Video Games and Spatial Activities

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Abstract

Previous research demonstrates that spatial training improves one's proficiency in spatial tasks (Uttal et al., 2013). This correlational study investigates spatial activities and their influence on spatial tasks in desktop and immersive virtual reality. We hypothesized that increased video game and navigation experience would lead to increased performance on desktop and immersive virtual reality tasks. Participants navigated routes and indicated direction of objects, measured by pointing accuracy and wayfinding efficiency in desktop and immersive VR tasks. Participants completed self-report questionnaires about previous spatial activity and video game experience. There was a significant correlation between participants with more navigation experience and pointing accuracy in immersive Virtual Reality; one gaming measure correlated marginally with immersive Virtual Reality wayfinding efficiency, $r(112) = -.19$, $p = 0.04$. Increased gaming experience did not correlate with immersive Virtual Reality pointing error, but did correlate with desktop pointing error. Limitations about this study and implications of video game experience on these measures are discussed.

Video Games and Spatial Activities

Navigation is a critical component of human experience, and the ability to locate objects is central to understanding and creating a cognitive map of our surroundings (Weisberg & Newcombe, 2018). Indeed, everyday activities such as gaming or artistic experience may influence the cognitive mechanisms used to solve navigational challenges (Munns et al., 2022). In the endeavor to understand spatial navigation, it is imperative to consider the kinds of spatial tasks individuals partake in, both informal and formal.

Previous research in spatial thinking suggests that humans navigate new surroundings through multiple perspectives, which are incorporated into a larger navigational structure. Route knowledge requires knowledge of the next path before the intended one (after this left, take a right) (Steck & Mallot, 2002). Graph knowledge allows people to locate objects based on a familiar context using proximal and distal landmarks. Survey knowledge, perhaps the perspective most embodying the idea of a cognitive spatial map, is the knowledge of an environment reliant on identifying landmarks and distances based on relative positions to each other.

Spatial thinking helps us solve the navigational challenge in real-world environments, since navigation is a full-body experience utilizing visual, sensory and spatial cues. People exercise and build upon their own spatial thinking through spatial activities such as direct navigation, building furniture, playing a sport or completing a creative task, such as weaving (Bennett-Pierre & Gunderson, 2022). Additionally, spatial training has been shown to improve one's proficiency in spatial tasks (Uttal et al., 2013) . A measure including certain activities such as the navigational, gaming, and creative activities from the Southern California Spatial

Activities Questionnaire (SoCalSAQ), have small but significant correlations with spatial tasks (Munns et al., 2022).

Previous literature has conducted extensive studies on video games and their impact on spatial cognition, particularly the impact of playing First Person Shooter games (FPS), which often require a command of visual and sensory functions to attend to the tasks demanded of the player, and previous research demonstrates increased performance from playing video games in these sensory, visual attentional, fine motor control, and memory mechanisms (Brunyé et al., 2012; Spence & Feng, 2010). Increased FPS game experience was found to be correlated with lower time completion in navigating a task (Smith et al., 2009).

An increasing body of research also looks at video game experience and spatial navigation through an immersive virtual reality environment, along with desktop tasks, with mixed results. The design of navigational desktop tasks resemble the design of several video games which include a navigational component, including designs that require maps, locating objects within an area, or guiding oneself along a designated route. In Richardson et al. (2010), researchers found previous video game experience was correlated with decreased pointing error on desktop and immersive environments; however, the immersive environment had a joystick mechanism for pointing, which the authors noted may have impacted the similarity to real-life navigational estimation. Another study that looked at desktop navigation reported that increased video game experience correlated with more efficient navigation through a desktop task. Participants who indicated they played video games with a navigational component were more efficient than for those who played video games without navigation, and more so than those who did not play video games at all (Murias et al., 2016). Video game experience is often self-reported, and previous studies did not measure other spatial activities which could influence spatial navigation performance.

Other studies have found video game experience does not impact spatial representations within immersive virtual reality or desktop virtual environments. A study that measured the similarity of a participant-drawn aerial map to the learned map route, between an immersive virtual environment and a desktop one, found that those with more video game experience performed better in the VR and desktop conditions than less experienced video game players. However, participants with more video game experience did not differ in map drawing accuracy from those with less video game experience, indicating that video game experience did not give participants an advantage when testing spatial knowledge (Marraffino et al., 2022). Additionally, Smith et al. (2009) found that those with greater video game experience perceived a familiar route in a virtual desktop environment as a more complex view from an aerial view than those who did not play video games. Skills associated with video game experience do not seem to predict holistic spatial knowledge.

