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A CROSS-CASE ANALYSIS OF GENDER ISSUES IN DESKTOP VIRTUAL REALITY LEARNING ENVIRONMENTS

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Abstract

This study examined gender-related issues in using new desktop virtual reality (VR) technology as a learning tool in career and technical education (CTE). Using relevant literature, theory, and cross-case analysis of data and findings, the study compared and analyzed the outcomes of two recent studies conducted by a research team at Oklahoma State University that addressed gender issues in VR-based training. This cross-case analysis synthesized the results of these two studies to draw conclusions and implications for CTE educators that may assist in developing or implementing successful virtual learning environments for occupational

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training. The cross-study findings suggested that males and females may be differently affected by VR and that females may be less comfortable, confident, and capable in virtual learning environments, particularly when the environments are highly technical and visually complex. The findings indicate caution in the use of VR in mixed-gender CTE programs, particularly in programs that are heavily female-gendered.

Introduction to Desktop Virtual Reality

To maximize their instructional effectiveness, career and technical education (CTE) programs need to apply effective learning tools in their classrooms and laboratories. Recent literature reviews of published research (c.f., Ausburn & Ausburn, 2004, 2008a, 2008b; Ausburn, Ausburn, Cooper, Kroutter, & Sammons, 2007; Ausburn, Ausburn, Ashton, Braithwaite, Dotterer, Elliott, Fries, Hermes, Reneau, Siling, & Williams, 2006) have consistently documented the effectiveness of virtual reality (VR) as a learning tool in a variety of settings. The research has shown that many educational institutions, industries, and organizations are now turning to VR to provide effective and cost-efficient ways of teaching and career preparation and development. The field most actively reported in the VR literature is medical/dental, where large numbers of published studies have attested to VR's benefits (Harb, Adams, Dominguez, Smith, & Randall, 2005; Imber, Shapira, Gordon, Judes, & Mitzgar, 2003; Jaffe & Brown, 2000; Jeffries, Woolf, & Linde, 2003; Mantovani, Gaggiolo, Castelnuovo, & Riva, 2003; Moorthy, Smith, Brown, Bann, & Darzi, 2003; Patel, Gallagher, Nicholson, & Cates, 2004; Riva, 2003; Seymour, Gallagher, Rorr, O'Brien, Bansal, & Anderson, 2002; Urbankova & Lichtenthal, 2002; Wilhelm, Ogan, Roehaborn, Caddedder, & Pearle, 2002).

Engineering has also reported considerable success with virtual reality instruction (Sulbaran & Baker, 2000).

A variety of other occupations and industries have reported positive performance results in the virtual reality research literature. These include auto spray painting (Heckman & Joseph, 2003), firefighting (Government Technology, 2003), forestry machine operation (LaPoint & Roberts, 2000), meteorology (Gallus, 2003), and welding (Mavrikois, Karabatsou, Fragos, & Chryssolouris, 2006). Use of VR for both career training and for product development has also been reported for several years in a variety of other industries such as aerospace, petroleum, equipment design, vehicle prototyping, lathing and manufacturing, accident investigation and analysis, law enforcement, anti-terror response, hazard detection, crane driving, aircraft inspection and maintenance, and facilities planning (e.g. Flinn, 2005; Government Technology, 2003; Halden Virtual Reality Center, 2004; Jezernik, 2003; Sandia National Laboratories, 1999; Scavuzzo & Towbin, 1997; Sims, 2000; Shneidermann, 1993).

Despite issues with costs, technology concerns, and instructional design challenges with VR, Watson’s (2000) conclusion that “Most would consider that … [VR] systems provide strong potential … for the educational process,” (p. 231) appears to represent well the current general position and expectation of virtual reality researchers and users.

The term *virtual reality (VR)* has undergone continuous changes since its introduction in the late 1960s as immersive experiences with computer-generated imagery via head-mounted displays (HMDs). According to Loftin, Chen, and Rosenblum (2005), VR is a set of “… integrated technologies that provide multimodal display of and interaction with information in real time, enabling a user… to occupy, navigate, and manipulate a computer-generated environment” (p. 479). Davies (2004) defined VR as a “… technique of using computers to model real … environments in a three dimensional space that allows people to interact with the environment in a fashion that is both natural and intuitive" (p. 3). Ausburn, Martens, Dotterer, and Calhoun (2009) viewed VR as simulation of locations that model for users the characteristics of the locations and allow them to "visit" and "… experience simulated locations with as much fidelity as possible" (p. 1). Di Blas and Poggi (2007) also emphasized the importance of "presence" in VR, which they identified as engendering in users a sense that they have actually *been* somewhere rather than just *seeing* it. In summary, virtual reality (VR) currently refers to a variety of computer-based experiences ranging from fully immersive environments with complex HMD gear and body suits, to realistic PC-based imagery environments. However, in all its forms, VR is basically a way of simulating or replicating a 3D environment through computer-generated imagery and giving the user a powerful sense of "being there," taking control, and actively interacting with the environment and its contents (Ausburn & Ausburn, 2004, 2008b; Ausburn, Martens, Dotterer, & Calhoun, 2009; Beier, 2004; Brown, 2001).

