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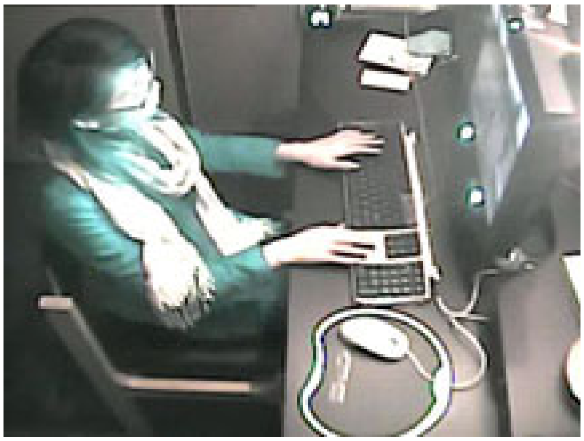

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Background

The research we report on here is based on a collaborative effort between researchers in gender studies with researchers in educational neuroscience focusing on affect and mathematical cognition and learning in virtual environments (e.g., Campbell, 2010a; 2010b; Du, Campbell, and Kaufman, 2010). For those of us in gender studies, this work began, not with using videogames as a research tool, but with an extended series of studies that looked at gender differences in access to, uses of and competence with new technologies, particularly videogames (Bryson and de Castell, 1995, 1996; de Castell and Bryson, 1998, Jenson and de Castell 2004, 2008, 2010).

Games have received substantial attention as educational resources (de Castell and Jenson, 2003; de Castell, Jenson and Taylor, 2007; Gee, 2003; Kafai, 2006; Steinkuehler, 2007). At the same time, and despite some recent advancements (Carr, 2007; Harvey, 2009), games continue to be regarded as 'boys' toys': largely made for, marketed to, and consumed by males (Bryce and Rutter, 2005). As the deployment of games in educational contexts increases and intensifies, we anticipate, along with other people doing similar work, that this signals a deepening educational disadvantage for girls (Jenson and de Castell, 2004, 2008, 2010).

Over a series of qualitative research projects involving school-based, gender-differentiated games clubs in a large Canadian city, we began to see gender differences as at least partially enacted and substantiated *through* gameplay: that, from a socio-cultural perspective, digital play can be seen as a resource/site for players to "perform" their gendered identities (Bryce and Rutter, 2005; Jenson and de Castell, 2008; Taylor, Jenson and de Castell, 2009). Furthermore, those ethnographic research projects allowed us to theorize that certain behaviors and preferences around gameplay that have long been regarded as gender-specific (for example, that boys are more competitive, or that girls are not as good at navigating three-dimensional space) are in fact not biologically based, but rather are contingent upon levels of access to, and competency with, digital games So while it has been proven that spatial orientation abilities have been importantly related to gender (Bruder, Steinicke, Hinrichs, Frenz, and Lappe, 2009; Cutmore , Hine, T. J., Maberly, Langford and Hawgood, 2000; Kimura, 1999; Moè, Meneghetti, and Cadinu, 2009; Mueller, Jackson, and Skelton, 2008; Ross, Skelton, and Mueller, 2006; Weiss, Kemmler, Fleischhacker, and Delazer, 2003); and this can be manifested in some computer games containing spatial orientation features., Feng, Spence, and Pratt (2007) found that playing an action video game can reduce gender difference in spatial cognition, whereas Moè, Meneghetti, and Cadinu (2009) found that self-perception of ability in women directly influences learning and performing mental rotation tasks.

Through these epistemic shifts, we have gone from using gender as a theoretical lens to study videogames, to now, using digital play as a site and resource for studying about gender: from gender *and* play to gender *in* play. Here, we explore how 3D, networked virtual worlds – in particular *Second Life*, which enables users to create and modify their own environments – can act as a kind of 'virtual' laboratory for studying gender difference. By tracking users' eye movements as they navigate a virtual rendition of the Morris Water Maze (the 'gold standard' for measuring gender difference in spatial orientation, navigation and mobility), this work constitutes an empirical basis for claims that we have attempted to make in the context of ethnographic work with female and male video game players, both novice and expert: that mastery of, and the ability to competently navigate through space, both real and virtual, is as much (if not more) learned and acquired, as it inheres in the bodies and brains of differently-sexed subjects (de Castell and Bryson, 1998; Jenson and de Castell, 2008).

