	6.000	17.000
Condition * NavigationType	Pillai's Trace	.000	.[b]	.000	.000
	Wilks' Lambda	1.000	.[b]	.000	20.500
	Hotelling's Trace	.000	.[b]	.000	2.000
	Roy's Largest Root	.000	.000[b]	6.000	17.000
PathType * NavigationType	Pillai's Trace	.000	.[b]	.000	.000
	Wilks' Lambda	1.000	.[b]	.000	20.500
	Hotelling's Trace	.000	.[b]	.000	2.000
	Roy's Largest Root	.000	.000[b]	6.000	17.000
Condition * PathType * NavigationType	Pillai's Trace	.000	.[b]	.000	.000
	Wilks' Lambda	1.000	.[b]	.000	20.500
	Hotelling's Trace	.000	.[b]	.000	2.000
	Roy's Largest Root	.000	.000[b]	6.000	17.000

Multivariate Tests[a]

Effect		Sig.	Partial Eta Squared	Noncent. Parameter
Intercept	Pillai's Trace	.000	.998	8556.552
	Wilks' Lambda	.000	.998	8556.552
	Hotelling's Trace	.000	.998	8556.552
	Roy's Largest Root	.000	.998	8556.552
Condition	Pillai's Trace	.	.	.
	Wilks' Lambda	.	.	.
	Hotelling's Trace	.	.	.
	Roy's Largest Root	1.000	.000	.000
PathType	Pillai's Trace	.	.	.
	Wilks' Lambda	.	.	.
	Hotelling's Trace	.	.	.
	Roy's Largest Root	1.000	.000	.000
NavigationType	Pillai's Trace	.	.	.
	Wilks' Lambda	.	.	.
	Hotelling's Trace	.	.	.
	Roy's Largest Root	1.000	.000	.000
Condition * PathType	Pillai's Trace	.	.	.
	Wilks' Lambda	.	.	.
	Hotelling's Trace	.	.	.
	Roy's Largest Root	1.000	.000	.000
Condition * NavigationType	Pillai's Trace	.	.	.
	Wilks' Lambda	.	.	.
	Hotelling's Trace	.	.	.
	Roy's Largest Root	1.000	.000	.000
PathType * NavigationType	Pillai's Trace	.	.	.
	Wilks' Lambda	.	.	.
	Hotelling's Trace	.	.	.
	Roy's Largest Root	1.000	.000	.000
Condition * PathType * NavigationType	Pillai's Trace	.	.	.
	Wilks' Lambda	.	.	.
	Hotelling's Trace	.	.	.
	Roy's Largest Root	1.000	.000	.000

Multivariate Tests[a]

Effect		Observed Power[c]
Intercept	Pillai's Trace	1.000
	Wilks' Lambda	1.000
	Hotelling's Trace	1.000
	Roy's Largest Root	1.000
Condition	Pillai's Trace	.
	Wilks' Lambda	.
	Hotelling's Trace	.
	Roy's Largest Root	.050
PathType	Pillai's Trace	.
	Wilks' Lambda	.
	Hotelling's Trace	.
	Roy's Largest Root	.050
NavigationType	Pillai's Trace	.
	Wilks' Lambda	.
	Hotelling's Trace	.
	Roy's Largest Root	.050
Condition * PathType	Pillai's Trace	.
	Wilks' Lambda	.
	Hotelling's Trace	.
	Roy's Largest Root	.050
Condition * NavigationType	Pillai's Trace	.
	Wilks' Lambda	.
	Hotelling's Trace	.
	Roy's Largest Root	.050
PathType * NavigationType	Pillai's Trace	.
	Wilks' Lambda	.
	Hotelling's Trace	.
	Roy's Largest Root	.050
Condition * PathType * NavigationType	Pillai's Trace	.
	Wilks' Lambda	.
	Hotelling's Trace	.
	Roy's Largest Root	.050

a. Design: Intercept + Condition + PathType + NavigationType + Condition * PathType + Condition * NavigationType + PathType * NavigationType + Condition * PathType * NavigationType

b. Exact statistic

c. Computed using alpha =

Levene's Test of Equality of Error Variances[a]

		Levene Statistic	df1	df2	Sig.
AvgAttention	Based on Mean	2.942	3	23	.054
	Based on Median	1.098	3	23	.370
	Based on Median and with adjusted df	1.098	3	10.699	.392
	Based on trimmed mean	2.722	3	23	.068
TimeSpent	Based on Mean	1.579	3	23	.222
	Based on Median	.551	3	23	.653
	Based on Median and with adjusted df	.551	3	16.833	.655
	Based on trimmed mean	1.360	3	23	.280
AvgDistance	Based on Mean	1.050	3	23	.389
	Based on Median	.719	3	23	.551
	Based on Median and with adjusted df	.719	3	18.756	.553
	Based on trimmed mean	1.045	3	23	.392
Sandbox	Based on Mean	3.292	3	23	.039
	Based on Median	1.395	3	23	.270
	Based on Median and with adjusted df	1.395	3	15.828	.281
	Based on trimmed mean	3.070	3	23	.048
CognitiveAssessment	Based on Mean	1.838	3	23	.168
	Based on Median	.996	3	23	.413
	Based on Median and with adjusted df	.996	3	19.602	.416
	Based on trimmed mean	1.810	3	23	.173
AvgSpatialAngleError	Based on Mean	2.836	3	23	.060
	Based on Median	.897	3	23	.458
	Based on Median and with adjusted df	.897	3	11.255	.473
	Based on trimmed mean	2.512	3	23	.084

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Condition + PathType + NavigationType + Condition * PathType + Condition * NavigationType + PathType * NavigationType + Condition * PathType * NavigationType

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square
Corrected Model	AvgAttention	295.182[a]	3	98.394
	TimeSpent	12.334[b]	3	4.111
	AvgDistance	94.848[c]	3	31.616
	Sandbox	55.399[d]	3	18.466
	CognitiveAssessment	88.606[e]	3	29.535
	AvgSpatialAngleError	1696.878[f]	3	565.626
Intercept	AvgAttention	206862.108	1	206862.108
	TimeSpent	2631.382	1	2631.382
	AvgDistance	935.608	1	935.608
	Sandbox	1188.275	1	1188.275
	CognitiveAssessment	5758.744	1	5758.744
	AvgSpatialAngleError	21381.466	1	21381.466
Condition	AvgAttention	.000	0	.
	TimeSpent	.000	0	.
	AvgDistance	.000	0	.
	Sandbox	.000	0	.
	CognitiveAssessment	.000	0	.
	AvgSpatialAngleError	.000	0	.
PathType	AvgAttention	.000	0	.
	TimeSpent	.000	0	.
	AvgDistance	.000	0	.
	Sandbox	.000	0	.
	CognitiveAssessment	.000	0	.
	AvgSpatialAngleError	.000	0	.
NavigationType	AvgAttention	.000	0	.
	TimeSpent	.000	0	.
	AvgDistance	.000	0	.
	Sandbox	.000	0	.
	CognitiveAssessment	.000	0	.
	AvgSpatialAngleError	.000	0	.
Condition * PathType	AvgAttention	.000	0	.
	TimeSpent	.000	0	.

Tests of Between-Subjects Effects

Source	Dependent Variable	F	Sig.	Partial Eta Squared
Corrected Model	AvgAttention	1.791	.177	.189
	TimeSpent	8.413	.001	.523
	AvgDistance	35.481	.000	.822
	Sandbox	1.401	.268	.155
	CognitiveAssessment	3.179	.043	.293
	AvgSpatialAngleError	3.092	.047	.287
Intercept	AvgAttention	3764.515	.000	.994
	TimeSpent	5384.730	.000	.996
	AvgDistance	1049.975	.000	.979
	Sandbox	90.164	.000	.797
	CognitiveAssessment	619.827	.000	.964
	AvgSpatialAngleError	116.891	.000	.836
Condition	AvgAttention	.	.	.000
	TimeSpent	.	.	.000
	AvgDistance	.	.	.000
	Sandbox	.	.	.000
	CognitiveAssessment	.	.	.000
	AvgSpatialAngleError	.	.	.000
PathType	AvgAttention	.	.	.000
	TimeSpent	.	.	.000
	AvgDistance	.	.	.000
	Sandbox	.	.	.000
	CognitiveAssessment	.	.	.000
	AvgSpatialAngleError	.	.	.000
NavigationType	AvgAttention	.	.	.000
	TimeSpent	.	.	.000
	AvgDistance	.	.	.000
	Sandbox	.	.	.000
	CognitiveAssessment	.	.	.000
	AvgSpatialAngleError	.	.	.000
Condition * PathType	AvgAttention	.	.	.000
	TimeSpent	.	.	.000