Here we investigate whether daily spatial tasks and video game experience will affect navigational performance within two environments, immersive virtual reality and desktop environments. The daily spatial tasks measurement, the SoCalSAQ, can further parse out the confounds often found in video game experience and spatial cognition studies.

Based on previous research investigating navigational skills on desktop and immersive virtual reality interfaces, we hypothesize that more self-reported video game and navigational experience will be correlated with higher pointing accuracy and more efficient times on the immersive Virtual Reality Task (DSP). Self-reported video game and navigational experience will also be correlated with higher pointing accuracy on the desktop task (SILCton).

Method

Participants

Participants (N = 119) consisted of university students from University of California, Santa Barbara, and University of California, Irvine. These participants are from a larger study which is drawn from a database of around a planned 150 behavioral participants. Participants are around 18-35 years old with normal or corrected-to-normal vision. Of 109 participants, the sex at birth equates to 41 male participants and 68 female participants. Navigation abilities vary widely in college populations, but there may also be participants from outside the university to increase the diversity of the sample.

Design

This is a correlational study investigating spatial experience using two experience measures and three measures of spatial activity and ability: this study used pointing accuracy and distance traveled (wayfinding efficiency) in immersive Virtual Reality, the desktop environment Virtual SILCton (angular error), the SoCalSAQ, and a self-reported survey of Video Game Experience (z-score) to measure participant ability and experience.

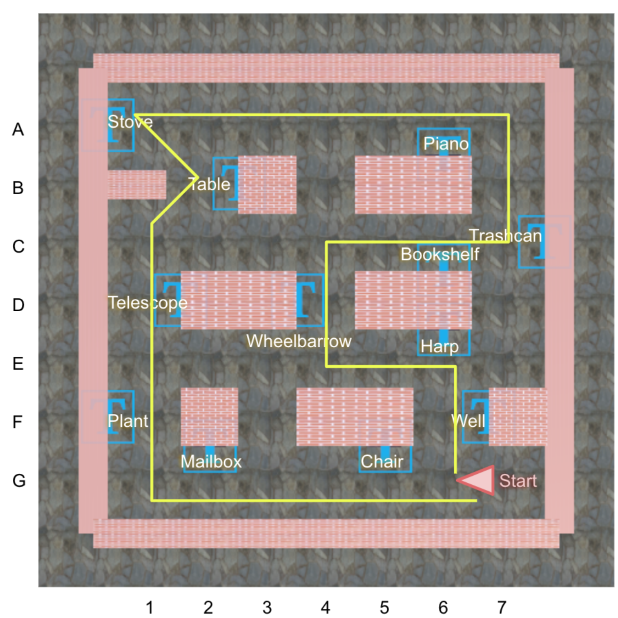
Materials

Dual Solutions Paradigm (DSP)

The DSP tests participants' navigational strategy, whether they prefer to take a route they know to reach a target location, or whether they prefer to take a novel shortcut. An immersive (walking) virtual maze environment was adapted from Boone et al. (Figure 1). Twelve object paintings were placed in a maze as the targets to be learned. Fog obscures vision beyond 2.5 meters and the clarity decreases between 1 and 2.5 meters so that the participant cannot learn the layout of long hallways. During the learning phase, people walk on a fixed tour of the maze by following arrows until they can reproduce the route without errors; the number of learning laps is treated as a measure of route learning. Even after they reproduce the route without errors, all participants are given a total of 5 tours on the route to ensure equal exposure. Participants then complete a pointing task where they view an image on the screen of one of the objects and use a desktop pointer to point to all the other objects; they complete this for all object pairs. Participants are then asked to go from one object in the maze to another object with a 30-second time limit. Participants can either take the learned route or take a novel shortcut; all of the object paintings were visible during the test phase. There are 24 trials in total. The primary measure of their strategy preference is the refined Solution Index, which indicates their preference for taking a novel shortcut vs.the learned route. A higher value indicates a stronger preference to take a shortcut across all trials.