The newest form of VR is called *non-immersive or desktop VR.* It uses QuickTime, Java, or Flash technology to present high-resolution panoramic imagery on a standard desktop computer. Desktop VR "movies" are created by taking a series of digital still photographic images and then using special VR software to "stitch and blend" the images into a single panoramic scene that the user can "enter" and explore individually and interactively. The user employs a mouse to move and explore within an on-screen virtual environment as if actually moving within a place in the real world. Movements can include rotating the panorama image to simulate physical movements of the body and head, and zooming in and out to simulate movements toward and away from objects or parts of the scene. Embedded individual virtual objects can be "picked up," rotated, and examined as the user chooses, and clickable "hot spots" can also be used to navigate at will (Ausburn & Ausburn, 2008b; Ausburn, Ausburn, Cooper, Kroutter, & Sammons, 2007). What characterizes these desktop VR movies and distinguishes them from traditional video is that *the user* chooses where, when, and how to move, explore, and examine rather than being controlled by the prior production decisions of a videographer (Ausburn & Ausburn, 2004).

What is important about the recent major technical advances in desktop VR for CTE educators is that these technologies now bring the advantages of VR experiences within the fiscal and technical capabilities of most schools and instructors. Because of the recent dramatic improvements in the technical capabilities and features of desktop VR and its accessibility to schools, teachers, and organizations, this technology is emerging as an important new tool for CTE. The new desktop VR is the focus of the research and findings reported in this paper.

Gender and Virtual Environments: Theoretical/Conceptual Framework and Supporting Literature

While VR has repeatedly demonstrated positive learning outcomes, some research has also shown that this effectiveness has not been identical across genders. This research is especially relevant to educational settings that involve training for occupations that are highly gendered, such as the health and medical fields. Educators who use virtual reality in training for gendered occupations need to be cognizant of gender-related issues associated with virtual reality in order to effectively use this new technology. Research has identified several theoretical and conceptual areas that suggest reasons for differential effects of virtual environments across genders. These include visual/spatial functioning, human navigation and wayfinding theory, and socially- and culturally-influenced perceptions of and experiences with computer technology. These factors come together in self-efficacy theory, as each influences the formation of an individual's technological self-efficacy, which determines an individual's performance and perception of that performance in a technology learning environment such as VR. These variables and concepts and their proposed relationships allowed the researchers to form a working theoretical and conceptual framework for the research reported in this study. This theoretical/conceptual framework is shown in Figure 1. This framework and its supporting literature are discussed below.

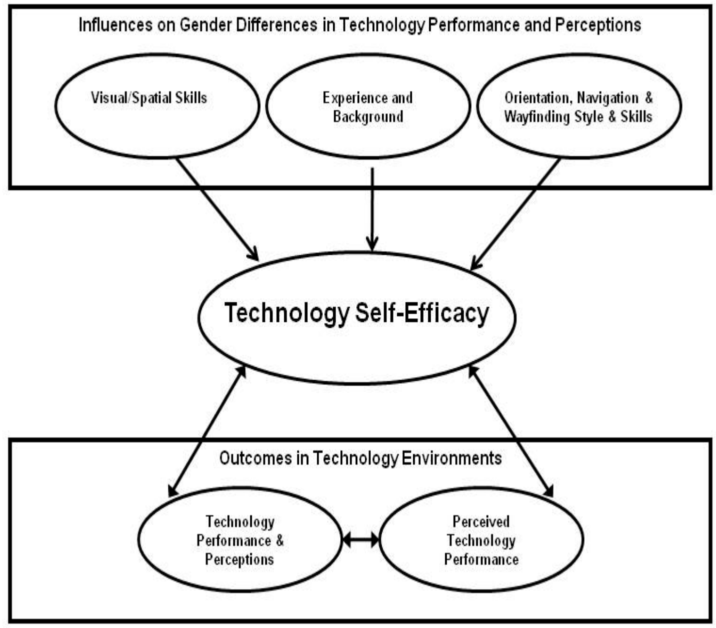

Figure 1. Theoretical/conceptual framework for this study. This proposed framework for gender effects in technology-based learning environments applies specifically to virtual reality environments in the context of this study.