Tests of Between-Subjects Effects

Source	Dependent Variable	Noncent. Parameter	Observed Power[g]
Corrected Model	**AvgAttention**	5.372	.404
	TimeSpent	25.240	.982
	AvgDistance	106.443	1.000
	Sandbox	4.204	.322
	CognitiveAssessment	9.537	.657
	AvgSpatialAngleError	9.277	.644
Intercept	**AvgAttention**	3764.515	1.000
	TimeSpent	5384.730	1.000
	AvgDistance	1049.975	1.000
	Sandbox	90.164	1.000
	CognitiveAssessment	619.827	1.000
	AvgSpatialAngleError	116.891	1.000
Condition	**AvgAttention**	.000	.
	TimeSpent	.000	.
	AvgDistance	.000	.
	Sandbox	.000	.
	CognitiveAssessment	.000	.
	AvgSpatialAngleError	.000	.
PathType	**AvgAttention**	.000	.
	TimeSpent	.000	.
	AvgDistance	.000	.
	Sandbox	.000	.
	CognitiveAssessment	.000	.
	AvgSpatialAngleError	.000	.
NavigationType	**AvgAttention**	.000	.
	TimeSpent	.000	.
	AvgDistance	.000	.
	Sandbox	.000	.
	CognitiveAssessment	.000	.
	AvgSpatialAngleError	.000	.
Condition * PathType	**AvgAttention**	.000	.
	TimeSpent	.000	.

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square
	AvgDistance	.000	0	.
	Sandbox	.000	0	.
	CognitiveAssessment	.000	0	.
	AvgSpatialAngleError	.000	0	.
Condition * NavigationType	AvgAttention	.000	0	.
	TimeSpent	.000	0	.
	AvgDistance	.000	0	.
	Sandbox	.000	0	.
	CognitiveAssessment	.000	0	.
	AvgSpatialAngleError	.000	0	.
PathType * NavigationType	AvgAttention	.000	0	.
	TimeSpent	.000	0	.
	AvgDistance	.000	0	.
	Sandbox	.000	0	.
	CognitiveAssessment	.000	0	.
	AvgSpatialAngleError	.000	0	.
Condition * PathType * NavigationType	AvgAttention	.000	0	.
	TimeSpent	.000	0	.
	AvgDistance	.000	0	.
	Sandbox	.000	0	.
	CognitiveAssessment	.000	0	.
	AvgSpatialAngleError	.000	0	.
Error	AvgAttention	1263.862	23	54.951
	TimeSpent	11.240	23	.489
	AvgDistance	20.495	23	.891
	Sandbox	303.119	23	13.179
	CognitiveAssessment	213.690	23	9.291
	AvgSpatialAngleError	4207.123	23	182.918
Total	AvgAttention	208855.410	27	
	TimeSpent	2670.926	27	
	AvgDistance	1077.713	27	
	Sandbox	1532.000	27	
	CognitiveAssessment	6081.000	27	
	AvgSpatialAngleError	27251.580	27	
Corrected Total	AvgAttention	1559.044	26	
	TimeSpent	23.573	26	
	AvgDistance	115.343	26	

Tests of Between-Subjects Effects

Source	Dependent Variable	F	Sig.	Partial Eta Squared
	AvgDistance	.	.	.000
	Sandbox	.	.	.000
	CognitiveAssessment	.	.	.000
	AvgSpatialAngleError	.	.	.000
Condition * NavigationType	AvgAttention	.	.	.000
	TimeSpent	.	.	.000
	AvgDistance	.	.	.000
	Sandbox	.	.	.000
	CognitiveAssessment	.	.	.000
	AvgSpatialAngleError	.	.	.000
PathType * NavigationType	AvgAttention	.	.	.000
	TimeSpent	.	.	.000
	AvgDistance	.	.	.000
	Sandbox	.	.	.000
	CognitiveAssessment	.	.	.000
	AvgSpatialAngleError	.	.	.000
Condition * PathType * NavigationType	AvgAttention	.	.	.000
	TimeSpent	.	.	.000
	AvgDistance	.	.	.000
	Sandbox	.	.	.000
	CognitiveAssessment	.	.	.000
	AvgSpatialAngleError	.	.	.000
Error	AvgAttention			
	TimeSpent			
	AvgDistance			
	Sandbox			
	CognitiveAssessment			
	AvgSpatialAngleError			
Total	AvgAttention			
	TimeSpent			
	AvgDistance			
	Sandbox			
	CognitiveAssessment			
	AvgSpatialAngleError			
Corrected Total	AvgAttention			
	TimeSpent			
	AvgDistance			

Tests of Between-Subjects Effects

Source	Dependent Variable	Noncent. Parameter	Observed Power[g]
	AvgDistance	.000	.
	Sandbox	.000	.
	CognitiveAssessment	.000	.
	AvgSpatialAngleError	.000	.
Condition * NavigationType	AvgAttention	.000	.
	TimeSpent	.000	.
	AvgDistance	.000	.
	Sandbox	.000	.
	CognitiveAssessment	.000	.
	AvgSpatialAngleError	.000	.
PathType * NavigationType	AvgAttention	.000	.
	TimeSpent	.000	.
	AvgDistance	.000	.
	Sandbox	.000	.
	CognitiveAssessment	.000	.
	AvgSpatialAngleError	.000	.
Condition * PathType * NavigationType	AvgAttention	.000	.
	TimeSpent	.000	.
	AvgDistance	.000	.
	Sandbox	.000	.
	CognitiveAssessment	.000	.
	AvgSpatialAngleError	.000	.
Error	AvgAttention		
	TimeSpent		
	AvgDistance		
	Sandbox		
	CognitiveAssessment		
	AvgSpatialAngleError		
Total	AvgAttention		
	TimeSpent		
	AvgDistance		
	Sandbox		
	CognitiveAssessment		
	AvgSpatialAngleError		
Corrected Total	AvgAttention		
	TimeSpent		
	AvgDistance		

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square
	Sandbox	358.519	26	
	CognitiveAssessment	302.296	26	
	AvgSpatialAngleError	5904.001	26	

Tests of Between-Subjects Effects

Source	Dependent Variable	F	Sig.	Partial Eta Squared
	Sandbox			
	CognitiveAssessment			
	AvgSpatialAngleError			

Tests of Between-Subjects Effects

Source	Dependent Variable	Noncent. Parameter	Observed Power[g]
	Sandbox		
	CognitiveAssessment		
	AvgSpatialAngleError		

a. R Squared = .189 (Adjusted R Squared = .084)

b. R Squared = .523 (Adjusted R Squared = .461)

c. R Squared = .822 (Adjusted R Squared = .799)

d. R Squared = .155 (Adjusted R Squared = .044)

e. R Squared = .293 (Adjusted R Squared = .201)

f. R Squared = .287 (Adjusted R Squared = .194)

g. Computed using alpha =

Custom Hypothesis Tests

Univariate Test Results[a]

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a. Cannot form an estimable function using the specified contrast. Hypothesis tests cannot be computed.

Post Hoc Tests

Condition

Multiple Comparisons

Bonferroni

Dependent Variable	(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error
AvgAttention	Long Teleportation	Long Locomotion	-6.8002095	3.96234171
		Short Teleportation	-8.3996181	4.12413601
		Short Locomotion	-7.2383236	3.96234171
	Long Locomotion	Long Teleportation	6.80020945	3.96234171
		Short Teleportation	-1.5994086	4.12413601
		Short Locomotion	-.43811417	3.96234171
	Short Teleportation	Long Teleportation	8.39961808	4.12413601
		Long Locomotion	1.59940863	4.12413601
		Short Locomotion	1.16129445	4.12413601
	Short Locomotion	Long Teleportation	7.23832363	3.96234171
		Long Locomotion	.438114174	3.96234171
		Short Teleportation	-1.1612945	4.12413601
TimeSpent	Long Teleportation	Long Locomotion	-1.601857*	.373659428
		Short Teleportation	-.25029983	.388917064
		Short Locomotion	-.00242757	.373659428

Multiple Comparisons

Bonferroni

				95% …
Dependent Variable	(I) Condition	(J) Condition	Sig.	Lower Bound
AvgAttention	Long Teleportation	Long Locomotion	.597	-18.236573
		Short Teleportation	.320	-20.302962
		Short Locomotion	.484	-18.674687
	Long Locomotion	Long Teleportation	.597	-4.6361539
		Short Teleportation	1.000	-13.502753
		Short Locomotion	1.000	-11.874478
	Short Teleportation	Long Teleportation	.320	-3.5037263
		Long Locomotion	1.000	-10.303936
		Short Locomotion	1.000	-10.742050
	Short Locomotion	Long Teleportation	.484	-4.1980398
		Long Locomotion	1.000	-10.998249
		Short Teleportation	1.000	-13.064639
TimeSpent	Long Teleportation	Long Locomotion	.002	-2.6803370
		Short Teleportation	1.000	-1.3728171
		Short Locomotion	1.000	-1.0809072