Gender and space

Social-scientific studies of restrictions on women's range of movement provide an important theoretical backdrop to the present research: studies of women's ties to the domestic sphere, increased threat with increased distance beyond the home, childrearing practices encouraging physical activity for boys and physical immobility for girls, women's restricted access to jobs requiring mobility, spatial limitations that constrain women's permitted movement within worksites, gendered allocations of lesser office and desk space, and even the typicality of gendered patterns of 'shared' space usage, where men consistently appropriate relatively more of any shared space than women, all demonstrate that, across a range of contexts and situations, women experience less spatial mobility than men. It should come as no surprise, then, to discover empirical-scientific research indicating women exhibit lesser spatial abilities—in navigation, wayfinding strategies, spatial orientation, and mental rotation tasks, than their male counterparts. The question is, however, whether this reported cognitive-behavioural pattern is a culturally produced or a biologically based set of differences. This matters specifically in the context of digital games research, because videogames both depend upon, and develop, relevant kinds of cognitive-behavioural dispositions and abilities. So to know whether and how these gendered effects are culturally produced through exposure, encouragement and experience or 'hard-wired' in the hormonal or neural makeups of sexed bodies, is a central question for both videogame researchers, and for educational researchers in tandem.

Research on gender has long had to contend with too-hasty assumptions that differences found between men and women biologically (eg hormonally, neurologically, 'bent-twig theories of evolutionary biology included- see, for example, Sherman, 1978) based. We still find ourselves having to contend with arguments about men as hunters and women as gatherers (e.g., Kimura, 1999), long after any hunting and gathering has been going on culturally, and to contest interpretations of gender-correlated differences which invoke evolutionary biology as salient to explaining contemporary findings. Even among those who see considerable absurdity in hunter/gatherer kinds of explanations, we see little decrease in the popularity with which hormonal, neurological, physiological or other biologically-based accounts are proffered and accepted.

In earlier work, beginning with school-based studies on gender differences in competence and confidence with digital technologies, and moving from there into studying gender, learning and digital games, what has become increasingly persuasive is the possibility that it is experience first and foremost which shapes and limits abilities traditionally invoked as biologically determined. We have demonstrated considerable success in ‘leveling up’ girls with boys simply by providing increased support, access and experience, thereby significantly increasing female participants’ interest in and competence and confidence with digital technologies—clearly a socio-culturally explicable outcome (Jenson and de Castell, 2008). That we can produce a given outcome through socio-cultural interventions does not, however, in and of itself, render biologistic explanations unsustainable. For that, we need to get *beneath the skin* of culture and society, to work directly with the phenomena being invoked by those for whom biologically based explanations are the evidential ‘gold standard’. As humanistic cultural theorists, this is very far indeed from any familiar or comfortable disciplinary territory.

Theoretical Background and Experimental Design

Since our own work had already taken us quite far into technology-focused research, however, we looked for ways to use our digital game–based research to afford us access to these otherwise unfamiliar theoretical concepts and methodological practices. We already had a sense from observations of girls and women playing digital games in 2- and 3-dimensional space, that there were gendered patterns in play. Could we find tools and methods to see differences in the ways males and females navigated virtual space that mapped usefully on to the ways they navigated real physical space? And if we could, what could we design to identify and understand these patterns?

It was our good fortune to have within one of the faculties in which we worked, a well-equipped mathematics research lab with leading edge tools supporting psycho-physiological research---eye tracking, GSR, and EEG capabilities, and an interested colleague with a skilled lab staff (Campbell, with the ENL Group, 2007), who was willing to collaborate with us to design and pilot a series of experiments to study gender differences in spatial ability in a game-based virtual environment.

Male/Female? or Novice/Expert ?

Dis-entangling gender from experience was our first study requirement, because we already had seen that, in the terms in which gender had been identified in digital games research, ‘gender’ could as well be read as ‘skill level/expertise/experience’ (Jenson and de Castell, 2008), because of the typical convergence between gender and access/experience. We had evidence to suggest that when males are novices they play like ‘girls’; when they are experts they play like ‘boys’. Girls do, too. So we needed to address directly this risk of conflating gender with experience. We needed, therefore, to structurally separate, by design, skill from gender. This we did by the structure of our sample, supplemented by observation and interview. Survey self-report is notoriously suspect for acquiring information about skill level, as females typically under-report their game competence; males over-report it.