In the area of *visual-spatial functioning*, half a century of research history with paper-and-pencil and performance tests such as the *Differential Aptitude Tests* (Bennett, Seashore, & Wesman, 1973), the *Cards Rotation Test*, (Allen, 1974), the *Generic Mental Rotation Test* (Hakstian & Cattell, 1975), the *Primary Mental Abilities- Spatial Relations Test*, *(*Keyes,

1983) and the Guilford-Zimmerman (1948) test of spatial orientation have revealed consistent gender differences in skill in mental rotation/manipulation of objects and spatial orientation, with females generally having lower skill and greater difficulty than males in these cognitive tasks. Numerous studies have documented this gender discrepancy. For example, Linn and Peterson (1985) and Voyer, Voyer, and Bryden (1995) both reported higher performance levels by males on mental rotation and spatial visualization tests. Terlecki and Newcombe (2005) claimed that facilitation of computer experience through training may have differential effects on men's and women's spatial performance, and reported that men not only perform at higher levels than women on tests of spatial and mental rotation ability, but also tend to have more spatial experiences. Research evidence has also suggested that the long-observed gender gap in mental rotational skills is exaggerated in virtual environments, and that men and women perceive virtual experiences quite differently, with men preferring more interactive environments than women (Space, 2001; University of Washington, 2001). Further, Waller, Knapp, and Hunt (1999) asserted that (a) understanding the spatial characteristics of virtual environments may be more challenging for women than for men, (b) in general, tests of mental visual manipulation and spatial orientation – in which females have typically been less skilled than males – are highly predictive of the ability to acquire accurate spatial information in a virtual environment, (c) gender-related differences in proficiency with a VR navigational interface are particularly important in determining ability to acquire spatial information, and (d) individual differences related to gender and cognitive ability account for more variance in performance on tasks requiring spatial knowledge acquisition from virtual environments than does the actual visual fidelity of the VR representation of the physical world. Waller (2000) subsequently agreed with that position and reported that spatial ability and interface proficiency – both of which had been statistically related to gender – had the strongest effects in spatial knowledge acquisition in virtual environments. He concurred with the earlier conclusion by Hunt and Waller (1999) that:

> Our results suggest that there are very strong male-female differences in the ability to benefit from VE [Virtual Environment] training. Recent work in our lab has suggested that most of the effect of gender in VR spatial learning is statistically associated with differences in spatial ability … and proficiency with the navigational interface. (p. 69)

Regarding the alterability of these two predictors of success in training with virtual environments, Hunt and Waller (1999) stated clearly their belief that "… there is surprisingly little evidence that gender differences in psychometrically-assessed spatial ability can be reduced by training" (p. 69). However, both Hunt and Waller (1999) and then Waller individually (2000) theorized that females' functioning in virtual environments and their ability to benefit from VR training could be improved, and the gender differences reduced or even eliminated, through appropriate training to increase women's proficiency with the VR user interface.

Several studies by Waller and his associates have specifically documented the existence of gender-related performance differences in virtual environments. Waller (2000) asserted that in his studies women who used desktop VR were statistically less likely to derive accurate spatial information from it than men, and that gender was one of the most powerful predictors of spatial knowledge transfer in virtual environments. Similarly, other studies of training in virtual environments have reported gender differences in favor of males on a variety of performance measures (Waller, Hunt, & Knapp, 1998a, 1998b; Waller, Knapp, & Hunt, 1999).

One possible explanation of at least part of observed male advantage in acquiring and using spatial configurational information in complex environments has been proposed by both Hunt and Waller (1999) and by Lawton (1994; Lawton, Charleston, & Zieles, 1996). The explanation proposed by these researchers is based in *human wayfinding and navigation theory*. This body of theory addresses how individuals know where they are in an environment, where important objects are in relation to them and to each other, and how to move from place to place. The proposed rationale for male advantage in spatial wayfinding is that it can be at least partially attributed to gender differences in specific strategies used during the "wayfinding" process. They proposed that males tend to use wayfinding strategies appropriate for navigation (e.g. bearing to landmarks), while females concentrate on strategies more suitable to tracking and piloting (e.g. describing control points and route cues such as street signs).

Several researchers have taken quite different theoretical directions for discussing gender differences in performance in virtual environments. One approach has been to examine male/female differences in *technology self-efficacy*. Bandura's well known theory (1994, 1997) defines the self-efficacy construct as belief or confidence in one's ability to take appropriate actions to successfully perform a certain task. Bandura also asserted that one's level of self-efficacy, regardless of its truth, could impact actual performance. Some researchers have discussed technology self-efficacy and identified it as an important factor in successfully using electronic technology (e.g. Eastin & La Rose, 2000; Kandies & Stern, 1999).

This notion of technology self-efficacy raises the possibility that gender differences in success with learning from and in virtual environments may be related to different experiences and perceptions of digital technologies. The technology literature of the 1980s – 2000 period presented many studies showing that attitudes toward technology differed significantly between males and females, reporting that males had greater interest in and knowledge of technology, and that females perceived technology as more difficult and less interesting. Typical of the period were studies by Temple and Lips (1989) that found males generally reported more comfort and confidence with computers, and by Waller, Knapp, and Hunt (1999) that found gender-related differences in prior computer use accounted for considerable variance in performance on tasks requiring gaining spatial knowledge from VR. Also abundant over the last 15 years have been studies documenting female "technophobia" and computer anxiety (e.g. Gilbert, Lee-Kelley, & Barton, 2003; Rainer, Laosethakul, & Astone, 2003; Schumacher & Morahan-Martin, 2001; Todman & Day, 2006; Weil & Rossen, 1995; Whitley Jr., 1996). The American Association of University Women (AAUW) (2000) conducted extensive research examining the technology gap between girls and boys and concluded that teacher attitudes, public media, software manufacturers, and curriculum all had detrimental effects on gender technology self-efficacy deficits and lowered self-confidence of young girls about technology.