Multiple Comparisons

Bonferroni

			95% Confidence .
Dependent Variable	(I) Condition	(J) Condition	Upper Bound
AvgAttention	Long Teleportation	Long Locomotion	4.63615392
		Short Teleportation	3.50372632
		Short Locomotion	4.19803975
	Long Locomotion	Long Teleportation	18.2365728
		Short Teleportation	10.3039358
		Short Locomotion	10.9982492
	Short Teleportation	Long Teleportation	20.3029625
		Long Locomotion	13.5027530
		Short Locomotion	13.0646388
	Short Locomotion	Long Teleportation	18.6746870
		Long Locomotion	11.8744776
		Short Teleportation	10.7420499
TimeSpent	Long Teleportation	Long Locomotion	-.52337761
		Short Teleportation	.87221740
		Short Locomotion	1.07605210

Multiple Comparisons

Bonferroni

Dependent Variable	(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error
	Long Locomotion	Long Teleportation	1.6018573*	.373659428
		Short Teleportation	1.3515575*	.388917064
		Short Locomotion	1.5994297*	.373659428
	Short Teleportation	Long Teleportation	.25029983	.388917064
		Long Locomotion	-1.351557*	.388917064
		Short Locomotion	.24787226	.388917064
	Short Locomotion	Long Teleportation	.00242757	.373659428
		Long Locomotion	-1.599430*	.373659428
		Short Teleportation	-.24787226	.388917064
AvgDistance	Long Teleportation	Long Locomotion	-2.445774*	.504572241
		Short Teleportation	2.3361588*	.525175439
		Short Locomotion	1.8434141*	.504572241
	Long Locomotion	Long Teleportation	2.4457738*	.504572241
		Short Teleportation	4.7819326*	.525175439
		Short Locomotion	4.2891878*	.504572241
	Short Teleportation	Long Teleportation	-2.336159*	.525175439
		Long Locomotion	-4.781933*	.525175439
		Short Locomotion	-.49274475	.525175439
	Short Locomotion	Long Teleportation	-1.843414*	.504572241
		Long Locomotion	-4.289188*	.504572241
		Short Teleportation	.492744745	.525175439
Sandbox	Long Teleportation	Long Locomotion	-2.71	1.940
		Short Teleportation	-3.88	2.020
		Short Locomotion	-2.86	1.940
	Long Locomotion	Long Teleportation	2.71	1.940
		Short Teleportation	-1.17	2.020
		Short Locomotion	-.14	1.940
	Short Teleportation	Long Teleportation	3.88	2.020
		Long Locomotion	1.17	2.020
		Short Locomotion	1.02	2.020
	Short Locomotion	Long Teleportation	2.86	1.940
		Long Locomotion	.14	1.940
		Short Teleportation	-1.02	2.020

Multiple Comparisons

Bonferroni

				95% …
Dependent Variable	(I) Condition	(J) Condition	Sig.	Lower Bound
	Long Locomotion	Long Teleportation	.002	.52337761
		Short Teleportation	.012	.22904022
		Short Locomotion	.002	.52095004
	Short Teleportation	Long Teleportation	1.000	-.87221740
		Long Locomotion	.012	-2.4740747
		Short Locomotion	1.000	-.87464497
	Short Locomotion	Long Teleportation	1.000	-1.0760521
		Long Locomotion	.002	-2.6779094
		Short Teleportation	1.000	-1.3703895
AvgDistance	Long Teleportation	Long Locomotion	.000	-3.9021023
		Short Teleportation	.001	.820363992
		Short Locomotion	.008	.387085511
	Long Locomotion	Long Teleportation	.000	.989445167
		Short Teleportation	.000	3.26613774
		Short Locomotion	.000	2.83285926
	Short Teleportation	Long Teleportation	.001	-3.8519537
		Long Locomotion	.000	-6.2977274
		Short Locomotion	1.000	-2.0085396
	Short Locomotion	Long Teleportation	.008	-3.2997427
		Long Locomotion	.000	-5.7455164
		Short Teleportation	1.000	-1.0230501
Sandbox	Long Teleportation	Long Locomotion	1.000	-8.32
		Short Teleportation	.403	-9.71
		Short Locomotion	.927	-8.46
	Long Locomotion	Long Teleportation	1.000	-2.89
		Short Teleportation	1.000	-7.00
		Short Locomotion	1.000	-5.74
	Short Teleportation	Long Teleportation	.403	-1.95
		Long Locomotion	1.000	-4.66
		Short Locomotion	1.000	-4.81
	Short Locomotion	Long Teleportation	.927	-2.74
		Long Locomotion	1.000	-5.46
		Short Teleportation	1.000	-6.85

Multiple Comparisons

Bonferroni

Dependent Variable	(I) Condition	(J) Condition	95% Confidence . Upper Bound
	Long Locomotion	Long Teleportation	2.68033696
		Short Teleportation	2.47407469
		Short Locomotion	2.67790939
	Short Teleportation	Long Teleportation	1.37281707
		Long Locomotion	-.22904022
		Short Locomotion	1.37038950
	Short Locomotion	Long Teleportation	1.08090725
		Long Locomotion	-.52095004
		Short Teleportation	.87464497
AvgDistance	Long Teleportation	Long Locomotion	-.98944517
		Short Teleportation	3.85195369
		Short Locomotion	3.29974268
	Long Locomotion	Long Teleportation	3.90210234
		Short Teleportation	6.29772744
		Short Locomotion	5.74551643
	Short Teleportation	Long Teleportation	-.82036399
		Long Locomotion	-3.2661377
		Short Locomotion	1.02305010
	Short Locomotion	Long Teleportation	-.38708551
		Long Locomotion	-2.8328593
		Short Teleportation	2.00853960
Sandbox	Long Teleportation	Long Locomotion	2.89
		Short Teleportation	1.95
		Short Locomotion	2.74
	Long Locomotion	Long Teleportation	8.32
		Short Teleportation	4.66
		Short Locomotion	5.46
	Short Teleportation	Long Teleportation	9.71
		Long Locomotion	7.00
		Short Locomotion	6.85
	Short Locomotion	Long Teleportation	8.46
		Long Locomotion	5.74
		Short Teleportation	4.81

Multiple Comparisons

Bonferroni

Dependent Variable	(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error
CognitiveAssessment	Long Teleportation	Long Locomotion	-4.71*	1.629
		Short Teleportation	-3.12	1.696
		Short Locomotion	-3.86	1.629
	Long Locomotion	Long Teleportation	4.71*	1.629
		Short Teleportation	1.60	1.696
		Short Locomotion	.86	1.629
	Short Teleportation	Long Teleportation	3.12	1.696
		Long Locomotion	-1.60	1.696
		Short Locomotion	-.74	1.696
	Short Locomotion	Long Teleportation	3.86	1.629
		Long Locomotion	-.86	1.629
		Short Teleportation	.74	1.696
AvgSpatialAngleError	Long Teleportation	Long Locomotion	19.8714	7.22927
		Short Teleportation	9.4143	7.52447
		Short Locomotion	17.5571	7.22927
	Long Locomotion	Long Teleportation	-19.8714	7.22927
		Short Teleportation	-10.4571	7.52447
		Short Locomotion	-2.3143	7.22927
	Short Teleportation	Long Teleportation	-9.4143	7.52447
		Long Locomotion	10.4571	7.52447
		Short Locomotion	8.1429	7.52447
	Short Locomotion	Long Teleportation	-17.5571	7.22927
		Long Locomotion	2.3143	7.22927
		Short Teleportation	-8.1429	7.52447

Multiple Comparisons

Bonferroni

				95% …
Dependent Variable	(I) Condition	(J) Condition	Sig.	Lower Bound
CognitiveAssessment	Long Teleportation	Long Locomotion	.049	-9.42
		Short Teleportation	.473	-8.01
		Short Locomotion	.160	-8.56
	Long Locomotion	Long Teleportation	.049	.01
		Short Teleportation	1.000	-3.30
		Short Locomotion	1.000	-3.85
	Short Teleportation	Long Teleportation	.473	-1.78
		Long Locomotion	1.000	-6.49
		Short Locomotion	1.000	-5.63
	Short Locomotion	Long Teleportation	.160	-.85
		Long Locomotion	1.000	-5.56
		Short Teleportation	1.000	-4.16
AvgSpatialAngleError	Long Teleportation	Long Locomotion	.069	-.9942
		Short Teleportation	1.000	-12.3033
		Short Locomotion	.140	-3.3084
	Long Locomotion	Long Teleportation	.069	-40.7370
		Short Teleportation	1.000	-32.1747
		Short Locomotion	1.000	-23.1799
	Short Teleportation	Long Teleportation	1.000	-31.1319
		Long Locomotion	1.000	-11.2605
		Short Locomotion	1.000	-13.5747
	Short Locomotion	Long Teleportation	.140	-38.4227
		Long Locomotion	1.000	-18.5513
		Short Teleportation	1.000	-29.8605