Figure 1

DSP Map



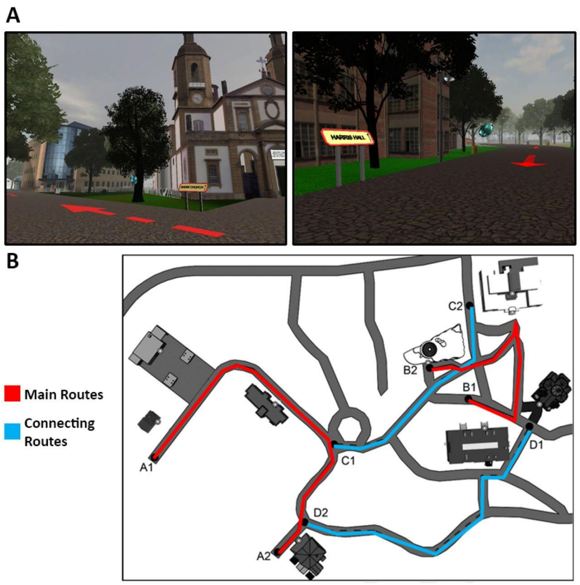
Note: This figure demonstrates the route participants walk in the DSP Virtual Reality. Objects participants see are listed around the route.

Virtual SILCton

Virtual SILCton is a standardized task designed to measure the acquisition of survey knowledge from navigation experience (Weisberg et al., 2014). In this desktop VR paradigm, participants follow two different routes in a virtual town, with landmarks (buildings, e.g., Tobler Museum and Golledge Hall) on each route. Each route is traversed in the forward and backward direction one time. Then participants are led on two connecting routes and again experience each of these in the forward and backward direction (see Figure 2). In the test phase, participants are placed at each of the landmarks and have to point to each of the other landmarks from that location for a total of 56 trials. Measurements are absolute angular errors for pointing to locations within the same route, absolute angular errors for pointing to locations between routes, and configural knowledge (participants place landmarks from the environment on a map and this is compared to an actual map of the environment using bidimensional regression). These are combined into a single Z-score for overall ability.

Figure 2

SILCton Route and Environment



Note: This figure demonstrates the main and connecting routes participants walk in the desktop Virtual Reality environment, and depicts images of the buildings participants see.

Southern California Spatial Activities Questionnaire (SoCalSAQ)

The spatial activities questionnaire consisted of 57 items about everyday activities that were related to one's navigation, spatial awareness, and sense of direction (Munns et al., 2022). The five subsections of the questionnaire were navigation, gaming, art, fitness, and technology. The items were on a 6-point scale. Questions about navigation referred to real-world navigation (e.g. hiking, orienting); the other questions were written similarly according to topic.

Video Game Experience Questionnaire

The video game experience questionnaire (see Appendix A1) consists of 8 items about video game experience on a 5-point scale, regarding the amount of experience, the performance level, and the amount of time spent on video game playing time. Questions referred to the kinds of game environments players encountered such as unmodified environments, labeled pre-existing environments (e.g. League of Legends) and self-created environments (e.g. Minecraft).

Procedure

Participants completed the following procedure and tasks as part of a larger ongoing study that tested over five sessions, each lasting approximately two hours. At the start of the first session, participants are given information about the study. Once they provide their informed consent and enter demographic information, experimenters begin with an introduction to the immersive VR equipment. The Dual Solutions Paradigm (DSP) starts in the ReCVEB with a calibration session in immersive VR. Before each immersive VR task, participants sit at a desktop computer and read the task instructions from a slide deck. After answering any questions the participant has, the experimenters help them wear the head mounted display (HMD) and calibrate it for the distance between the participant's pupils, hand them the controllers, and verbalize the task instructions to the participant. In between immersive VR tasks, participants complete questionnaires not reported in this study about the VR experience on the desktop computer. After the DSP ends, in a session a few days to one week after the first session, the next task participants did was the spatial activities questionnaire, (SoCalSAQ). Following that, in another session a few days to one week later they completed the Video Game Experience questionnaire (see Appendix A1). It was administered through Qualtrics. Participants are in immersive VR for less than an hour total per session. After completing the VR tasks, the experimenters lead the participant outside for a break before walking them to a different testing room where they complete the second part of the session. During this second part, participants sit in front of a computer, a PC with a connected mouse and keyboard, and complete desktop-based VR, which in this case is the Virtual SILCton as the final task discussed in this study. Commands to navigate desktop virtual environments were the WASD keys for moving forwards, backwards and side to side respectively, or sometimes the arrow keys located to the right side of the keyboard. The mouse could be used for finer-tuned movements, such as going forwards on a path using the W or the upwards arrow key, and then moving the mouse right to move the view to the right while moving forwards.

