

## Visual Influence of a Primarily Haptic Environment

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**Abstract**— As our society is thrust further and further into the digital age, haptic interfaces are becoming all the more common place. The majority of this technology comes in the form of adding haptic feedback to visually based systems. Despite this, there is a noticeable lack of information regarding visual feedback to primarily haptic systems. In response to this lack of raw data, our study hopes to investigate how varying levels of visual information affect people's ability to navigate a haptically rendered virtual maze.

This virtual environment was accessed via a phantom omni that was set to render one of two mazes. Both the phantom omni and the pc that provided visual feedback were programmed using C++. Although two mazes were used in this study, it is important to note that only one maze was written and then inverted to provide that both mazes were inherently different but of the same difficulty level.

Our study initially intended to test students and see if any correlations occurred based off of chosen major, sex, and the strategies they chose to employ to complete the mazes. Due to time restraints and limited resources we decided to narrow our research and temporarily eliminate differences based on academic major. Only engineering majors were tested (14 of them in total), as they were easily accessible and contained many overlapping classes that required very similar levels of spatial reasoning.

Our end results supported our initial assumptions that the level of visual information provided would be the greatest factor in maze completion time. We were also correct in our assessment of maze type difficulty. The mazes were indeed of comparable difficulty and were easy to figure out given a minimal level of visual feedback. It would seem that the only piece of data that conflicted with current literature was our data that showed no difference in performance between male and female participants.

### I. INTRODUCTION

Throughout the course of this class, much attention has been given to haptic interfaces and how they augment visual information. There seems to be a deficiency however, in papers written about haptic environments with visual feedback. Therefore it is the purpose of this project to assess how limited visual information can affect perception of a purely haptic environment. This environment comes in the form of a simple two dimensional maze that must be completed using a Phantom Omni stylus. Each participant in this study completed two separate mazes, one with purely haptic feedback and one with both haptic and visual feedback. To ensure both mazes were of comparable difficulty, one

maze was written and then inverted (along the  $Y = X$  line) to make the second maze.

Our initial motivations for this project were two fold. First, we were interested in gathering data involving the augmentation of haptic environments with visual information. As haptics is generally used to make other systems seem more realistic, our group wanted to work with systems that were primarily haptic in nature. Secondly, we were interested in testing the spatial acuity of different groups of people. There has been much research in spatial reasoning and how it generally varies between the sexes (e.g. National Geographic's television show "Brain Games" had an episode focusing on this topic). We were initially interested in testing said acuity between not only the sexes but also academic majors and handedness (presented here as a discrete variable of either left handed, right handed, or ambidextrous). Due to time constraints, testing of academic major was set outside the scope of this study with the intent to revisit if this project were to be expanded.

### II. BACKGROUND

After our initial round of research, it became clear that although haptic mazes had indeed been used for research before, there was far less information on the topic than we had hoped. Most of the information we found turned out to be too removed from our focus to use. There were however, several papers that were indispensable to the formulation of our maze experiment.

A group tested whether adding haptic feedback to a 3D virtual environment would improve performance of participants. Their study focused on participants navigating through a 3D maze. This study used a handheld haptic device to provide feedback to the users. It was reported that over longer times 75% of the participants that completed the 3D maze with haptic feedback were faster than the participants with no haptic feedback. [4]

Researchers looked into whether adding certain types of haptic cues would increase users' performance in 2D mazes. They found that haptic feedback improved users' ability to complete more mazes than that of participants with no haptic feedback. The second conclusion they were able to make is that participants were able to finish the mazes quicker without dynamic haptic feedback. This group had a hypothesis that participants would travel less distance in the static configuration, but their hypothesis could not be supported with the data generated by this study. [1]

A research group studied the effects of haptic guidance on learned skills such as handwriting. This group employed a phantom omni as their haptic device. It was found that continued practice of guided motion tasks with the omni, such as writing letters and words, would significantly improve the user in a relatively short time. They also tested it with two

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types of mazes, one with walls and one that was a constrained maze. They found on both of these the user would improve by practicing with the omni. Users finished the constrained maze faster than that of the walled maze. [2]

By looking at the previous works in the aforementioned journals, our group was able to avoid many of the pitfalls that would have otherwise been unavoidable in our research. This invaluable data no doubt saved us countless hours in the construction of this experiment. In the results section we will discuss our results and see if they are similar or contradicting to the work of other researchers in the field of haptics.