Multiple Comparisons

Bonferroni

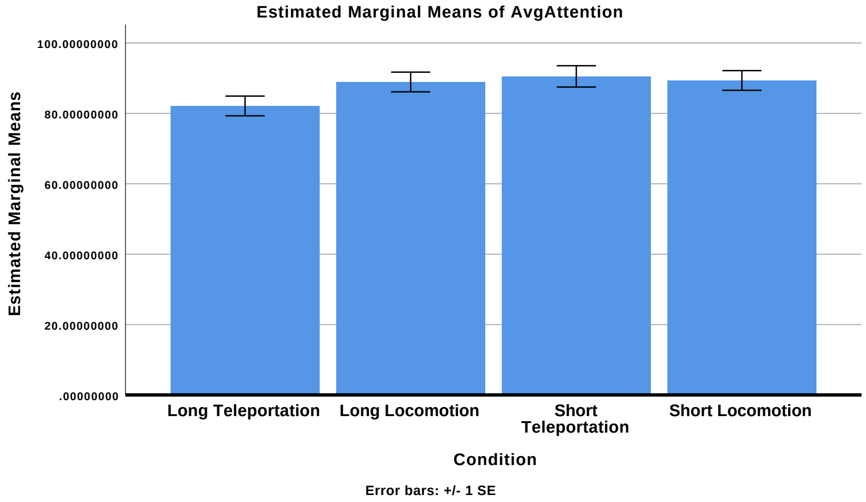
			95% Confidence .
Dependent Variable	(I) Condition	(J) Condition	Upper Bound
CognitiveAssessment	Long Teleportation	Long Locomotion	-.01
		Short Teleportation	1.78
		Short Locomotion	.85
	Long Locomotion	Long Teleportation	9.42
		Short Teleportation	6.49
		Short Locomotion	5.56
	Short Teleportation	Long Teleportation	8.01
		Long Locomotion	3.30
		Short Locomotion	4.16
	Short Locomotion	Long Teleportation	8.56
		Long Locomotion	3.85
		Short Teleportation	5.63
AvgSpatialAngleError	Long Teleportation	Long Locomotion	40.7370
		Short Teleportation	31.1319
		Short Locomotion	38.4227
	Long Locomotion	Long Teleportation	.9942
		Short Teleportation	11.2605
		Short Locomotion	18.5513
	Short Teleportation	Long Teleportation	12.3033
		Long Locomotion	32.1747
		Short Locomotion	29.8605
	Short Locomotion	Long Teleportation	3.3084
		Long Locomotion	23.1799
		Short Teleportation	13.5747

Based on observed means.
The error term is Mean Square(Error) = 182.918.

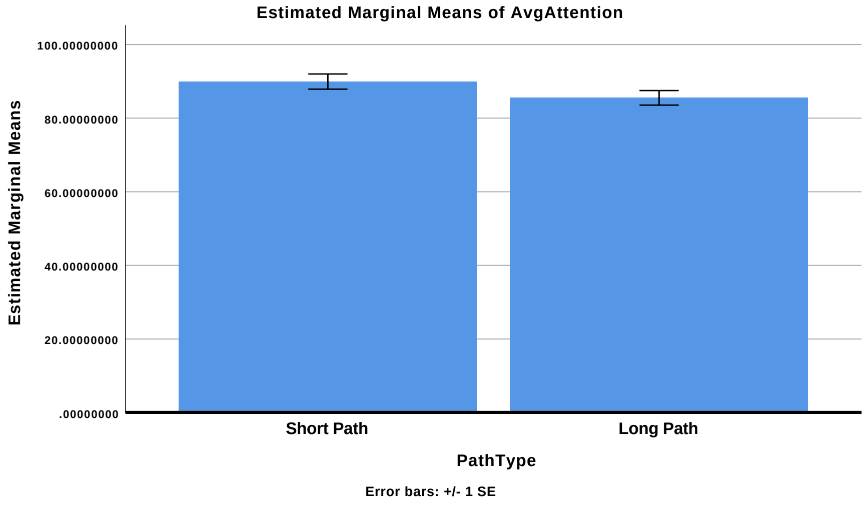
*. The mean difference is significant at the

Profile Plots

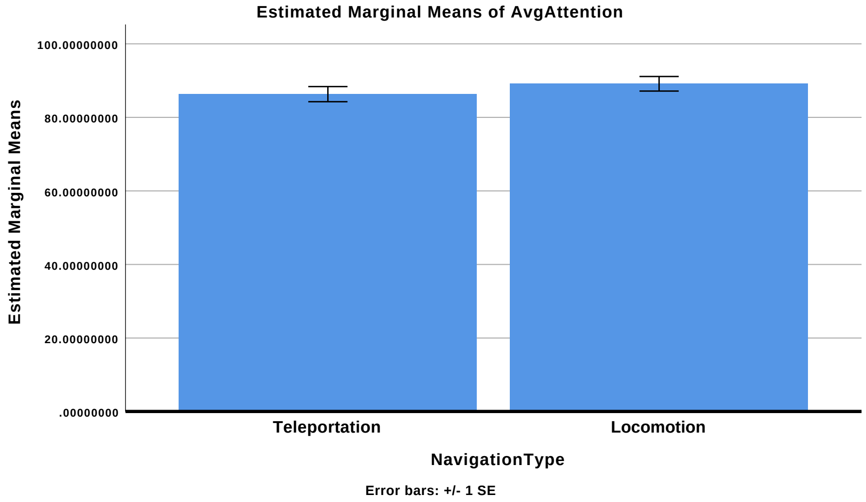
AvgAttention



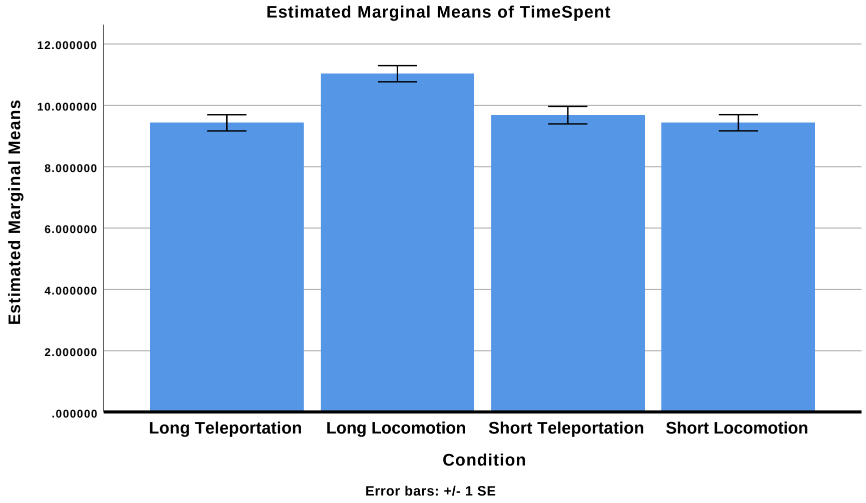
Estimated Marginal Means of AvgAttention
Estimated Marginal Means
100.00000000
80.00000000
60.00000000
40.00000000
20.00000000
.00000000
Long Teleportation
Long Locomotion
Short Teleportation
Short Locomotion
Condition
Error bars: +/- 1 SE

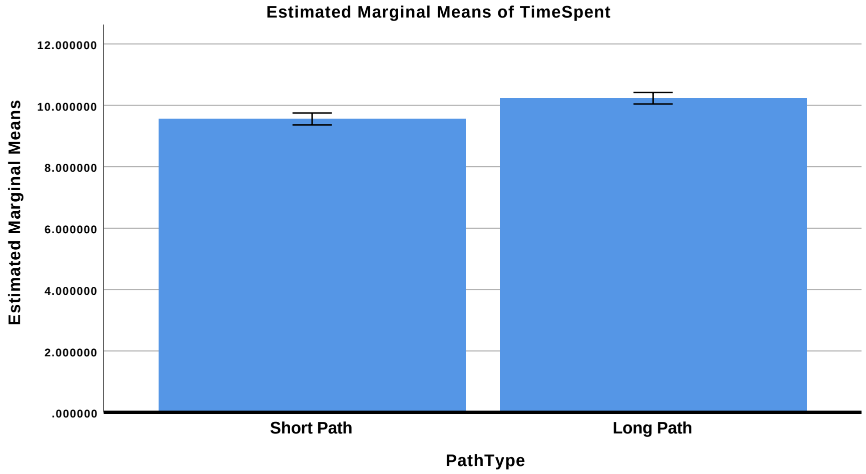


Estimated Marginal Means of AvgAttention
Estimated Marginal Means
100.00000000
80.00000000
60.00000000
40.00000000
20.00000000
.00000000
Short Path
Long Path
PathType
Error bars: +/- 1 SE