A challenge in any small-scale pilot study is to secure a data set which, while it can by no means be presumed to be representative of the population being studied, is at least warrantably suggestive and illustrative of its defining features. Since our challenge was to discriminate between spatial abilities that could have been developed/acquired/learned through experience from spatial abilities that may be an expression of biologically-based gender (sex) differences, we needed a data set that included both males and females, and since we wanted to see whether gender differences were maintained across levels of expertise, we needed both videogame novices and gameplay experts. We wanted to look at both gameplay environments, and play-oriented but not game-based environments, so we sought 8 players of *World of Warcraft* (WoW), and 8 *Second Life* users, with 4 males and 4 females in each set, of whom 2 females and 2 males would be experts and two females and two males would be novices in each environment.

WOW: M(X)	SL: M(X)	WOW: F(X)	SL: F(X)
WOW: M(N)	SL: M(N)	WOW: F(N)	SL: F(N)
WOW: M(X)	SL: M(X)	WOW: F(X)	SL: F(X)
WOW: M(N)	SL: M(N)	WOW: F(N)	SL: F(N)

Table 1: Separating participants by skill level, gender, and game environment

Subjects were recruited by snowball sampling, beginning with people known to the research team. Subsequently university student subjects were recruited using several large, brightly illustrated posters in the university's main hallway, with another one just to the side of the lab. A dedicated email address was shown prominently in the recruitment poster, which asked simply for women and men, either experts and novices, who played in WoW or *Second Life*, and incentives in the form of a $20 honorarium were provided.

To better assure that we were indeed accessing subjects who fully fit the categories our design required, we had access to survey data which identified subject's game experience, preferences and expertise, as well as the usual demographic data on age, sex, ethnicity, language, SES, educational level, etc. Complementarily, we had short qualitative interviews, as well as observational reports by the graduate research assistants setting up and observing the lab sessions, to supplement our video and eye tracking studies. That additional information enabled us to take into consideration spatial abilities that may have been developed through early (childhood) games and toys requiring and developing spatial ability (Voyer et al, 2000), as well as the likelihood that previous game experience would impact ability in current gameplay, even if that game was one to which the player was, technically speaking, a newcomer.

Video games as research tools: Serious play

One of the benefits of using digital games as virtual laboratories – aside from the obvious advantage, concerning the ethical and practical issues around submerging participants in a real pool of water – is that they leverage engagement with technologies which are, by definition, inherently incentivizing. While it may seem strange to suggest that our participants were perhaps *more* serious about our experiments precisely because it involved a not insignificant amount of *play*, there is an extensive body of educational research (our own included) that suggests that digital games elicit intense – and voluntary - attentional focus (de Castell, Jenson and Taylor, 2007). For us, then, the Virtual Morris Water Maze (VMWM) is far more than a convenient (and drier) alternative to real life contexts for the controlled study of gender and spatial orientation, which capitalizes on a socio-technical practice in which participants willingly and enthusiastically engage in a significant amount of attentional and cognitive 'work'.

Virtual worlds as experimental environments

As Kelly and Gibson point out, "the use of computer-generated immersive virtual realities and virtual environments appears to be quite fruitful for furthering our knowledge of spatial cognition" (Kelly and Gibson, 2007).

Studies of spatial abilities which make use of VR tools (cave, VR glove etc) have shown VR can be very useful for understanding spatial representation and spatial memory (Moffat, Zonderman, and Resnick, 2001; Rose et al., 1999), however VR technology has a few downsides: expense, unwieldy technological requirements, and the not infrequent induction of a kind of dizziness (termed "cybersickness,") that can confound attempts to standardize experimental conditions. (Liu, Watson, and Miyazaki, 1999). What Kelly and Gibson (2007) propose as a better alternative is the use of virtual environments (VE's), which they characterize as being more economical, more portable, and more ecologically valid. Being less immersive than VR, VE's do not induce the complicating factor of motion (cyber) sickness. As well, variables that complicate 'real world' experiments, such as anxiety, motivation, environmental cues and differences in physical ability are more readily controlled for in VE versions of well-established experiments.