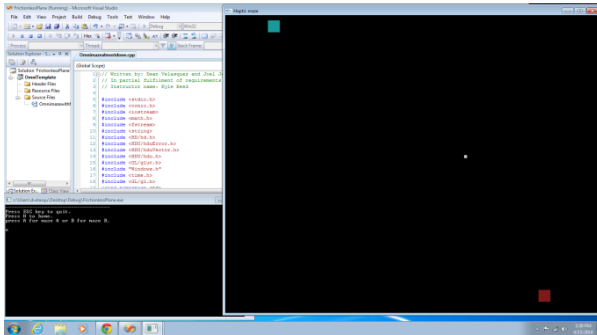


Figure 1. C++ program

### III. PHANTOM OMNI

The Phantom Omni is one of the most affordable haptic devices on the market. A haptic device is a device that can deliver tactile feedback to a user through means of vibration, force feedback, etc. The Omni is capable of applying force feedback. It uses motors to exert force on the user in one of three Cartesian directions. With these abilities the Omni can simulate two dimensional and three dimensional objects such as, planar walls, spheres, complex polygons, and in our case a two dimensional maze (the two dimensions being vertical and left/right). This device has a work space of roughly 6.4in wide x 4.8in high x 2.8in depth. The maximum force the Omni can exert on a user is about 3.3 newtons, although we limited our forces to 2 newtons or less for the sake of machine longevity. [5]



Figure 2. The Phantom Omni haptic device

### IV. EXPERIMENT SETUP

The overall setup for this research consisted of one Phantom Omni haptic device that was described above and a computer running a C++ program, which created the virtual maze. The program was designed with four modes. Mode one consists of a home feature that tells the omni to move to the upper left of its work space, where both mazes start.

The second mode was a training module that consisted of a virtual box where the top right corner led to a short hallway as shown in figure 3. For this training module the participants were provided with a shaded area representing the inside of said box so they could distinguish where the walls were and what they felt like. In this training they were also informed that the left wall had damping along its surface so that when the participant brushed against the virtual object it would feel different than the other smooth walls. This damping in the actual maze lets the user know if they are going down a dead end. Once the participant completed a minimum of two minutes in our training module and felt comfortable with how the walls and corners felt, knowing what force they should exert on the walls, etc. they could move on to complete the mazes.

The next two modes are maze A and maze B. We wanted to stick with simple designs for the mazes so that all participants could complete each maze and do so in a timely manner. If the test took too long then the participant could potentially get tired and skew the data. The design for maze A was kept simple as shown in the figure below. To ensure maze B was of the same difficulty, we decided to invert maze A over the  $Y = X$  line ( $Y$  being vertical and  $X$  being left/right).

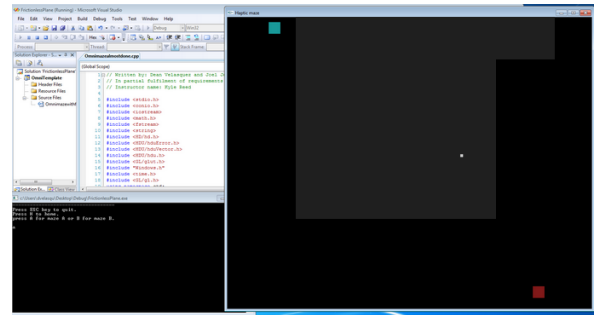


Figure 3. Training mode

$$F = k ( o - p ) \quad (1)$$

$F$  = force omni exerts

$p$  = omni position

$o$  = offset

$k$  = spring constant

The position minus the offset is used so that when the participant just touches the wall there is only a minimal amount of force produced. This helps to maintain stability in the omni device. In addition to the spring force each wall provided normal to its surface, walls that shaped the dead

ends were programmed to provide a damping force when the participant travelled along its surface.

Also the program had a simple feature to allow for the visual portion of the maze to be activated or repressed. For the graphical portion of the program we implemented the OpenGL Utility Toolkit or GLUT to create a graphical display to show participants where the omni position was with respect to the startpoint and endpoint of the maze. This feature was used to test how low levels of visual feedback would affect how participants completed our mazes.

