Memory Task Performance across Augmented and Virtual Reality

Pete Willemsen* William Jaros Charles McGregor
Department of Computer Science
University of Minnesota Duluth

Edward Downs† Maranda Berndt Alexander Passofaro
Department of Communication
University of Minnesota Duluth

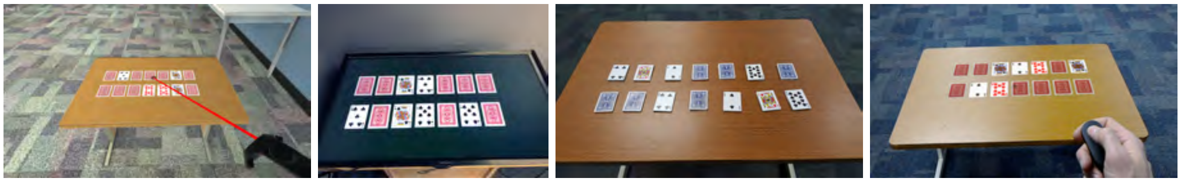

Figure 1: Images showing the card matching memory task in the four technological conditions compared in this experiment: Immersive Virtual Reality with the HTC Vive, Table-top Touch Screen, Real and Augmented Reality with the Microsoft Hololens.

ABSTRACT

As commodity virtual reality and augmented reality hardware becomes more accessible, the opportunity to use these systems for learning and training will increase. This study provides an exploratory look at performance differences for a simple memory matching task across four different technologies that could easily be used for learning and training. We compare time and number of attempts to successfully complete a memory matching game across virtual reality, augmented reality, a large touchscreen table-top display and a real environment. The results indicate that participants took more time to complete the task in both the augmented reality and real conditions. Augmented reality and real environments were statistically different than the fastest two conditions, which occurred in the virtual reality and table-top touch display conditions.

Index Terms: Human-centered computing [Human computer interaction (HCI)]: Empirical studies in HCI— [Applied computing]: Education—Interactive learning environments

1 INTRODUCTION

In today's society, technology is everywhere, especially in educational settings. Educational technology is defined as any item, mechanism, system, electronic device, or combination of hardware and software that is designed for, or used for, the supposed purpose of enriching or contributing to the learning process [1]. Regardless of its form, researchers agree that to be called an educational technology, an apparatus must contribute to the learning process in a meaningful way, and it must be ethical [3]. For critics, adoption of technologies seems to occur at a faster rate than each technology can be adequately studied, yet technology beckons and offers solutions to overstretched educators even without solid empirical evidence to back-up learning claims.

This study begins a program of research that examines learning in four different environments. We examine the affordances that different types of technological environments utilize, and use this information to help to provide foundational materials from which a larger *learning in technological environments* may be realized. We aim to focus on the exploration of affordances, or capabilities that can shape how content is perceived in a technological medium [5]. The spectrum of technologies available today and the affordances they contain can be thought to exist on a reality continuum [2]. The continuum spans the full range of realities that can be experienced and is anchored on one side with real environments and on the other side with virtual environments. A real, or analog, environment can be defined as an environment which is experienced without the aid of a technological device. We chose a memory task where participants flip playing cards as an example of a real, analog task and compared participants' performance across three additional environments to span the range of this reality continuum: table-top touch screen, augmented reality (AR), and virtual reality (VR) environments. Each of these environments affords differing ways of perceiving salient information. The touch screen environment acts as real digital *mediated* environment [4]. In AR, users must navigate between information presented in the real world, and digital information dropped on top of the real world, whereas in VR, users are completely surrounded by the VE, providing physical immersion and psychological presence.

To determine if there are differences in performance abilities in a basic card matching task as afforded by the these four environments, this study asks two research questions related to performance in this task: **RQ1**: Will average number of attempts across (6) trials differ across the four tech environments? and **RQ2**: Will time to completion differ across the four tech environments?

2 METHOD

2.1 Participants

We recruited 91 participants (66 females) for this study. The average age of participants was 19.42 years. All participants had normal or corrected to normal vision and consented to participate in the experiment. IRB approval was obtained for this research study.

2.2 Design

A between-subjects design was used to explore performance in a memory task across four different visual display environments: immersive VR, a table-top touch screen display, AR, and a real environment. Subjects were asked to complete a simple memory task involving 7-identical pairs of regular playing cards. In this task, all fourteen (14) cards were first placed face up on a table in front of the subject and arranged in two rows of seven. Subjects were given 15 seconds to view all the cards and asked to spend that time noting the locations of the cards. After viewing the cards, the cards were turned face down. Once all cards were turned over, subjects were instructed to locate the matched cards by flipping a pair to be face up. If the two cards matched, the subject could move on to the next match. If, however, the two cards did not match, subjects were instructed to flip each card back over so they would be face

*e-mail: willemsn@d.umn.edu
†e-mail: epdowns@d.umn.edu

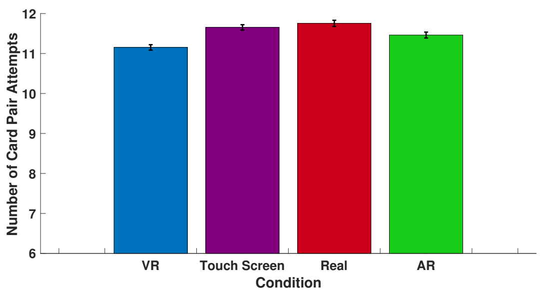

Figure 2: Average card pair flips to complete the task in all conditions. Error bars represent the Standard Error of the Mean (SEM).