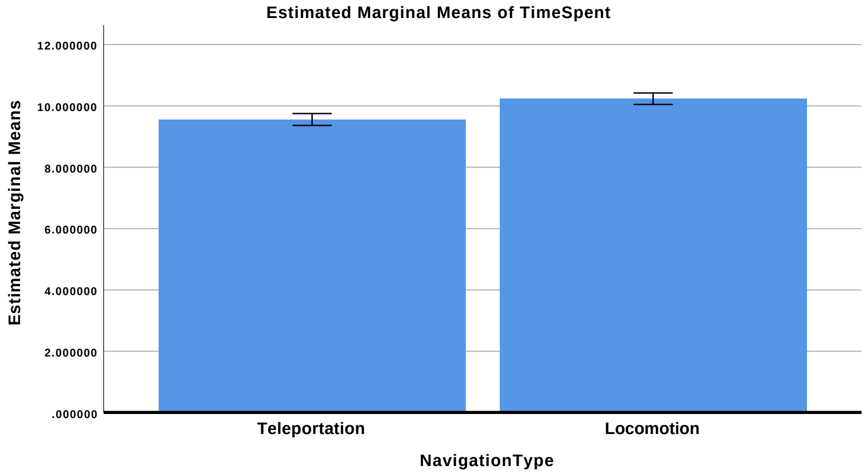

Estimated Marginal Means of AvgAttention
Estimated Marginal Means
100.00000000
80.00000000
60.00000000
40.00000000
20.00000000
.00000000
Teleportation
Locomotion
NavigationType
Error bars: +/- 1 SE

TimeSpent


Estimated Marginal Means of TimeSpent
Estimated Marginal Means
12.000000
10.000000
8.000000
6.000000
4.000000
2.000000
.000000
Long Teleportation
Long Locomotion
Short Teleportation
Short Locomotion
Condition
Error bars: +/- 1 SE

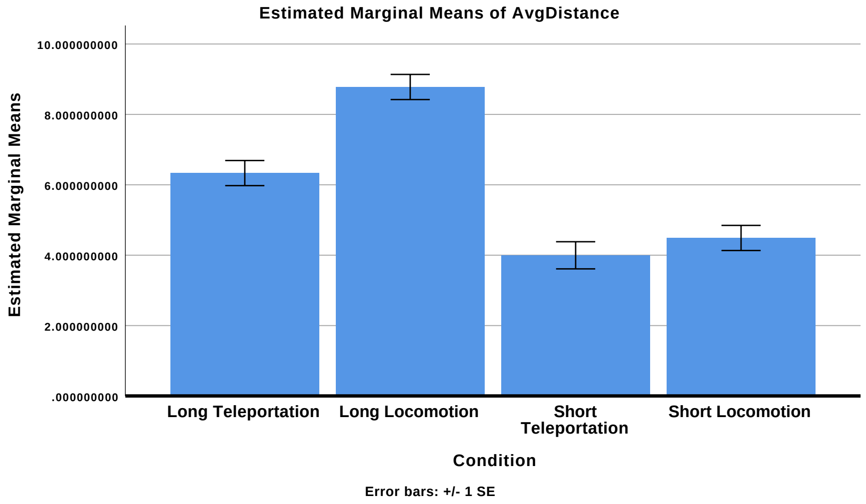

Estimated Marginal Means of TimeSpent

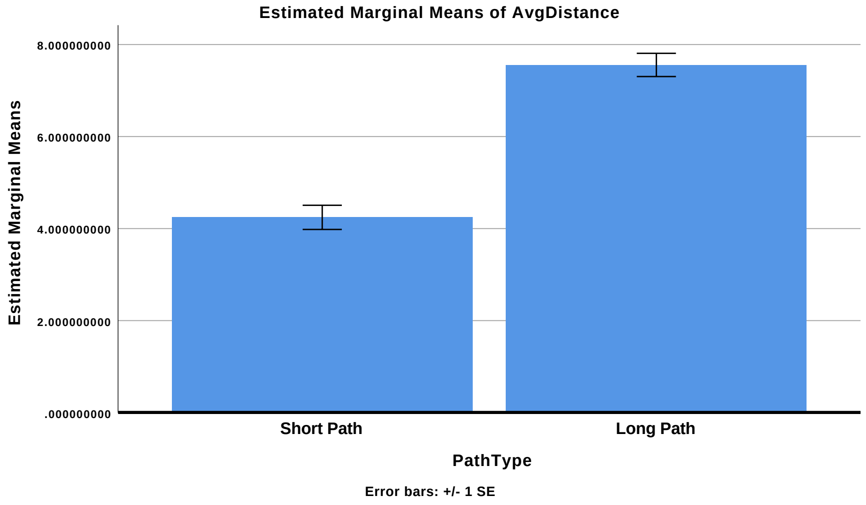
Error bars: +/- 1 SE

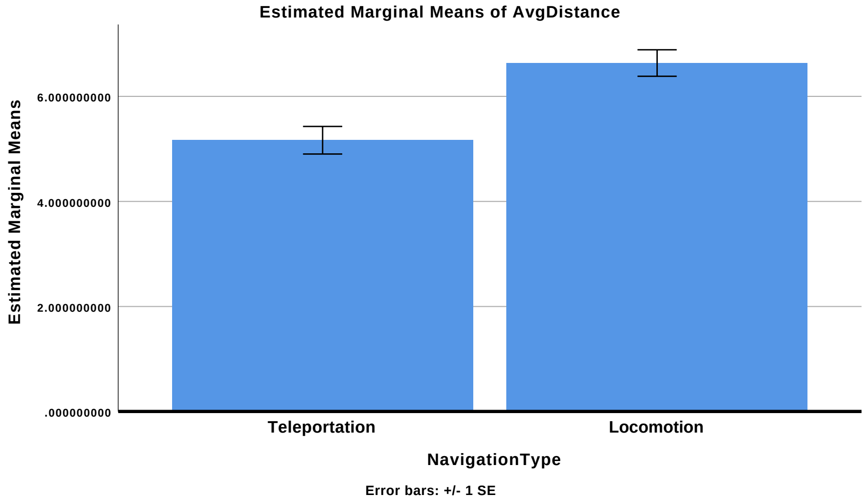

Estimated Marginal Means of TimeSpent

Error bars: +/- 1 SE

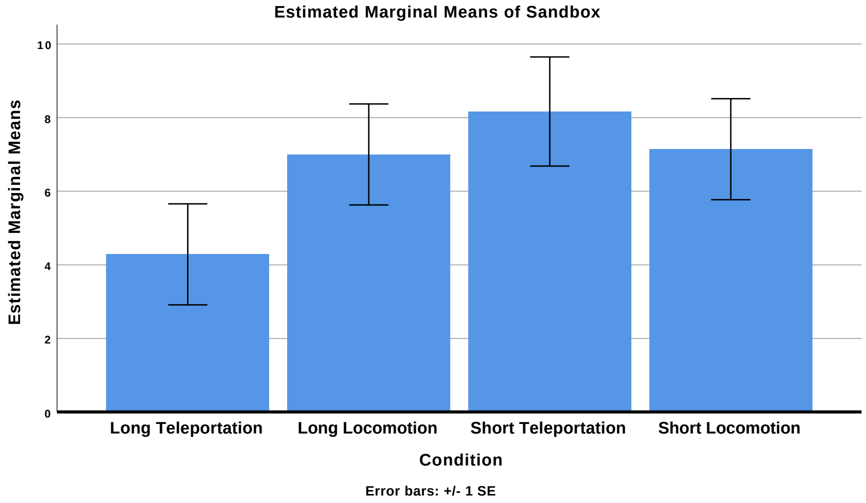
AvgDistance

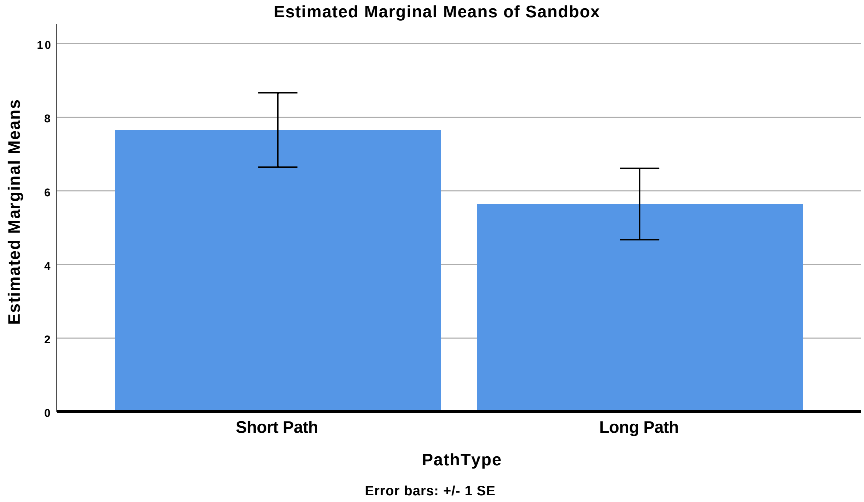

Estimated Marginal Means of AvgDistance
Estimated Marginal Means
10.000000000
8.000000000
6.000000000
4.000000000
2.000000000
.000000000
Long Teleportation
Long Locomotion
Short Teleportation
Short Locomotion
Condition
Error bars: +/- 1 SE