The design of the first maze was drawn up with all of our previous expectations in mind. We finally settled on a maze that has an “S” shape as its main path with multiple dead end pockets that could easily be travelled down. This maze was only one of many initially created and reviewed. Out of all mazes created however, only this maze met our requirements of directness without becoming overly simplified. As stated previously, the second maze was the exact spatial opposite of this.

## V. RESULTS

We first ran an ANOVA on our data. We used time to complete the mazes as our dependent variable and had independent variables of subject, level of visual information given, and maze type (original or inverted maze). As shown in figure 4, there was no significant difference between maze type or the subject when compared with maze time. There was found to be a significant difference between visual or non-visual on the completion time.

Analysis of Variance					
Source	Sum Sq.	d. f.	Mean Sq.	F	Prob>F
Maze type	1.20985e+09	1	1.20985e+09	0.7	0.4177
visual/non_visual	6.52977e+10	13	5.0229e+09	2.92	0.0361
subject	4.32572e+09	1	4.32572e+09	2.52	0.1385
Error	2.96094e+10	12	1.71745e+09		
Total	9.08908e+10	27			

Constrained (Type III) sums of squares.

Figure 4. Example of a figure caption. (figure caption)

Figure 5 is a graph of the total amount of time it took for each subject to finish maze A (red) and maze B (blue). Figure 6 is a graph of the percentage of time subjects touched an activated wall (dead end or not) versus total time to complete the maze. The scatter plot does not have any distinct trends that could suggest the percentage of time touching walls affects the overall time it takes for each participant to complete the maze. One interesting trend that can be pulled from figure 6 is that most of the participants, excluding the outliers, touched the walls between forty and fifty percent of the time they were in the maze. This seems to confirm most subjects own accounts of their strategies to complete our mazes. The two most common of these strategies are

bouncing between walls to find openings and gliding along them.

Of the remaining graphs, figure 7 is what participants thought of the training versus time to complete the mazes. One of the participants who was very familiar with the omni haptic device rated the training low for helpfulness because the person already knew how to use the device. Also, we believe many of the participants were already vaguely familiar with haptic devices, which may have skewed the data because participants might have been grading it based on if they thought it could help someone who has not used a haptic device before. Figure 8 is the average times to complete the mazes when maze A was provided first and if maze B was shown first. Figure 9 is a graph of men and women versus their respective time in maze A and maze B. Finally, figure 10 is a plot of mazes A and B in both their visual and nonvisual forms versus time in each maze.