Table 1

Means, standard deviations, and correlations with confidence intervals

Variable	*M*	*SD*	1	2	3	4	5	6	7	8
1. Absolute Pointing Error (DSP)	73.79	20.91								
2. Inefficiency (DSP)	1.75	0.35	.60**							
			[.47, .70]							
3. Navigation (SoCalSAQ)	2.20	0.70	-.27**	-.14						
			[-.43, -.09]	[-.31, .05]						
4. Gaming (SoCalSAQ)	2.46	0.87	-.16	-.19*	.30**					
			[-.33, .02]	[-.36, -.01]	[.13, .46]					
5. Creative (SoCalSAQ)	2.06	0.85	-.30**	-.15	.52**	.13				
			[-.46, -.12]	[-.32, .04]	[.37, .64]	[-.06, .30]				
6. Fitness (SoCalSAQ)	2.45	0.71	-.13	-.13	.62**	.34**	.55**			
			[-.31, .05]	[-.30, .06]	[.49, .72]	[.17, .50]	[.41, .66]			
7. Technical (SoCalSAQ)	2.01	0.97	-.13	-.05	.45**	.29**	.38**	.39**		
			[-.31, .05]	[-.23, .14]	[.29, .58]	[.11, .45]	[.21, .52]	[.22, .53]		
8. Video Game Experience Questionaire	3.53	1.12	.01	-.09	.16	.73**	-.22	-.02	.03	
			[-.23, .24]	[-.32, .15]	[-.08, .38]	[.59, .82]	[-.43, .01]	[-.26, .21]	[-.20, .27]	
9. Absolute Pointing Error (SILCton)	0.07	0.78	.20	.33**	-.13	-.24*	.06	.07	-.12	-.33**
			[-.02, .41]	[.12, .51]	[-.34, .09]	[-.44, -.03]	[-.16, .28]	[-.15, .28]	[-.33, .10]	[-.52, -.09]

Note. M and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation (Cumming, 2014). * indicates $p < .05$. ** indicates $p < .01$.

Results

We predicted that the video game and navigation components on the SoCalSAQ would be correlated with higher pointing accuracy and more efficient times on the immersive Virtual Reality Task (DSP), and, that these components will be separately and also correlated with higher pointing accuracy on the desktop task (SILCton). Indeed, there was a significant correlation between participants with high self-report scores on the navigation, as well as the creative components of the SoCalSAQ, and pointing accuracy in immersive Virtual Reality; however, only the gaming component correlated marginally with immersive Virtual Reality inefficiency, $r(112) = -.19$, $p = 0.041$ (see Table 1). Neither the gaming component of the SoCalSAQ nor the video game experience questionnaire correlated with immersive Virtual Reality pointing error, but more video game experience on both the SoCalSAQ and the video game questionnaire correlated with desktop pointing error.

Correlation between video game experience questionnaire and the gaming component on the SoCalSAQ was strong, $r(68) = .73$, $p < .01$. There is a strong correlation between absolute pointing error (DSP) and wayfinding efficiency, indicating that they measure a similar spatial ability. Alternatively, the measure of SILCton pointing error did not correlate with pointing error in the immersive Virtual Reality (DSP). The fitness and technical components are positively correlated with all components of the SoCalSAQ, but no other measures.

Absolute angular error, or the average difference (across trials) between the direction the participants pointed in and the right direction was used to measure pointing task performance. A smaller angular error means better performance in pointing tasks. The range of angular error is from 0 degrees to 180 degrees. 90 degrees of angular error is chance performance. Wayfinding efficiency is computed by dividing the actual distance traveled divided by the shortest possible distance. A higher ratio means worse performance. The closer ratio was to 1, the more efficiently the participants found the target.

Discussion

Taken together, the hypotheses were somewhat supported. Both gaming components correlated with better navigation efficiency and desktop virtual environment pointing error, but not at all with immersive virtual pointing error. Navigation experience correlated with absolute pointing error on the immersive virtual reality paradigm only, and not with the desktop virtual environment measure. Overall, the spatial task measures themselves generally correlated with each other, as expected; however, the desktop measure of pointing error did not correlate with the same pointing error measure in immersive Virtual Reality.

As the gaming experience questionnaires correlated with better wayfinding efficiency within the immersive virtual reality task and the absolute pointing error in the desktop task, but not with the same pointing error measure in the immersive virtual reality, this suggests that at the very least these measures are not measuring the same spatial ability. Actual navigation experience correlated with absolute pointing error in immersive Virtual Reality but not on the desktop task, indicating yet again that it seems to be measuring a different spatial ability than its same counterpart of absolute pointing error on the desktop.