We believe that gameworlds offer rich virtual environments and we are interested in finding out what research opportunities these game-based VE's provide, and as well in whether and how we can modify aspects of game-based virtual worlds, adding to them well-established experimental scenarios, so as to take advantage of the distinctive affordances of games for increasing engagement and decreasing anxiety; reduced stress and increased pleasure can be afforded by play-based activities. In this specific pilot project, we are looking for patterned variation, as captured through eye tracking, in the ways males and females, novices and experts, in spatial abilities in virtual world games and in virtual lab environments. We hope to be able to distinguish patterns these categories identify, with respect to group differences in spatial abilities that offer empirical evidence of measurable physical differences underlying those categories.

To that end, we created in Second Life a VE experimental test, a Virtual Morris Water Maze (Figure 1), modeled on its real world predecessor, the Morris Water Maze (MWM), which is the 'gold standard' for experimental studies of spatial ability.

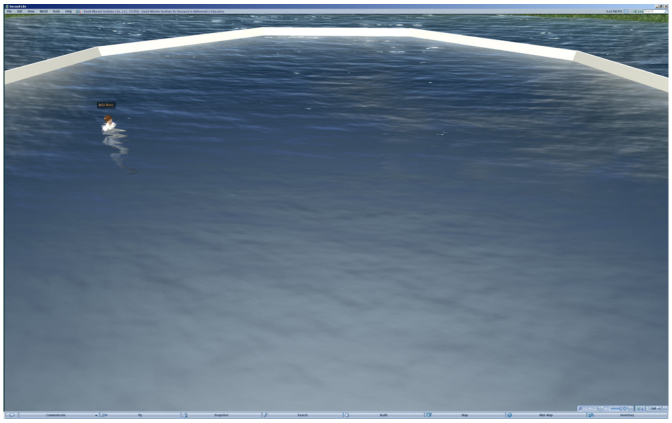

Fig.1: Virtual Morris Water Maze

Using the play-oriented resources of the second life virtual environment provides both a rich and varied and dynamic virtual environment as well as a well-structured, (and structurable) experimentally validated standardized virtual environment within which to seek significant navigation/spatial orientation skills and strategies across these categories of player. Our eventual goal, should the data we collect prove to be fruitful for distinguishing male/female and novice/expert players, is to implement within a commercial game, a functional equivalent of the virtual Morris Water Maze, but recast in the form of a game (a treasure hunt), as a first attempt to design games that can also serve as stable experimental virtual lab settings, and can advance both quantitative and qualitative inquiry.

Questions of 'transfer' are made particularly evident when we are shifting media, as in this case from material world entities, agencies and activities, to virtual agents, simulated actions and digital realities. (This is, in another way of course, just another ---albeit dramatically remediated---set of 'real world' identities, actions and materialities, since VW player subjects continue to inhabit bodies located in real space.)

Can we design play-based VE tools whose use will yield answers about 'real world' questions? Kelly and Gibson (2007) pose the question fundamental for this study: "Is the spatial information presented using VE sufficient to generate similar spatial representations as that when one is navigating through a real-world environment?" (p. 116). Their study uses VE to simulate a task originally designed to study spatial learning in rodents, as a way of answering that critical question.

Of particular interest has been a wider set of challenges around different orders of fidelity. How 'true' is our VMWM to its origins? Are we looking for environmental fidelity? Functional fidelity? Or both? What confidence transfers from reported findings with water and rodents, to human males and females steering an avatar through a screen-based representation of water? How does VW movement tell us about RW movement?

From game-based v-labs to "real" videogames

A further but no less important transfer question is about justifying the use of VE labs, experimentation and testing for video*game* based research. How can VE research and digital game studies mutually inform one another? *Second Life* is not, after all, a game, though it is reasonably well described as a playful virtual environment. There are questions we would want to ask about spatial navigation in videogames, and whether there are discernibly distinctive patterns in game-based spatial abilities that correlate with gender as distinct from expertise.

Fig 2: Eye-tracking in 'real' virtual world games

Even if we can explain and justify and illustrate the successful use of virtual environment-based tests and experiments, how has this informed the larger question of using videogames as a research tool? To address this question, we are, as well as eye-tracking using VMWM in a (*Second Life*) virtual environment, also eye tracking expert/novice/male/and female players of World of Warcraft (Figures 2, 3 and 4).

Fig. 3: Eye-tracking shows early 'intuitive' use of map diagram by an expert male player, who is a novice to WOW (first time played)

Fig. 4: Eye tracking the same (experienced) player efficiently accessing unfamiliar game commands.