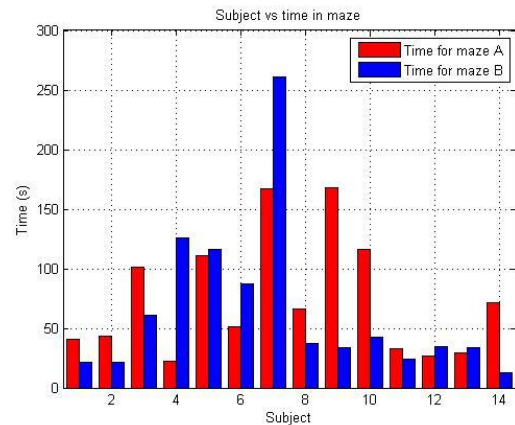


Figure 5. Subject vs time

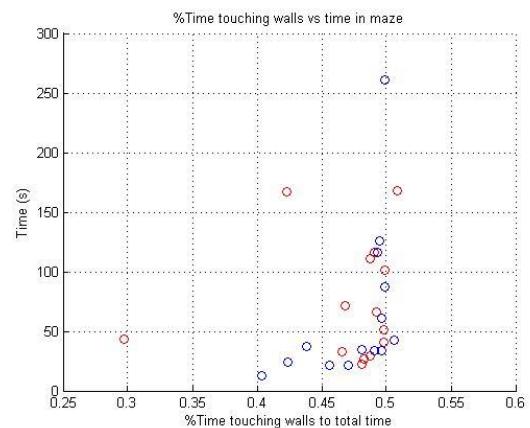


Figure 6. Percent time on walls vs total time

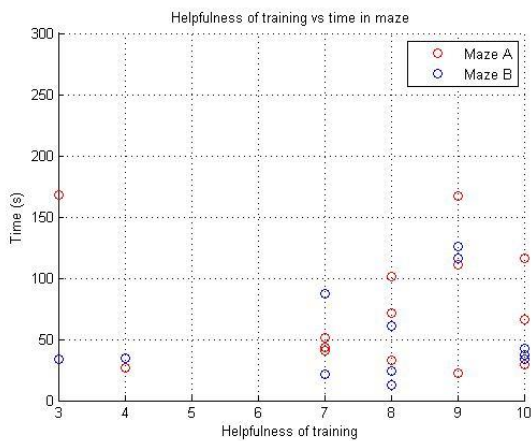


Figure 7. Training helpfulness vs total time

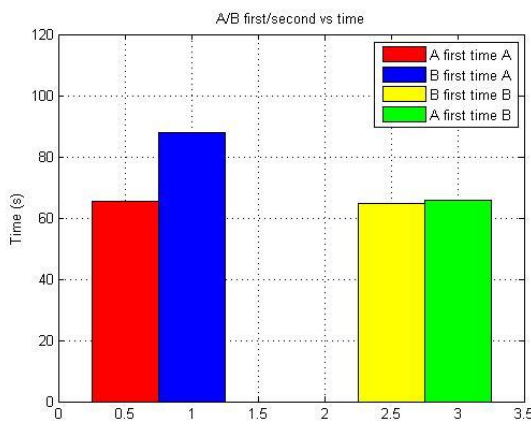


Figure 8. A/B first/second vs total time

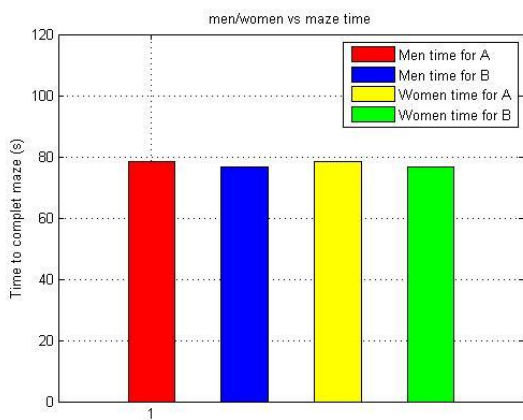


Figure 9. Men/women time in each maze

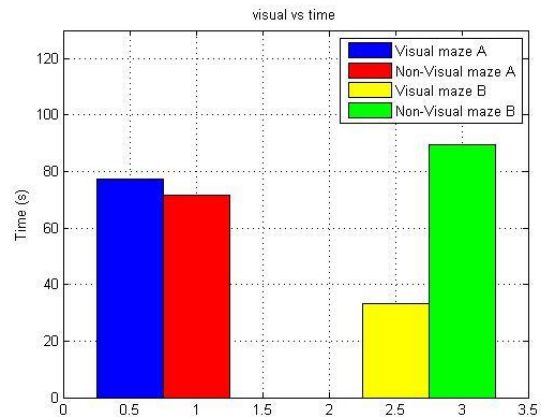


Figure 10. Visual/Non-Visual vs total time

## VI. DISCUSSION

Although our results were not surprising, we still found them to be significant. It should be no surprise that there was no statistically significant difference between maze A and maze B, after all maze B was simply an inversion of maze A. That means that every twist and turn would be present regardless of which maze was being used at the time. With a p value of a lofty .418, our ANOVA supports this hypothesis entirely.

Equally as predictable is the data on visual information's effect on maze completion. It was clear from the first participant that simply knowing where one is in a maze is invaluable to completing it quickly. This vital information was key to many participants strategies of getting through the maze and caused much confusion when not presented. Again our ANOVA heavily supports this with a p value of only .036.

Perhaps the most notable and well received portion of this study was the mandatory training module. As previously stated, each participant was required to spend at least two minutes in this module (there was no maximum time limit placed on training and an official at the University of South Florida with documented experience using omni devices was not held to the minimum time requirement) in order to assess specific maze characteristics such as the differences between damped and undamped walls.