Navigation and creative components correlated only with immersive absolute pointing error (DSP). This may indicate that immersive virtual reality is more similar to real-world navigation utilizing all bodily cues, as well as visual, whereas desktop tasks are primarily visual cues (Pastel et al., 2021). The DSP paradigm may be closer to real-world navigation than the desktop environment, and therefore an increased experience in a non-immersive desktop virtual reality would not have influenced the pointing error navigation in a real-world simulation. The navigation and creative component correlations to real-world paradigms may be indicating that these tasks may require the participant to engage in more overall bodily cues beyond visual attention, demonstrating those with individual navigational experience and/or creative experiences may have more of a command of these functions, and therefore be able to utilize said cues to visualize their environments more effectively.

The desktop pointing error correlation for increased video game experience could be a result of participants who are adjusted to navigating computer-based virtual environments. More experience with such interfaces will allow them more practice, and thus potentially more efficient times and a more comprehensive grasp of where objects are located, resembling a graph and route knowledge of their environment. A possible strategy that could attribute increased gaming experience with a decrease in inefficiency and absolute angular error in desktop virtual environments is the familiarity of the participants with the design of the virtual environment. Many video games are interactive environments with distinctive landmarks, some resembling a grid like structure (Counter-Strike Global Offensive), or some resembling a self-created environment such as Minecraft, that require a basic graph or route knowledge to navigate the terrain. These desktop virtual environments consistently require players to use left/right directions, or utilize set maps to navigate. With more experience, players grasp the familiar layout of the virtual environment and therefore can dedicate more attentional visual direction to other aspects of the game, not just navigation, such as movement from other players. Sound cues as well as mastery of the controls are necessary for the best performance, as many FPS games have both elements to rely on for navigation and to make the experience more immersive. However, as stated, familiarity of desktop virtual environments does not seem to transfer to immersive virtual environments, as there was no correlation between more video game experience and the DSP paradigm.

It could simply be that more experienced video game players are adjusted to navigating using the computer keyboard and are familiar with the interface used to test participants. Frequent use of shortcut keys for navigation in these desktop virtual environments are WASD, or arrow keys, and a command of a mouse. Those with more video game experience, especially computer games, may have a more efficient command of combining movement and mouse functions on computer interfaces to navigate and therefore it may have contributed to more efficient navigation times in DSP (Richardson et al., 2011). Although the significant negative correlation between the desktop absolute pointing error and increased video game experience demonstrates knowledge of the environment from the participants beyond just rote memorization, so players may be aided by their familiarization of the interface, but the result cannot be solely explained by this alone.

Future directions may be limited by some of the same constrictions of this study. It is correlational, as previous real-world experience studies often are, so there are no causal conclusions to draw from this study. Additionally, not all of the data from the video game experience questionnaire and SILCton scores were collected for all the participants, so more power may be useful in determining the strength of these correlations. Previous studies investigated the kinds of video games played, ideally if the video games have a strong navigational component or not, but that was not assessed in this study, nor was the strategy of participants observed, which could narrow down the kinds of knowledge participants exhibited when completing the tasks.

Overall, this research replicated and extended past work on previous spatial abilities and their impact on spatial task performances within immersive virtual reality and desktop virtual reality. More specifically this paper investigated and discussed the effect of past video game experience on spatial measures. Previous navigational and creative activities seemed to correlate with navigation performance in immersive virtual reality, whereas previous gaming experience seemed to correlate with performance in desktop virtual environments. Absolute pointing measure between the two virtual environments seemed to measure two different spatial abilities, as they did not correlate with each other. Implications of route and graph knowledge for navigating the desktop environment were discussed. Parsing out the confounds of the different variables that affect spatial cognition is imperative to further understanding how human navigation works.

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Appendix A

Questionnaire

How much video game experience do you have?
How well do you perform in video games?
Reflect on your video game experience. In the period of your life that you are/were most active in playing video games. What was the average number of hours per week that you spent on playing video games?
How long is/was the period that you are/were most active in playing video games?
How many hours per week do/did you spend on each category of games during the period of your life that you are/were most active period of playing video games? - Pre-existing Environment
How many hours per week do/did you spend on each category of games during the period of your life that you are/were most active period of playing video games? - Self-created Environment
How long is/was the period that you were most active in playing video games in each category? - Pre-existing Environment
How long is/was the period that you were most active in playing video games in each category? - Self-created Environment

Appendix A1. The video game experience questionnaire.