Bain and Rice (2006-2007) recently reviewed the body of literature on gender and technology and then addressed the question of whether gender differences in perception and use of technology still existed. They found that the majority of females in their study did not perceive computers as being difficult and were using them more than in the past, but did not have the same level of confidence or technology self-efficacy as their male peers. In another recent study, Hogan (2006) documented the persistence of higher levels of technophobia among older women and men in Ireland, suggesting this persistence may not be confined to the United States.

Research has frequently identified gender as a strong predictor of technological self- efficacy, with females more likely to rate self-perception of their computer skills lower than males (Bain & Rice, 2006-2007; Busch, 1995; Hargittai & Shafer, 2006; Hogan, 2006; Temple & Lips, 1989). Women have also frequently reported less confidence and more anxiety with usage of spatially-related materials and computer software (Terlecki & Newcombe, 2005).

It would thus appear from the research evidence that despite gains in their positive perceptions and usage of computers, females may still lag behind males in technology self-efficacy, which may continue to impact their performance in high-technology learning environments such as VR.

Several reasons have been proposed for gender differences in technology self-efficacy. These have included (a) the spatial ability differences discussed by Waller and his associates, (b) differences in interest and experience with video games and related technologies such as VR (Philips, Rolls, Rouse, & Griffiths, 1995), (c) psycho-social gender differences in preferences related to functions and features of games (Heeter, Chu, Mishra, Egidio, & Lee, 2005; Heeter, Mishra, Egidio, & Wolf, 2005; Heeter & Winn, 2005; Heeter, Winn, Egidio, Mishra, & Lownds, 2003; Heeter, Winn, & Greene, 2005), and (d) a general "masculinization" of computer gaming and related technologies. For example, Graner (2004) asserted that males are encouraged to gain pleasure from aggressive behavior and competitive play of violent games while females, because of their historically more nurturing care-giving roles, are less comfortable with aggressive competitive violence in gaming. Oldenziel (1999) contended that technology as a masculine domain is a socially constructed concept which has been historically used to define masculine/feminine roles. The AAUW (2000) study cited above echoed this contention that the "computer culture has become linked to a characteristically masculine worldview" (p. 16) which forces girls and women to make decisions whether to embrace technology or opt for culturally accepted views of themselves as feminine. Gannon (2007) asserted that the language, images, and concepts used to mass-market various forms of technologies to either women or men perpetuate cultural stereotypes of the nature of technology. Similarly, Heeter, Chu, Mishra, Egidio, and Lee (2005) supported the existence of gender differences and cultural stereotyping in gaming preferences. They found that boys liked game features such as weapons, fighting, challenging levels, complex controls, and navigating sharply through the game space using teleporting or warps; while girls liked game features such as story lines, multiple levels to accommodate varying skill levels, adequate instructions, collaboration and chat, and on-screen avatars representing females and appealing pets. The notion of gaming masculination was supported by Hess and Niura (1985). Their study found a significant amount of the computer videogame genre to be focused towards typically "masculine" interests, with emphasis on aggression or violence. This led them to conclude that because of this gender bias, females may be less likely to engage in spatially- related computer activities such as gaming.

The relationships among the variables impacting the gender differences observed in research on learning technology have been well documented over more than two decades in the reported literature in educational technology, computing and information sciences, cognitive sciences, and sociology. This research history was synthesized by Cooper (2006) in an extensive review of 20 years of digital divide literature based on gender. In a psychological analysis of these variables, Cooper contended that the gender digital divide in technology self-efficacy and performance is fundamentally a problem of computer anxiety rooted in gender socialization interacting with stereotype of computers as toys for boys. For Cooper, this anxiety leads to, and manifests itself in, the differences in computer attitudes and performances that are frequently observed and reported in cross-gender computer studies (2006).

Virtual Reality Studies at Oklahoma State University

As desktop virtual reality began to improve technically and to offer CTE programs and instructors a cost-effective way to bring the benefits of virtual learning environments into educational settings, a research team at Oklahoma State University (OSU) launched a line of inquiry into this dramatic new technology. Prior to the OSU research, published VR studies had focused primarily on complex immersive VR technologies rather than on the more accessible new desktop alternatives (Ausburn & Ausburn, 2004, 2008b), and the few studies that did test desktop VR (e.g. Jeffries, Woolf, & Linde, 2003; LaPoint & Roberts, 2000; McConnas, MacKay, & Pivik, 2002; Scavuzzo & Towbin, 1997; Seth & Smith, 2002) were not focused on potential gender issues with emerging virtual technology.