This training module was considered very successful based on the feedback received from our questionnaire. We asked participants to rate the effectiveness of the training session from 0 (having no effect) to 10 (very helpful). Taking all participants into account, we received an average score of 7.79 with a standard deviation of 2.12. If we were to exclude a participant who was unsure of how to answer (the subject could see the value of training but received little benefit due to having high levels of experience using an omni) we received an average score of 8.15 and a standard deviation of 1.68. Regardless of which numbers we chose to focus on, we may conclude that this module was successful in its goal of teaching subjects how to adapt to the omni in this setting. This adaptation allowed us to then test the role of visual information's effect on spatial reasoning without having

participants learn to control the omni while trying to complete the first maze.

## VII. FUTURE WORKS

While much could be taken away from this study as is, there is still much work to be done. Ideally a continued study would include a much greater population of subjects that span a large number of occupations and majors (as opposed to this study that tested engineering majors exclusively). One of our initial ideas was to test this potential difference of spatial reasoning between different student majors. Please note that determining if some majors attract people with higher levels of spatial reasoning or if studying certain subjects at a college level increase one's reasoning ability is well outside the scope of this paper's present and future works. That does not mean however, that a correlation cannot be made. In fact, this is one of the initial questions posed by our research group. Unfortunately due to time constraints our group only had enough resources to test one major thoroughly.

Another modification that should be made is changing the haptic apparatus used in the experiment. The Phantom Omni is a well designed and cost effective piece of machinery. This device can only remain stable however, within a very small range of forces. This presented a problem in the form of softer walls in the maze and a need for our comprehensive training module to minimize the number of walls our subjects would try to push through.

Lastly, our next round of experiments should include an additional level of visual feedback. Currently our non-visual maze only displays the starting and ending positions in said maze. Our visual maze displays everything previously stated but also includes a point representing your current position in our maze. We would like to include an additional level of visualization that includes everything stated above but also includes a "spot light". This spot light would be centered around your current position and show all walls within a specified radius of the point representing the user's current position.

It is our belief that although this study has proven fruitful so far, making these few alterations could provide even more data that could be applied to the fields of haptics, behavioral science, game design, and more.

## VIII. CONCLUSION

In brevity, our study of the effects of visual information on spatial perception provided interesting yet predictable data. We saw that when two mazes of comparable difficulty were presented, the only statistically significant indicator of performance was the type of visual feedback used. This case was easily made not only through our ANOVA but also through our own testimony as well; as the maze proctors, it was clear that when information on current location was not given our participants were easily confused and got lost within the maze.

Perhaps the greatest benefit of this study was its ability to generate a large amount of data pertaining not only to haptics but many other fields as well. Using our setup, we were able to gather all the information we expected to obtain from a haptic point of view. We also managed to gather data on

human behavior in the form of how participants reacted to our training program and how strategies were planned and changed given a preset level of visual information.

Finally, by performing this experiment we were able to find a clear path for future work. Our bumps in the road allowed us to identify new variables that could be tested in expanded studies and see what alterations could be made to our current setup for optimum results.

## REFERENCES

- [1] Crossan, Andrew , and Stephen Brewster. "Two-Handed Navigation in a Haptic Virtual Environment." CHI 2006 22-27. W.-K. Chen, *Linear Networks and Systems* (Book style). Belmont, CA: Wadsworth, 1993, pp. 123–135.
- [2] Maniya, Jatin B.. "Design and Development of Virtual Objects to be Used with Haptic Device for Motor Rehabilitation." journal of software engineering and applications 990-997. Print 2014
- [3] Orozco, M.; El-Saddik, A., "AdHapticA: Adaptive Haptic Application Framework," Instrumentation and Measurement, IEEE Transactions on , vol.57, no.9, pp.1840,1851, Sept. 2008  
doi: 10.1109/TIM.2008.919869  
URL:<http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4484577&isnumber=4589158>
- [4] Sepulveda-Cervantes, G.; Parra-Vega, V.; Dominguez-Ramirez, O., "Haptic cues for effective learning in 3D maze navigation," Haptic Audio visual Environments and Games, 2008. HAVE 2008. IEEE International Workshop on , vol., no., pp.93,98, 18-19 Oct. 2008  
doi: 10.1109/HAVE.2008.4685305  
URL:<http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4685305&isnumber=4685283>
- [5] PHANTOM Omni® Haptic Device (PHANTOM OMNI)  
<http://www.dentsable.com/haptic-phantom-omni.htm>.