We have reasonable confidence we can discriminate distinctive novice and expert patterns of visual attention along the lines diagrammed below (Figure 5). In our initial scan of the data, this appears to be a good approximation of these distinguishing visual-attentional patterns.

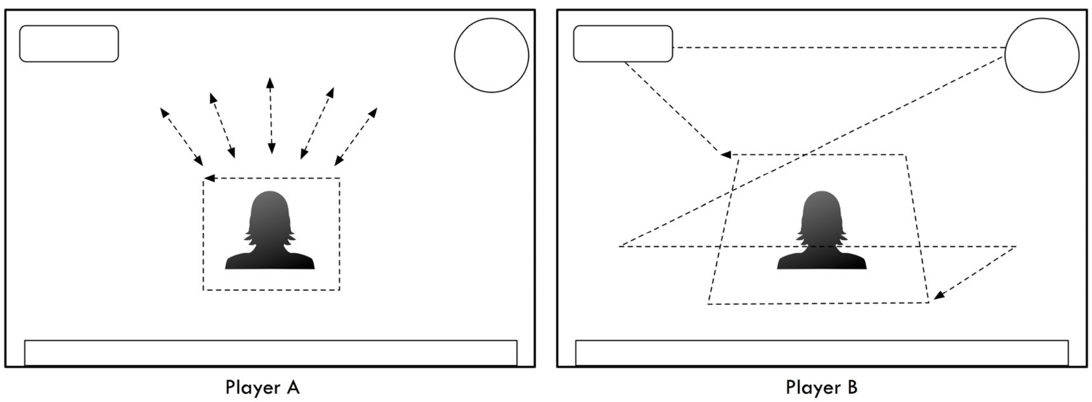

Figure 5: Distinguishing Between Novice Viewing Patterns (unfamiliar with genre vs. familiar)

Given that action-driven videogames in general, and first person shooters in particular, both depend upon and develop spatial abilities (Feng, Spence, and Pratt, 2007), we hypothesize that female players with comparable access, support and experience to male players will demonstrate comparable spatial abilities. However we are also seeing ways in which in-game roles (e.g. healers in WoW) and associated mobility and spatiality demands are normatively gender-stratified, which means we will likely see less mobility and spatial competence in normatively role-bound female players than in males, and this will complicate the picture.

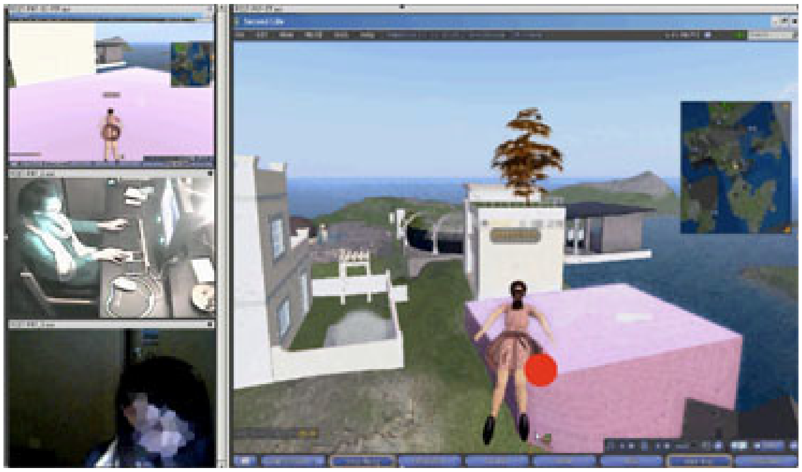

Fig. 6: Experienced female player finding the VMWM in *Second Life*---by flying

Trials and Tribulations

Collecting eye tracking data is not fool-proof, and experimental design proceeds at least half the time more by error than by trial. Significant issues we have already encountered include: design of our VMWM needing changes, such as automating exits and re-entries and timing of trials (Figure 6), preventing subjects from changing points of view, which renders the ET data non-comparable, the need to add landmarks to the environment as distinct from directional cues, hardware failure, software failure, typical human error and 'difficult' subjects (those with glasses and those who don't look directly at the screen). This has left many of our sessions (6 of 16) with incomplete eye tracking data, or none at all.