The desktop VR studies at OSU have taken a different approach from the anthropology or descriptive case study methodology that Moore and Kearsley (2005) contended has often defined and limited the usefulness of research on new technologies. Instead, the OSU studies have been quasi-experimental in design and grounded in both classic and contemporary instructional design theories such as media supplantation capabilities (Ausburn & Ausburn, 1978, 2003; Salomon, 1970, 1972), media concreteness theory (Dale, 1954), cognitive load theory (Sweller, 1988; Sweller, 1999; Sweller & Chandler, 1994), self-efficacy theory (Bandura, 1994, 1997), individual differences theories, and Aptitude-Treatment Interaction theory (Cronbach & Snow, 1977). Ausburn and Ausburn (2008a) summarized the research model for the OSU studies in their recent review of the research series:

> They have focused on applications of desktop VR in technical education and have had … samples of technical and occupational students and educators as participating subjects. All the OSU studies have used random assignment of subjects to treatment groups and post-test-only research designs. All data have been collected in technical education institutions by trained members of the VR research team using standardized protocols to ensure uniform data collection procedures. The sample sizes have been small, and the studies have been considered to be pilot studies that will point the way to larger studies in the future. (p. 53)

Two of the empirical studies in this series by the OSU VR research team specifically addressed gender issues in desktop VR environments. These studies are summarized below as data sources or *cases* for the cross-case analysis presented in this paper.

Purpose and Methodology of the Present Study

The two previously-published OSU studies were chosen for this analysis because they were believed to be both “instrumental” and “collective,” as defined by Stake (2003) in his analysis of case study research. According to Stake, an *instrumental* case study is examined to provide insight into an issue or to re-examine a generalization. An instrumental case study serves to facilitate the researcher’s interest and promote understanding in something else other than the narrow specifics of the case under study. Stake identified *collective* case study technique as a way to build on an instrumental case by extending it to several cases. In collective case studies, two or more individual cases are selected for study because the researcher believes that examining them together will lead to a better understanding of an even larger collection of cases (2003). The two studies chosen for comparative analysis in the present research has several important similarities. Both addressed (a) the effectiveness of VR as a learning technology, (b) the interaction of gender and VR, and (c) learner outcomes based on both performance and perceptions. Both studies used similar quasi-experimental research designs and similar instrumentation. Comparing the nature of the VEs they presented and the differences in their learner outcomes in a collective instrumental case analysis allowed the researchers to advance understanding of gender differences in VR learning environments and the theoretical foundations of those differences.

The methodology of comparing and synthesizing the two instrumental research cases has been termed *cross-case analysis* (Miles & Huberman, 1994) or *cross-case synthesis* (Yin, 2009). Miles and Huberman (1994) defined cross-case analysis as searching for patterns, similarities, and differences across cases with similar variables and similar outcome measures. Yin (2009) asserted that cross-case synthesis should involve at least two cases and that the selected cases could be conducted as independent studies authored by different researchers or as predesigned parts of a single study. In either situation, each case should be treated as a separate study in the cross-synthesis. The two previous OSU research studies selected as the source cases for the present cross-case analysis of gender in VR environments represent the former situation. The cross-case analysis conducted using the two OSU studies focused on comparing the goals, methodology, instrumentation, VE characteristics, and learner performance outcomes. The two source cases had strong similarities in research goals, instrumentation, and methods, as described below. The nature of the VEs they presented was quite different, as described below. The outcome synthesis for the cross-case comparison focused on (a) identifying key findings across the studies, (b) examining discrepancies in the major findings and their contributing factors, and (c) interpreting the outcomes in terms of relevant theories.

Case/Data Source #1

The purpose of the first OSU source study in which gender was a variable (Ausburn & Ausburn, 2008a, 2008b) was to compare the effectiveness of desktop VR with traditional still color images typically used in textbooks in presenting a *non-technical environment* to learners of both genders and two age groups. This quasi-experimental study addressed three aspects of learning outcome by comparing scores of learners who received a desktop VR presentation of the interior rooms of a house with the scores of learners who received still images of the same scene. The subjects were 80 representative adults drawn from the general population who were stratified by gender and age as follows: 20 males aged 18-35, 20 males aged 36-60, 20 females aged 18-35, and 20 females aged 36-60. A limitation of this study was that no information was collected about the previous computer or VR experience or skill of the subjects and equality of the two experimental groups on these variables could not be verified. However, procedures were used to ensure that equal numbers of subjects from each gender and age group were randomly assigned to receive either desktop VR (e.g. interactive panorama movie with hot spots for navigation) or still imagery (e.g. 8 color photos) presentation of the house rooms. The two presentations were created with the same digital camera using the same lens. Both sets of images contained identical visual information. Both treatments were presented via desktop computer and accessed by action button from inside the same PowerPoint® presentation. Both gave the subjects identical instructions for completing their learning tasks. Each subject was tested individually in a setting of his/her choice.