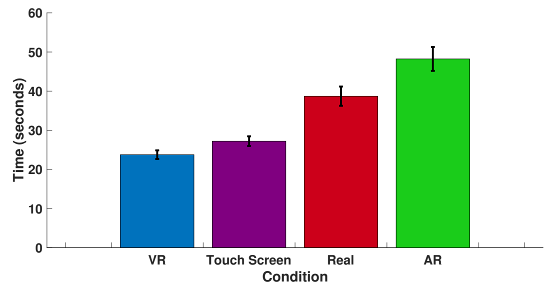

Figure 3: Average time to complete memory task in all conditions. Error bars represent the Standard Error of the Mean (SEM).

down before they started a new attempt at a matched card. Once all pairs were matched correctly and face up, the trial ended. Subjects completed a total of seven (7) trials with the first trial being a practice trial. Practice trial data was not analyzed.

2.3 Materials

In the VR condition, an HTC Vive was used to provide a fully immersive display with one set of controllers to provide user input about card selection. The virtual environment replicated the physical lab space (21ft by 33ft), including various furniture. For the AR condition, we used the Microsoft Hololens and Bluetooth connected Hololens clicker to provide user input rather than air-tapping. In both VR and AR, subjects were provided with basic fitting of the devices and training on how to use the input mechanisms. The Table-top Touch Screen display utilized a 50-inch TV with a PQ Labs touch screen interface to provide natural touch interaction for card selection. All virtual scenes were rendered using a custom-built Unity application. In the virtual conditions, the software randomly shuffled cards between each trial. In the physical, real condition, experimenters shuffled the cards between trials.

The memory task differed slightly based on the natural affordances within each technology. For all conditions, subjects were instructed to use their dominant hand to flip a single card. For the VR condition, subjects used a Vive controller and the visualization of a laser pointer for selection. For the Touch Screen display, subjects were allowed to use one hand and touch the cards they wished to flip. In the AR condition, subjects used the clicker and gaze to make card selections. In AR, the virtual cards were placed upon a real table. Figure 1 shows images from each of the four conditions. In all virtual conditions, subjects stood to complete the task.

One-handed selection in the digital conditions required card selection in the real condition be limited to one hand, which can be challenging. Thus, cards were thickened using a foam-core layer between the face-up and face-down sides of the card. This made the physical cards thick enough to grasp with one hand and flip over.

3 Results

An ANOVA across the four environments indicated that the number of card pair attempts (**RQ1**) across 6 trials (see Figure 2) did not differ statistically by type of environment, $F(87,3) = .61$.

Examining **RQ2**, we find that an ANOVA indicates that the amount of time taken across 6 trials (see Figure 3) did statistically differ by type of environment, $F(87,3) = 29.518$, $p < .001$, partial $\eta^2 = .504$. Games-Howell post hoc analyses (used because Levens test revealed homogeneity of variance was violated) reveals that participants in the VR condition took ($M = 23.752, SD = 5.456$) seconds to complete each of the 6 trials, and participants in the Touchscreen condition took on average ($M = 27.210, SD = 6.09$) seconds to complete each of the six trials. The two conditions did not differ from each other, but differed across the other two conditions at $p < .001$. By comparison, the two conditions that took the most time to complete, real and augmented reality conditions, ($M = 38.707, SD = 11.273$) seconds and ($M = 48.232, SD = 14.341$) seconds, respectively, did not differ from each other, but differed from each of the other conditions, $p < .001$.

4 Discussion

The results from this study document participants performance on a simple card-matching task in four different environments. With regard to the time difference, we offer the following as plausible explanatory mechanisms. First, it is possible that the clicker used to interface with the Hololens AR environment introduced some systematic delay into the time data. However, exploratory analyses indicate that a number of participants were able to complete trials in the AR condition in similar ranges of time as the other conditions. This helps us to rule out any systematic artifact in the data. Another plausible explanation for the increase in time (but not number of trials for successful completion of the card matching trials), could be related to available processing bandwidth. Participants in other conditions only had to process one type of environment: fully immersive VR, real, or focused on a single touch screen. The augmented reality environment afforded the ability to be in both digital and real spaces. The need to process both concurrently may have taken up more processing bandwidth - enough to account for a statistically different time outcome across the technological environments.

5 Conclusion

Future research should replicate work examining performance and learning with different technologies in order to build a body of literature that can be used to theorize about processing and learning across different technological environments. Additional variables should also be considered including psychological variables such as presence, novelty, and enjoyment of task and learning experiences.

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