There are several reasons for this:

1. Because we are attempting to collect so much data at one time, the systems that we are using to collect that data are heavily burdened: meaning, we have to have a large amount of hard disk space, and the machines we are using to collect that data must not be running anything else at the same time, otherwise the hard disk crashes, or we have software failure because we are asking one machine to do too much at once. As mundane as this kind of problem is, it bears reporting on, because it illustrates how incredibly difficult it can be to generate a complete data set consistently across all subjects, because of system resource intensiveness, even in a lab so well equipped.

2. While eye tracking equipment is supposed to be able to be calibrated to work with eyeglasses and peculiarities of subjects, it has not yet been the case that we have been successful in capturing accurate eye tracking data on all subjects who wear glasses, and equally frustrating, we have also had two sessions that did not produce readable data because in one case the participant was looking down when viewing the screen and in the other case because they were heavily squinting at the screen in an attempt to view it. These kinds of inconsistencies have meant that we have needed to almost double our participant pool in order to get adequate data.

3. Finally, because it takes quite a lot of time, energy and resources (both human and machine) to collect this kind of data, human error also remains a significant barrier to

accurate, usable data. This could including something as simple as not noticing over a 30 minute period that someone was looking down a lot so we were not getting accurate eye tracking, or not accurately guessing how much hard drive space to free up so the session could be captured, or something as banal, but important as not giving explicit, clear instructions, leading to the participants' feeling either frustrated, confused or anxious.

Noteworthy as well is the decision about which view to use in a VW experiment. We would not be able to compare the eye tracking data over the same visual environment of the water maze, if some subjects took an egocentric, and some an allocentric view, so we had to ensure that all subjects would be restricted to a single view. In our case, we discovered to our cost that the egocentric view, which gave us such clear and crisp information, utterly confused a female subject who was otherwise very much an expert gamer (Figure 7). In the absence of a third person allocentric view of her avatar's body in (virtual) space, she was unable to find her way even as capably as a rank novice to VW navigation. She expresses her confusion verbally, and it is visible on her face as she tries to figure out an insufficiently 'marked' environment. Also, of course, though we could determine where her pupils were focused, we could not determine what she herself was seeing, so we could not interpret the significance of whatever her eyes did focus on.

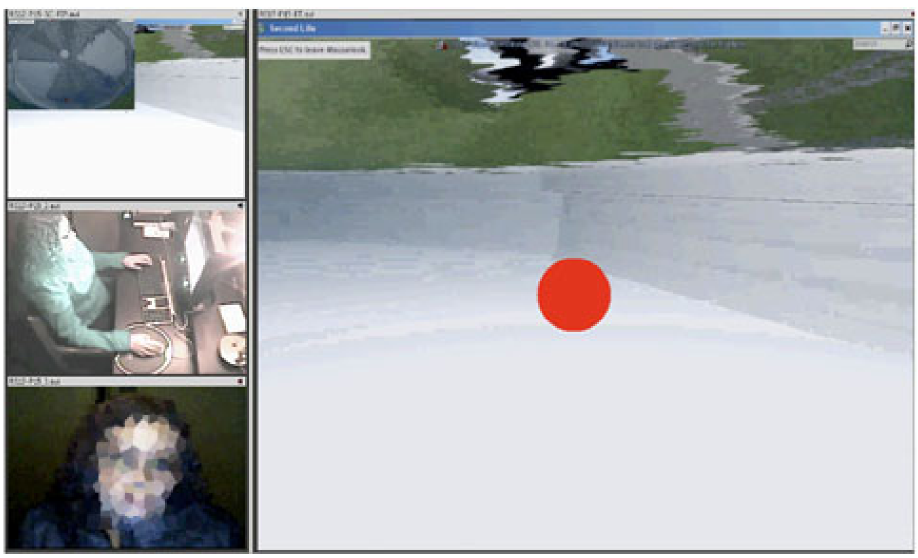

Fig. 7: Design problems: No Avatar! Experienced gamer disoriented by an egocentric view

Notwithstanding obstacles and complications, technical as well as theoretical, we went ahead with admittedly flawed instruments and unstable procedures in order to complete the pilot study we report here. For this initial study, which commenced mid-January 2010, we wanted to recruit equal numbers of males and females, half of whom would be (self-reported) 'expert' users and half of whom would be novices in the virtual worlds involved (*Second Life* and *World of Warcraft*, two popular virtual worlds, markedly different in their rule structures, graphics, environments, and orientations to/affordances for in-game activities).