After receiving their presentations, subjects completed three testing instruments developed by the research team to measure (a) *scenic orientation*, (b) *recall of scenic details,* and (c) *perceived confidence in scenic comprehension.* The scenic orientation variable was operationalized as 15 multiple choice items that required subjects to position or locate themselves mentally within the house scene and identify the location of designated objects in relation to their position, such as “behind you” or “to your right.” This operationalization was based on Hunt and Waller’s (1999) definition of orientation as knowledge of one’s location in an environment relative to other important objects and ability to locate objects relative to each other. Recall of scenic details was operationalized as number of correct and non-duplicative items in the house rooms that could be recalled and listed within one minute. This time was established through field testing as optimal for discriminating good and poor recall. Perceived confidence in scenic comprehension was operationalized as self-reported rating on a five-point Likert-type scale ranging from 1 = absolutely no confidence to 5 = absolute confidence. All instruments were field tested to ensure clarity and readability.

Data obtained from this study were analyzed with 2-way ANOVAs. Complete descriptive data, ANOVAs, and findings were reported by Ausburn and Ausburn (2008b); selected data and findings are reported here to support the cross-case gender analysis that is the focus of the present study. The ANOVA analyses supported the efficacy of desktop VR, which produced significantly better scenic orientation, overall

(M_{VR} = 10.95; $M_{Still = 9.55}$; *F* = 5.51; *df* = 1,79; *p* = .02), detail recall (M_{VR} = 7.08; M_{Still} = 5.35; *F* = 6.95; *df* = 1,79; *p* = *.01)*, and confidence (M_{VR} = *3.63;* M_{Still} = 3.03; *F* = 8.54; *df* = 1,79; *p* = .005) and for both genders and both age groups. According to Green and Salkind's criteria (2005), all effect sizes were moderate (.11 < η^2 > .06) using the eta-squared statistic. Also important in this study were its findings related to gender and VR. Unexpectedly, and in contrast to the hypothesized outcomes based on theory and literature, in this familiar and non-technical scenic environment, the females performed significantly better overall than the males with moderate effect size in both scenic orientation ($M_{Females}$ = 11.18; M_{Males} = 9.33; *F* = 9.62; *df* = 1,79; *p* = .003; η^2 = .11) and recall of details ($M_{Females}$ = 7.13; M_{Males} = 5.30; *F* = 7.78; *df* = 1,79; *p* = .007; η^2 = .09). They also tended to be more confident overall about their understanding of the house scene than the males ($M_{Females}$ = 3.48; M_{Males} = 3.18; *F* = 2.134; *df* = 1; *p* = .15) and to benefit more from the VR presentation than the males on both the orientation ($p_{interaction}$ = *.16)* and confidence ($p_{interaction}$ = .09) variables. Complete descriptive and ANOVA data were presented by Ausburn & Ausburn (2008b).

Case /Data Source #2

The unexpected gender-related results of the first study set the stage for a second study by the OSU team. In this study, gender effects in desktop VR were studied in the context of a highly technical environment in a strongly gendered occupation using a mix-method design. The subjects were 42 post-secondary surgical technology students at a large urban technology center. All testing took place in the technology center in a classroom or computer lab. Because of the gendered nature of the surgical technology occupational program, this sample was heavily gender-weighted, with 36 females (85.7%) and only six males (14.3%). In the quasi-experimental part of the study, students were randomly assigned to receive one of two alternative VR presentations of a set of unfamiliar operating rooms. One VR presentation had only the standard panning and "hot spot" navigation features of desktop VR in which clicking on a "hot" item moved the user to another location or additional views of an item, while the other had an additional visual location and navigation mapping feature to assist users in orienting themselves and locating items relative to themselves. The VR scenes in both presentations were extremely complex visually, with many objects unfamiliar to the students, numerous labels and arrows, and complex navigation tools for moving around and examining objects. This VE was very different from the simple and familiar house environment presented in the first study.

Dependent measures for this study were similar to those for the first source study/case reported above and included a similar multiple-choice test of scenic orientation, number of details correctly recalled in one minute, self-reported confidence on a five-point Likert-type scale, and self-reported perceived task difficulty on a five-point scale (not assessed in the first study). Using five-point Likert-type scales, data were also collected on the subjects' self-reported computer skills, experience with video games, and experience with virtual reality. Level of visualizing skill was also assessed using *Successive Perception Test 1* (SPT1), which is a video-based test that requires subjects to view complex figures behind a moving slot and mentally integrate the pieces to form and identify complete patterns. Using SPT1, subjects were classified as either high- or low-visual based on a median split. The two randomly-assigned treatment groups were similar on these skill and experience variables.