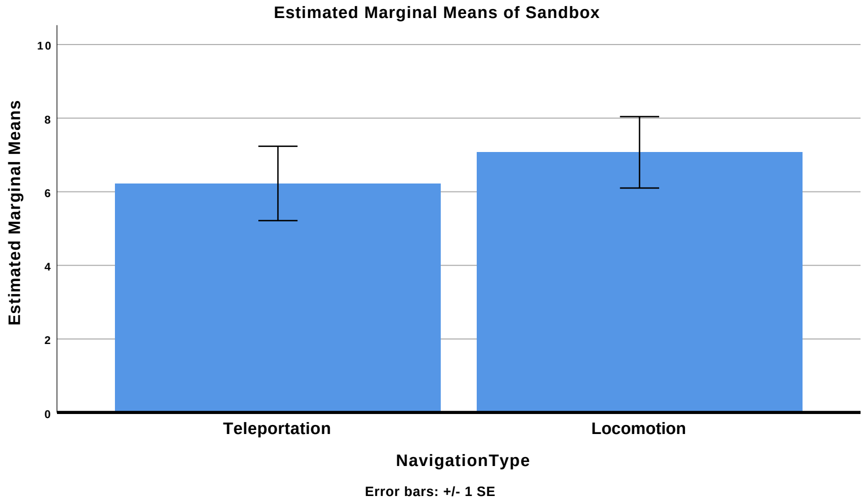

Estimated Marginal Means of AvgDistance
Estimated Marginal Means
8.000000000
6.000000000
4.000000000
2.000000000
.000000000
Short Path
Long Path
PathType
Error bars: +/- 1 SE


Estimated Marginal Means of AvgDistance
Estimated Marginal Means
6.000000000
4.000000000
2.000000000
.000000000
Teleportation
Locomotion
NavigationType
Error bars: +/- 1 SE

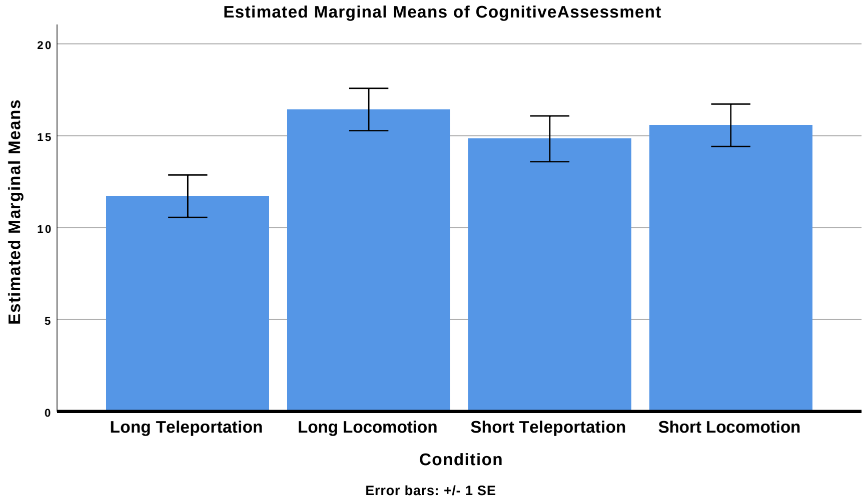
Sandbox

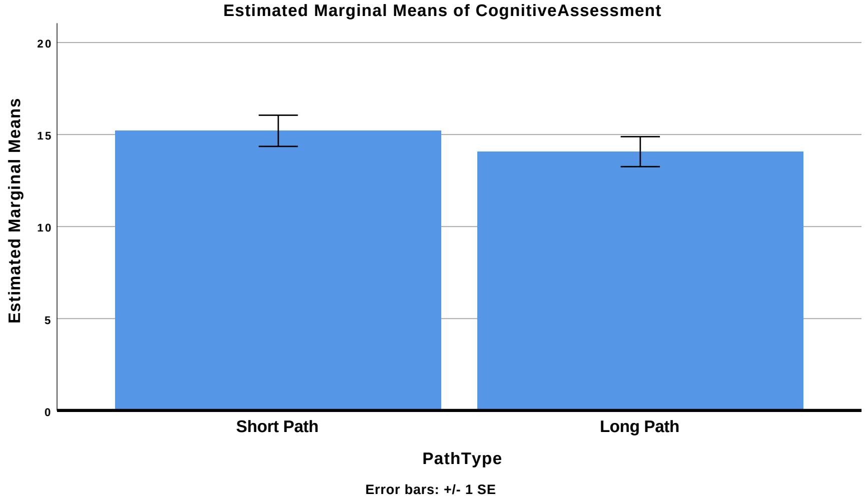

Estimated Marginal Means of Sandbox
Estimated Marginal Means
10
8
6
4
2
0
Long Teleportation
Long Locomotion
Short Teleportation
Short Locomotion
Condition
Error bars: +/- 1 SE