All participants were asked on entering the lab to read about the project, ask any questions and sign the informed consent form. Once participants had been informed about the study and consented to participate, they were interviewed (quickly) about their gameplay habits (e.g., what games they were familiar with, if, and what, they play at home, and so on) and then invited to sit in the small room at the machine where the study took place. Because the room is sound proofed, participants were fully enclosed during the data collection process, although they could see the researcher through a large square hole in the dividing wall, through which they also receive instructions. To begin, the participant was asked to fill in a survey covering basic demographics and drill-down information on game play experience, choices and habits. Eye tracking was tested (to make sure it works) at this point, and participants' completion of the online survey was fully screen captured. Both cameras (one positioned directly at the participant, the other on a side view) were operational at this time.

Subjects were then asked to try the Virtual Morris Water Maze and asked to find a hidden platform beneath the surface of a pool. Once they found the platform, they were asked to look around and get their bearings, and then to re-enter the pool and find the platform again (see Figure 8).. The trial was timed, and eye tracking recorded the subjects visual attentional pattern, both measurements being in the hope of revealing whether, as would be predicted by previous studies, male subjects completed trials faster, and navigated by reference to distant, directional clues, while female subjects took longer time, and oriented themselves by reference to closer landmarks.

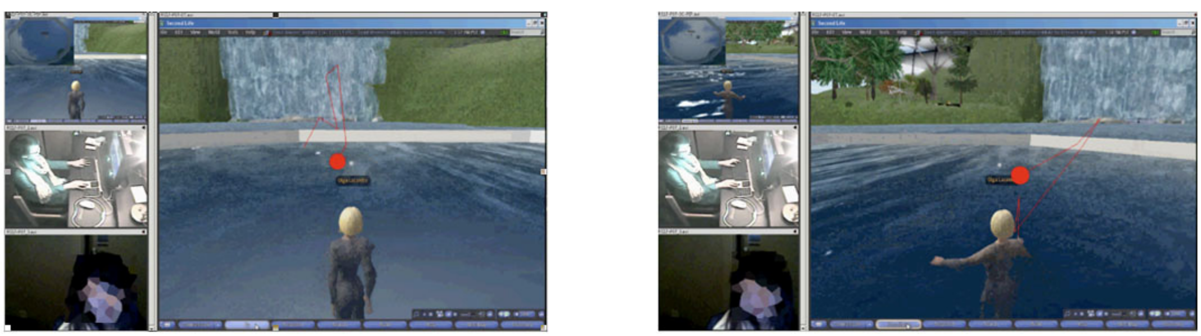

Fig 8: Experienced female player finds the hidden platform

In lab-based play sessions of 30-60 minutes each, participants' in-game activities (avatar actions) as well as embodied actions (gestures, posture, voice) were audio-visually recorded simultaneously as subjects carried out prescribed in-game tasks, requiring varying degrees of competency, comfort, and fluency with the game environment, as well as varying levels and kinds of avatar movement and mobility. Spatial-related tasks (SRT) include: spatial location memory; spatial perception; targeting; spatial orientation; mental rotation; and disembedding (i.e., identifying simple objects embedded in more complex figures). Participants' eye movements, gaze, and pupillary response were obtained (using a Tobii eye-tracking monitor) and synchronized with audio-visual data to produce a richly multimodal data set of participants' psychophysiological, discursive, and 'virtual' re/actions to in-game activity.

Eye-tracking methods included fixation duration and pupillary response measurements, which, in turn, can identify the types of strategies related to males and females for certain spatial orientation tasks. For example, strategy based on memory encoding is associated with larger pupil dilation and longer fixation duration (Meuller, Jackson, and Skelton, 2008).

Pre-preliminary findings and implications

Armed with insights from this pilot study, we have embarked on a redesign of the experiment. We are automating several of the avatar movements, including an automatic termination of each trial after 40 second, and automating the viewing period (20 seconds) if the avatar has successfully located the hidden platform. Human error was considerable here, with a lag of several seconds before the RA communicated to the subject that he had found the platform, and the intended 20 seconds of looking around from the platform stretched in one case into 2 minutes and 30 seconds of looking around, flying over the area, etc before re-entry for the second trial (Figure 9). We are therefore automating both exits (after 20 seconds viewing) and re-entry, to ensure subjects do not acquire additional navigational information by surveying the area and determining their own re-entry point.