This second study yielded numerous findings, several of which are relevant to the gender issue of interest in the present paper and are reported here for comparison with the findings of the first source study/case. The gender results of this second study in a highly technical and visually complex environment (e.g. operating rooms) rather than a familiar non-technical one (e.g. house) were dramatically different from those of the first study. This time, the findings were very much in line with the theory- and research-driven gender expectations. The quantitative two-way ANOVA data showed that regardless of the presence or absence of the navigation mapping tool, the females scored significantly lower overall than the males with large effect size on the test of scenic orientation ($M_{Females}$ = 15.58; M_{Males}= 20.33; F = 7.02; df = 1,41; p = .01; η^2 = 16). They were also significantly less confident than the males with moderate effect size ($M_{Females}$ = 2.55; M_{Males} = 3.60; F = 4.63; df = 1,37; p = .04; η^2 = .12) and rated the learning tasks as significantly more difficult with large effect size ($M_{Females}$ = 3.24; M_{Males} = 2.20; F = 6.83; df = 1,37; p = .01; η^2 = .17).

Additional qualitative gender-related data were also collected in this second study through interviews with 19 of the 42 participants selected at random from the two genders. Basic qualitative findings were consistent with the quantitative findings of the study. The qualitative data, in the form of interview responses, revealed several findings relevant to the purpose of the present cross-case comparative synthesis. Initial analysis of the qualitative interview data consisted of searching for key words and phrases that suggested either positive or negative feelings about, or experiences with, the VR treatment presentations.

All four males who were interviewed made positive comments about their experience with the VR operating rooms. None reported serious navigation or orientation problems, and all gave generally positive impressions of the VR experience. Their descriptions included terminology such as “cool,” “neat,” “easy to get around,” “easy to guide yourself through,” and “good graphics.”

By contrast, the 15 interviewed females presented a less positive impression of the VR experience. Only six of the 15 gave a positive impression of the VR overall, with an additional two leaving a neutral impression. Seven of the females appeared to feel negatively about the VR, reporting unpleasant feelings ranging from physical discomfort and nausea to confusion and frustration. Two of the females stated clearly that they did not like to learn from computers and preferred hands-on or person-to-person learning. Several of the females’ comments indicated problems with orienting and navigation in the VR and revealed feelings of “confusion,” “uncertainty,” “difficulty,” “frustration,” and “being lost.” While the small number of males available due to the gendering of this occupation is a limitation, the four males who were interviewed did not express any of the negative feelings reported by many of the females.

Several specific quotations from the interviewed female participants about their VR experience serve to illustrate the general feelings and impressions of their comments:

<u>Female age 18</u>
“I like to feel it, touch it, so [the computer] kind of makes me feel a little stressed….”

<u>Female, age 21</u>
“I would learn a whole lot more if I was actually physically in the room.”

<u>Female, age 26</u>
“That was very frustrating.”

<u>Female, age 21</u>
"…it doesn't motivate me at all to look at that, I'm just like…there's no point."

<u>Female, age 26</u>
"I don't care for it….If it was there, I might use it but I…would rather learn by touch or someone [asking] questions…."

<u>Female, age 21</u>
"…it was kind of confusing…a little bit difficult…."

<u>Female, age 21</u>
"I was thinking, 'I got it,' then I looked and all those numbers came up and I feel like I didn't really get it."

<u>Female – young – age not reported</u>
"I got the different operating rooms confused. I don't know why. They're pretty much the same, but I think things were mixed up and that I got stuff jumbled a little bit."

These impressions and statements from the study's subjects were consistent with several informal reports of the researchers who recorded personal observations of confusion, frustration, disengagement, and even annoyance among some of the female participants.

Several comments from the female interviewees indicated they had additional problems related to the VR presentation. Some were not aware of the similarity between computer gaming and VR, stating that they had played some computer games but had never seen virtual reality. Some did not seem to recognize or value their own previous computer experience. For example, one respondent adamantly denied having any previous experience with computer gaming or virtual reality, claiming that she "watched her brothers play online games, but didn't participate." However, during the course of the interview, she revealed that she did play Nintendo 64 games. Another female participant told the interviewer she had no previous experience with virtual reality, but later stated she played many online games. It was clear to the interviewer that this student did not equate the online games in which she actively participated with virtual reality. This was consistent with statements of another female student who stated that she had no previous experience with virtual reality, but when discussing the VR scenes of the surgical operating rooms, compared them to an online tour she took of the college campus the previous year. The interviewer concluded that these females did not have a complete understanding of virtual reality technology and that many of them discounted their previous experience as unimportant and irrelevant.

Cross-Case Outcome Comparison, Conclusions, and Implications: Gender Issues for Desktop Virtual Reality as a Learning Technology in CTE

The two desktop virtual reality studies presented above served as the data sources or cases for a cross-case comparative analysis. The purpose of the cross-case analysis was to determine if the available empirical evidence from these two studies in aggregate supported or refuted theoretical expectations and evidence from the literature of differences in performances and/or perceptions between males and females in virtual environments. The variables, methods, and instrumentation of the two studies were similar; at issue were comparisons of the nature of the VEs presented and differences in their learning outcomes.