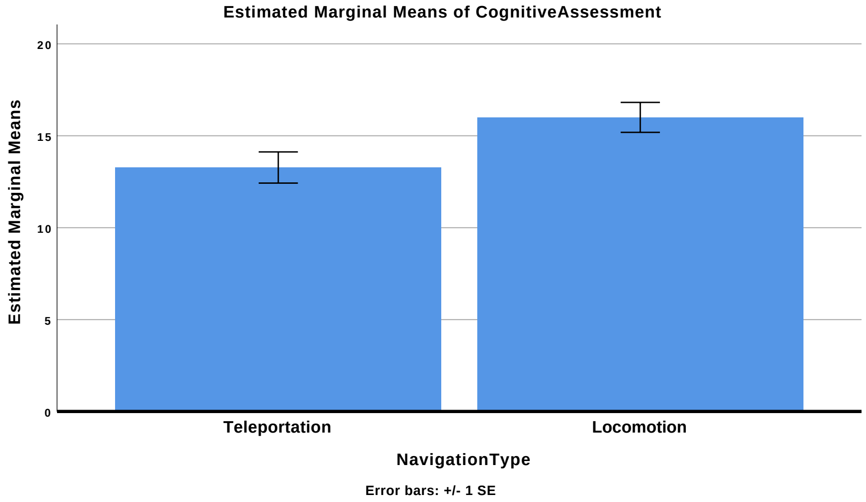




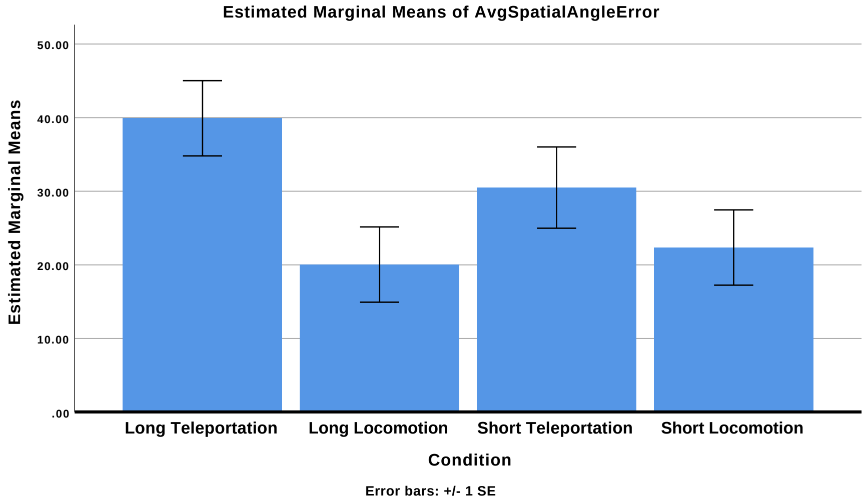
CognitiveAssessment

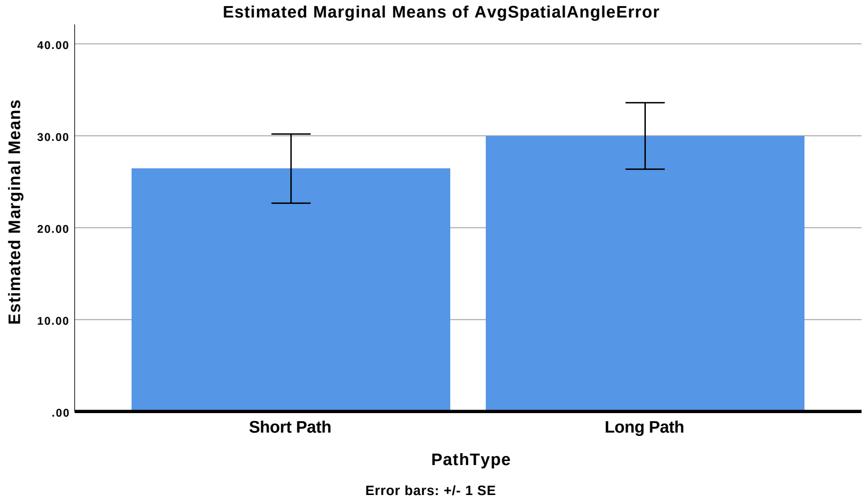

Estimated Marginal Means of CognitiveAssessment
Estimated Marginal Means
20
15
10
5
0
Long Teleportation
Long Locomotion
Short Teleportation
Short Locomotion
Condition
Error bars: +/- 1 SE

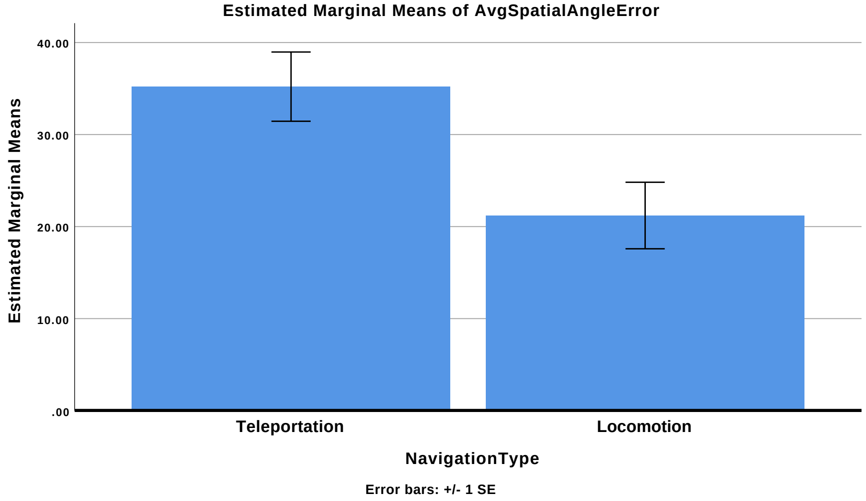

Estimated Marginal Means of CognitiveAssessment
Estimated Marginal Means
20
15
10
5
0
Short Path
Long Path
PathType
Error bars: +/- 1 SE



AvgSpatialAngleError




Estimated Marginal Means of AvgSpatialAngleError
Estimated Marginal Means
40.00
30.00
20.00
10.00
.00
Short Path
Long Path
PathType
Error bars: +/- 1 SE


Estimated Marginal Means of AvgSpatialAngleError
Estimated Marginal Means
40.00
30.00
20.00
10.00
.00
Teleportation
Locomotion
NavigationType
Error bars: +/- 1 SE

```
// Railscontroller.cs Script
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using System.IO;

public enum Pathway
{
    longrails, shortrails
}

public enum Kinesthetic
{
    teleportation, locomotion
}

public class RailsController : MonoBehaviour
{

    // Properties for experiment
    public string participant;
    public Pathway path;
    public Kinesthetic kinesthetic;
    public GameObject tracker;

    /**
     * Public
     **/

    public Camera player; // this is the VR camera
```

```
    public GameObject countDownPrefab;
    public int CounterTime;
    // Tombstone Planes
    public GameObject[] tombPlanes; // plane is a child object of
        tombstone

    /**
     * Private
     **/
    private GameObject currentPlane, cloneTimer, HitPlane;
    private float totalTime, remTime;
    private Vector2 playerPosition, pointPosition;
    private Vector3 timerPos;

    //Gets attention value from all tombstones
    [SerializeField]
    private List<string> attentionToPlane;
    [SerializeField]
    private List<string> pathInfo;
    private Vector3 playerPath;
    private string lastPath;

    private GameObject firstObject = null, secondObject = null; //This
        is only necessary for short and long rails.

    // record distance between tombstones
    private string inBtwDistance = "START\r\n";
    private bool written = false;

    // Use this for initialization
    void Start()
```

```
    {
        currentPlane = null;
        remTime = 0;
        totalTime = CounterTime * 50;
        countDownPrefab.GetComponent<countDownTimer>().timer =
            CounterTime;


        // Teleportation
        if (kinesthetic == Kinesthetic.teleportation)
        {
            tracker.SetActive(true);
            tracker.GetComponent<Laser_Controller >().enabled = true;
        }

        //Initialize path as
        lastPath = ””;
    }

    void FixedUpdate()
    {
        remTime = remTime - 1;

        // call function pathInformation
        playerPath.x = player.transform.position.x;
        playerPath.y = player.transform.position.y;
        playerPath.z = player.transform.position.z;
        if (lastPath != playerPath.ToString(”F2”))
        {

            //pathInfo.Add(playerPath.x.ToString() + ”,” + playerPath.y.
```

```
                    ToString() + ”,” + playerPath.z.ToString());
            inBtwDistance = inBtwDistance + playerPath.ToString(”F2”) +
                ”\n”;
        }
        lastPath = playerPath.ToString(”F2”);

        // Writes to file at the end of last tombstone
        if(written == false)
        {
            if (experimentOver() && remTime <= 0) // experiment is over
                and timer is zero!
            {
                WriteToFile();
                written = true; // flag true!
            }
        }

    }

    // Update is called once per frame
    void Update()
    {
        if (!experimentOver())
        {
            checkCollision();
        }
        else
        {
            if (remTime <= 0)
            {
                Destroy(cloneTimer);
```

```
            }

            Debug.LogError("Experiment is over!");
        }
    }

    public bool experimentOver()
    {
        for (int i = 0; i < tombPlanes.Length; i++)
        {
            if (tombPlanes[i].GetComponent<planeController>().visited == false)
            {
                return false;
            }
        }
        return true;
    }

    void checkCollision()
    {
        // If no object is currently being viewed then activate new tomb objects

        if (remTime <= 0.0f)
        {
            /** Destroy an already instantiated clock Timer **/
            Destroy(cloneTimer);
            ActivateObject();
        }
        else
```

```
        {
            // Do nothing!
        }
    }

    // This function checks the distance between player and one teleport point, a child object of plane
    // to activate tombstone text!
    private void Proximity(GameObject firstPlane)
    {
        float proximity;
        playerPosition.Set(player.transform.position.x, player.transform.position.z);
        pointPosition.Set(firstPlane.transform.GetChild(0).gameObject.transform.position.x, firstPlane.transform.GetChild(0).gameObject.transform.position.z);
        proximity = Vector3.Distance(playerPosition, pointPosition);
        if (proximity <= 0.15f && remTime <= 0.0f)
        {
            firstPlane.GetComponent<planeController>().Activate(); // activates text on tombstone
            firstPlane.GetComponent<planeController>().timeremaining = totalTime;
            remTime = totalTime;

            // Instantiates timer
            cloneTimer = Instantiate(countDownPrefab); //Instantiates a Timer when a tombstone is activated!
            cloneTimer.transform.position = new Vector3(player.transform.position.x, 1.75f, player.transform.position.z);
        }
```

```
    }

    private void Proximity(GameObject firstPlane, GameObject secondPlane)
    {
        Vector2 pointA = new Vector2(firstPlane.transform.GetChild(0).gameObject.transform.position.x, firstPlane.transform.GetChild(0).gameObject.transform.position.z);

        playerPosition.Set(player.transform.position.x, player.transform.position.z);

        // if Player is closer to first point object
        if (Vector3.Distance(playerPosition, pointA) <= 0.15f && remTime <= 0.0f)
        {
            firstPlane.GetComponent<planeController>().Activate(); // activates text on tombstone
            firstPlane.GetComponent<planeController>().timeremaining = totalTime;
            remTime = totalTime;

            // Instantiates timer
            cloneTimer = Instantiate(countDownPrefab); //Instantiates a Timer when a tombstone is activated!
            cloneTimer.GetComponent<countDownTimer>().applyRotation(firstPlane);
            cloneTimer.transform.position = new Vector3(firstPlane.transform.position.x, firstPlane.transform.position.y + 1.0f, firstPlane.transform.position.z);