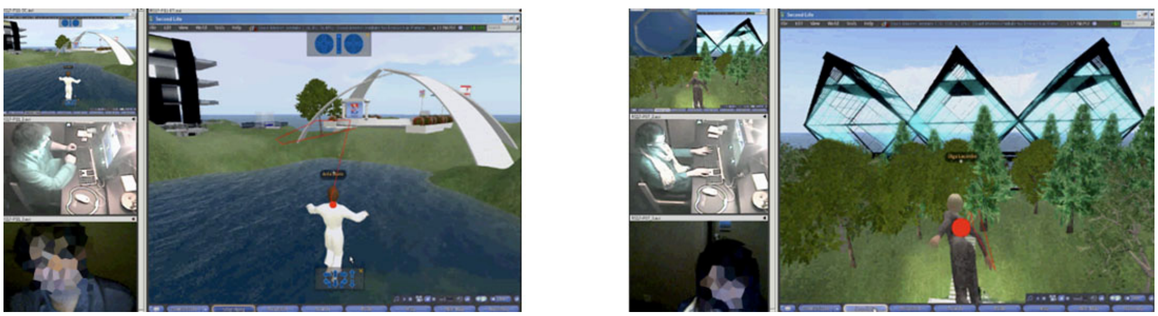

Fig. 9: The easy way…

We also needed to eliminate as such as possible all verbal directions given by lab staff (inevitably, relevant information was being provided by lab staff, e.g. "there's another entrance over there, you see on the left? You can go there"). Significant time was taken up by verbal hesitations in human instruction-giving - as much as 30 second to advise the subject of the 20 second time period for looking around from the platform. So we are implementing written instruction set, for se both prior to and during the experiment, as well as 'just in time' instructions on screen. We are restricting avatar movement: as mentioned, we found experienced users will simply FLY over the area to re-enter, allowing an excellent birds-eye view, and obviating the need to strategically map out the environment using pool-based locational and directional cues.

Another rather embarrassing artifact of flawed initial design was that we were losing an important indication of novice status: in game play, we found that novices would focus visual attention on their avatar, while experts would focus on maps, inventories and other information grids. However, in the VMWM we found experts and novices alike gazing most of the time at their avatar's head, since that provided the ONLY indication for finding the platform.

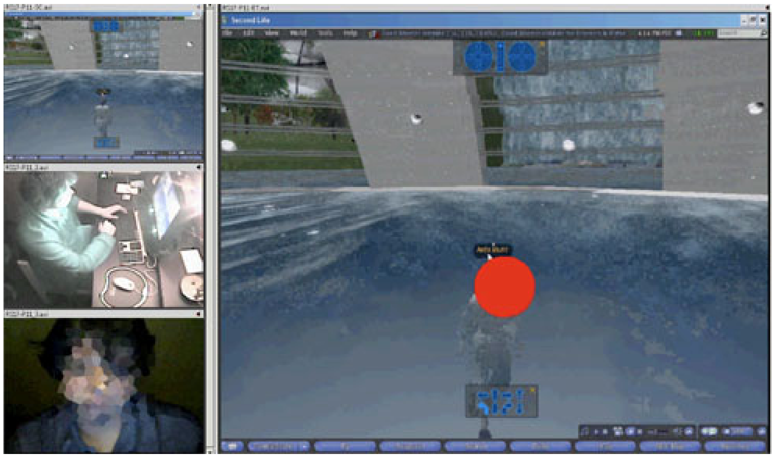

Fig. 10: Eyes on the head

So we are adding an auditory cue, as well as a visual one, immediately prior to the avatar's head rising form the pool when the platform is located.

We anticipate that these and other design modifications developed through our pilot testing will allow the psychophysiological analyses using eye-tracking data involved in this study to deepen and extend what we have argued previously on the basis of our socio-cultural and ethnographic analyses of gaming: that what are often construed as sex-based differences between men and women in their ability to navigate three-dimensional space will prove--objectively--to be, in large part, a function of *experience*, and that differences in spatial mobility and ability result more significantly from socio-cultural differences, rather than biological ones.

Methodologically, this multi-disciplinary collaboration between gender scholars working in ethnographic research traditions and mathematics scholars involved in neuroscience and psychophysiology seeks to bridge qualitative and quantitative studies of gender, to provide an objective basis for adjudicating between biological and sociocultural explanations of gender differences in general, and sex-linked differences in spatial ability, in particular, through this innovative use of digital game-based research.

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