Based on evidence in the literature, desktop virtual reality (VR) appears to have well-documented potential as a technology for learning and instruction. It can take learners safely and realistically into unfamiliar environments and give them a sense of immersion and personal control of their exploration and discovery. The two Oklahoma State University (OSU) studies reported here appear to support the efficacy of VR in helping some learners orient in visual environments, recall details of the environments, and feel confident in their understanding of the environment. The results of these studies also suggest that, as documented in other VR research literature, the effectiveness of this technology may not be uniform across genders in all circumstances, and that cautions may be appropriate when using VR with female learners to present technical and visually complex environments, as frequently occur in CTE programs. In the OSU studies, the females did well – in fact, better than the males – in orienting within a VR scene, recalling details in the scene, and feeling confident in their understanding *when the scene depicted virtually was simple and familiar to them.* The house interior scene in which the females performed well with VR presentation was visually simple, contained no labels or other visual identifiers, was familiar and comfortable, and was free of complex navigation requirements. In such an environment, the females appeared to exhibit none of the problematic spatial skills, navigation strategies, or technology self-efficacy often claimed for them in the research literature. From a theoretical and explanatory perspective, it may be that the concreteness, accuracy, and representational fidelity of VR, plus its ability to explicitly perform or “supplant” (Ausburn & Ausburn, 1978, 2003, 2008b) for females the task of mentally combining images from multiple sources, may have assisted them in spatial imagery processing. Cognitive load (Sweller, 1988, 1999) inherent in the visual/spatial processing performed by the subjects was perhaps reduced through the supplantation process. This assistance may have both improved their performance and raised their self-efficacy (Bandura, 1994, 1997) with the VR technology.

However, when the VR environment became unfamiliar, technical, visually complex, and navigationally difficult – as in the second study with the surgical operating rooms – the picture changed dramatically with regard to gender. In the operating room environment, the females appeared to experience more difficulty and to lose the performance and confidence advantage they exhibited in the house environment. When the desktop VR presentations depicted unfamiliar locations, contained visually complex fields full of competing details, and presented complicated navigation options, the gender gap in performance, confidence, and perceived difficulty appeared to re-assert itself. The high levels of visual-cognitive load, necessary spatial processing, and visual orientation/wayfinding/navigation complexity implicit in the virtual operating room environment appeared to result in performance and self-efficacy problems for the females that they did not experience in the more familiar and comfortable house environment. At theoretical level, it could be hypothesized that what may have happened here is that the heavy visual-spatial cognitive load overrode the supplantational benefit of VR and resulted in spatial processing problems, heightened anxiety, and loss of self-efficacy for the females.

The aggregate cross-case findings of these two studies of gender and virtual learning environments suggest that the effects of desktop virtual reality may not be identical for males and females, and that the differences may be exacerbated when VR is used to place female learners in technical settings or settings with visual and navigational complexity. These results tend to support the findings and contentions of much of the research literature regarding gender differences in spatial, orienting/wayfinding/navigating, and technology self-efficacy functioning. An important note for CTE teachers and teacher educators is that these findings also suggest that special care may be necessary to help females benefit from learning opportunities offered by desktop virtual reality technologies, especially in strongly gendered learning situations such as CTE programs in cosmetology and some health occupations. Waller (2000) asserted that female functioning in virtual environments and their ability to benefit from VR training can be improved, and the gender differences reduced or even eliminated, through appropriate training to increase women's proficiency with the VR user interface. This possibility may be particularly important when using VR to instruct females in strongly gendered occupations and classrooms.

Conclusion

Recent improvements in desktop hardware and software have dramatically increased the visual fidelity and the interactivity of desktop virtual reality. The new high-fidelity VR hardware and software options provide access to this exciting technology at costs that can be borne by most schools and at levels of technology skills that can be mastered by many CTE instructors. Increasing numbers of education programs and industries are taking advantage of cost-effective desktop VR technology and are using desktop VR for instruction and for product development and prototyping. Mastery of complex or dangerous environments, risk-free manipulation of expensive equipment, cost-effective product development and evaluation, and interactive exploration of multivariate problems are all now feasible at the desktop in virtual settings. New high-quality desktop VR is now within the technical and fiscal reach of many schools, programs, and instructors. These developments have important implications for CTE in which mastery of such skills are frequently critical in providing optimum curricula.

However, if VR is to reach its full potential as a CTE instructional tool, it will be the task of VR designers to develop, and of CTE instructors to carefully evaluate and select, user interfaces and implementation strategies to overcome gender-specific limitations of this medium. CTE instructors wishing to implement desktop VR in their curricula should be aware of potential gender-related learning issues and take steps to maximize the learning benefits of this exciting new technology for everyone.

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