```

```
                // Deactivate the teleport light on both points if one is already activated and reset the objects
                secondPlane.transform.GetChild(0).gameObject.SetActive(false);
                firstObject = null;
                secondObject = firstObject;

                //tag this position
                inBtwDistance = inBtwDistance + ”END\r\nSTART\r\n”;
            }
            // else if player is closer to second point object
            else if (secondPlane != null)
            {
                Vector2 pointB = new Vector2(secondPlane.transform.GetChild(0).gameObject.transform.position.x, secondPlane.transform.GetChild(0).gameObject.transform.position.z);
                if (Vector3.Distance(playerPosition, pointB) <= 0.15f && remTime <= 0.0f)
                {
                    secondPlane.GetComponent<planeController>().Activate(); // activates text on tombstone
                    secondPlane.GetComponent<planeController>().timeremaining = totalTime;
                    remTime = totalTime;

                    // Instantiates timer
                    cloneTimer = Instantiate(countDownPrefab); // Instantiates a Timer when a tombstone is activated!
                    cloneTimer.GetComponent<countDownTimer>().applyRotation(secondPlane);
                    cloneTimer.transform.position = new Vector3(secondPlane.
```

```
                    transform.position.x, secondPlane.transform.position.y+1.0f, secondPlane.transform.position.z);

                // Deactivate the teleport light on both points if one is activated
                firstPlane.transform.GetChild(0).gameObject.SetActive(false);

                firstObject = null;
                secondObject = firstObject;

                //tag this position
                inBtwDistance = inBtwDistance + ”END\r\nSTART\r\n”;
            }

        }
        else
        {
            // Do nothing
        }
    }

    private void ActivateObject()
    {
        int i = 0; // counter to count if all tombstiones are visited

        /*
        // This sets up the rail system
        if (path == Pathway.rails)
        {
            // Loop Through all Plane to determine which is current.
```

```
            bool setPlane = false;
            while (i < tombPlanes.Length && setPlane == false)
            {
                if (tombPlanes[i].GetComponent<planeController>().visited == true)
                {
                    i++;
                }
                else
                {
                    setPlane = true;
                }
            }

            currentPlane = tombPlanes[i];
            currentPlane.transform.GetChild(0).gameObject.SetActive(true); // Turn on location marker for next tombstone
            //Calls proximity function to activate tombstone text.
            Proximity(currentPlane);
        }
        */

        // This sets up the rail system
        if (path == Pathway.longrails)
        {

            float distance = 0.0f;
            Vector2 thisPoint = new Vector2(0, 0);
            if (firstObject == null && secondObject == null)
            {
                playerPosition.Set(player.transform.position.x, player.
```

```
            transform.position.z);
        // Loop Through all Plane to determine which the first
            farthest.
        for (i = 0; i < tombPlanes.Length; i++)
        {
            thisPoint.Set(tombPlanes[i].transform.position.x,
                tombPlanes[i].transform.position.z);
            if (Vector2.Distance(playerPosition, thisPoint) >
                distance && tombPlanes[i].GetComponent<
                planeController>().visited != true)
            {
                distance = Vector2.Distance(playerPosition,
                    thisPoint);
                firstObject = tombPlanes[i];
            }
        }

        // Loop Through all Plane to determine which the second
            farthest.
        distance = 0.0f;
        for (i = 0; i < tombPlanes.Length; i++)
        {
            //check that this object is not already chosen
            if (firstObject.transform.GetInstanceID() !=
                tombPlanes[i].transform.GetInstanceID() &&
                tombPlanes[i].GetComponent<planeController>().
                visited != true)
            {
                thisPoint.Set(tombPlanes[i].transform.position.x
                    , tombPlanes[i].transform.position.z);
                if (Vector2.Distance(playerPosition, thisPoint)
```

```
                           > distance)
                        {
                            distance = Vector2.Distance(playerPosition,
                                thisPoint);
                            secondObject = tombPlanes[i];
                        }
                    }
                }


                // Turn on location marker for next tombstones
                firstObject.transform.GetChild(0).gameObject.SetActive(
                    true);
                if (secondObject != null)
                {
                    secondObject.transform.GetChild(0).gameObject.
                        SetActive(true);
                }
            }
            else
            {
                //Calls proximity function to activate tombstone text.
                Proximity(firstObject, secondObject);
            }
        }
        // This sets up the short rails system
        else if (path == Pathway.shortrails)
        {

            float distance = 999.9f;
            Vector2 thisPoint = new Vector2(0, 0);
```

```
            if (firstObject == null && secondObject == null)
            {
                playerPosition.Set(player.transform.position.x, player.transform.position.z);
                // Loop Through all Plane to determine which the first farthest.
                for (i = 0; i < tombPlanes.Length; i++)
                {
                    thisPoint.Set(tombPlanes[i].transform.position.x, tombPlanes[i].transform.position.z);
                    if (Vector2.Distance(playerPosition, thisPoint) < distance && tombPlanes[i].GetComponent<planeController>().visited != true)
                    {
                        distance = Vector2.Distance(playerPosition, thisPoint);
                        firstObject = tombPlanes[i];
                    }
                }

                // Loop Through all Plane to determine which the second farthest.
                distance = 999.9f;
                for (i = 0; i < tombPlanes.Length; i++)
                {
                    //check that this object is not already chosen
                    if (firstObject.transform.GetInstanceID() != tombPlanes[i].transform.GetInstanceID() && tombPlanes[i].GetComponent<planeController>().visited != true)
                    {
```

```
                        thisPoint.Set(tombPlanes[i].transform.position.x, tombPlanes[i].transform.position.z);
                        if (Vector2.Distance(playerPosition, thisPoint) < distance)
                        {
                            distance = Vector2.Distance(playerPosition, thisPoint);
                            secondObject = tombPlanes[i];
                        }
                    }
                }


                // Turn on location marker for next tombstones
                firstObject.transform.GetChild(0).gameObject.SetActive(true);
                if (secondObject != null)
                {
                    secondObject.transform.GetChild(0).gameObject.SetActive(true);
                }
            }
            else
            {
                //Calls proximity function to activate tombstone text.
                Proximity(firstObject, secondObject);
            }
        }

        /*
        else if (path == Pathway.roam)
```

```
        {
            /* This block of code checks the location of the camera.
             * If the current object stared at is an unvistied tombstone, reuse the proximity function to activate it
             *
            Ray ray = player.ViewportPointToRay(new Vector3(0.5F, 0.5F, 0));
            RaycastHit hit;
            if (Physics.Raycast(ray, out hit))
            {
                // check if game object is a tombstone.
                // NOTE: raycasts can't hit a plane. Hence, if the object is a tombstone, we'll check if the child is a plane
                if (hit.transform.GetChild(0).gameObject.transform.GetType() == tombPlanes[0].transform.GetType())
                {
                    var thisPlane = hit.transform.GetChild(0).gameObject;
                    // Check if this plane has been visited
                    if (thisPlane.GetComponent<planeController>().visited != true)
                    {
                        currentPlane = thisPlane;
                        i += 1;
                    }
                }
            }
            //Calls proximity function to activate tombstone text.
            Proximity(currentPlane);

```

```
        }
        */

        else { } // ignore this else.
    }

    // Call this function when all tombstones are visited.
    private void GetAttention()
    {
        for (int i = 0; i < tombPlanes.Length; i++)
        {
            //attentionToPlane.SetValue(i, ); // yep, that's long!//
            attentionToPlane.Add(tombPlanes[i].GetComponent<
                planeController>().attention.ToString());
        }
    }


    private void WriteToFile()
    {
        if(tombPlanes.Length > 10) // This is just to differentiate
            training scene from experiment!
        {
            // Before application quits, it writes all information to
                TXT file.
            // Participant's name
            // Path: Rails or Free roam
            // Kinesthetic: Teleportation or Locomotion
            // Attention on each Tombstone
            GetAttention();
            // Total time spent in application in minutes
```

```
            // Path taken from start to finish!!!
            totalTime = Time.time / 60;
            string filename = "Ex#_" + participant + "_" + path +"_" + kinesthetic + "_" + Time.frameCount + ".txt";


            var att = attentionToPlane.ToArray();
            inBtwDistance = inBtwDistance + "END\r\n";
            // var pthX = pathInfo.ToArray();

            // Write all to txt file
            File.AppendAllText(getPath() + "/Output/Experiment/" + filename, "Participant: " + participant + "\r\nPath: " + path + "\r\nKinesthetic: " + kinesthetic + "\r\nAttention: " + string.Join(", ", att) + "\r\nTotal Time spent(mins): " + totalTime.ToString() + "\r\nPath Information:\r\n" + inBtwDistance + "\r\n");

        }
    }

    // Get path for given CSV file
    private static string getPath()
    {
        return Application.dataPath;// +"/"+ fileName;
    }


}
```