Effect of Virtual Reality Graded Exposure on Heart Rate and Self-Reported Anxiety Levels of Performing Saxophonists

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This study is an examination of the effect of computer-generated virtual reality graded exposure on the physiological and psychological responses of performing musicians. Eight university saxophone majors, five men and three women, participated in twelve 15- to 20-minute weekly practice sessions during which they were immersed in one of four different virtual environments designed to elicit various anxiety levels. Baseline heart rates and subjective measurements were taken prior to immersion and continued throughout the exposure period. In addition, heart rate and subjective measurements were recorded for three live performances given by each subject before beginning the virtual reality exposure and after completion of the sixth and the twelfth exposure sessions. Findings indicated that the virtual environments did elicit a sense of presence and may have provided the means for desensitization. Heart-rate readings and psychological indications of anxiety did not always correspond.

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Virtual reality is a computer simulation of real or imaginary environments that enables real-time interaction with the environment. In most cases, the user wears a head-mounted display that presents visual and audio information. Many head-mounted displays are equipped with tracking devices that allow the video and audio to change in a natural way with head and body motion. Given the positive results of virtual reality research and the fact that both virtual environments and many aspects of music teaching, learning, and performing rely on visual and auditory information, it seems reasonable that virtual reality might be readily adaptable to music education and

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performance situations. Since anxieties and phobias have been the focus of a vast amount of the virtual reality research, it seemed prudent to first consider this adaptation of virtual reality within music education and performance.

Several studies involving the use of virtual reality to treat different types of social anxiety have shown promising results. Rothbaum et al. (1995a) identified 20 college students with acrophobia and randomly assigned them to either a treatment or wait-list group. Seventeen students completed the study. After 7 weekly 35- to 45-minute virtual reality sessions, the treatment group showed significant improvement compared to the wait-list group that remained unchanged. In a case study, a 19-year-old undergraduate student with acrophobia was treated using a virtual environment of a working glass elevator. Analysis of pretest and posttest measures revealed that virtual reality graded exposure, whereby the patient was gradually and systematically introduced to increased heights by moving to higher floors on the glass elevator, was successful in reducing this individual's fear of heights (Rothbaum et al., 1995b). The efficacy of virtual reality was also studied with a 42-year-old woman who suffered from a debilitating fear and avoidance of flying (Rothbaum et al., 1996). After exposure to flying in a virtual airplane during six weekly 35- to 45-minute sessions, the subject's self-reported anxiety measures decreased, and she completed an airplane flight that she had previously avoided taking. Another case study (Rothbaum et. al., 1999) showed that virtual reality graded exposure was successful in treating a 50-year-old man who suffered from posttraumatic stress syndrome.

In a related publication, Rothbaum, Hodges, and Kooper (1997) discuss possible future uses of virtual reality. They stress that a virtual environment must provide a sense of presence where individuals actually feel as if they are in the presented environment rather than simply looking at a photograph or viewing a video. Hodges et al. (2001) reported on findings of previous studies involving virtual reality graded exposure in the treatment of phobias and social anxieties. Findings reported are that anxious individuals can feel anxious in a virtual environment, that virtual environments can generate both interpersonal and physical cues, and that even low-level computer graphics can be effective, because individuals seem to add their own personal experience to the environment.

The first known study to use virtual reality in a music performance environment with performing musicians was a case study in which the researcher explored the question of whether virtual environments could generate a sense of reality for performing musicians (Orman, in press). Three upper-division undergraduate saxophonists, two women and one man, performed while immersed in four virtual environments, each designed to gradually increase the level of anxiety. Heart rates and subjective measurements were taken throughout the exposure period. Results indicated that virtual reality graded exposure did elicit physiological and psychological indica-

tions of increased anxiety while the subjects were immersed in the environments designed for that purpose.

Music performance anxiety has been identified as a type of social anxiety commonly experienced by performing musicians. In one study (Fishbein et al. 1988), researchers found that 24% of orchestral musicians surveyed experienced music performance anxiety, and 16% indicated that this anxiety was acute enough to interfere with their performance. While music performance anxiety can have positive effects on performance, it can also impair a performer, causing the performance to deteriorate to a level lower than the performer is capable of producing (Wolfe, 1989).

In several studies, investigators have identified performing condition as a predictor of the level of music performance anxiety experienced (Brotons, 1994; Cox & Kenardy, 1993; Hamann, 1982; LeBlanc et al., 1997; Picard, 1999; Wardle, 1975). LeBlanc (1994) put forth a working theory of music performance anxiety that he hoped would "facilitate future experimental research" in the area of music performance anxiety (p. 60). When describing variables related to the performing condition, LeBlanc suggested the debilitating effects of music performance anxiety might be reduced by the performer attempting to discern or determine what the performing environment would be and practice under similar conditions. Kendrick, Craig, Lawson, and Davidson (1982) and Wardle (1975) found that behavioral-rehearsal or imagery were effective at reducing music performance anxiety. Various measurements of performance anxiety exist throughout the literature; however, only two types of physiological measurements were found: first, various forms of observational techniques that establish an acceptable reliability level among observers, and second, heart-rate measurements that have been used as a predictor of music performance anxiety (Brotons, 1994; Kendrick et al., 1982; LeBlanc, Campbell, & Codding, 1993; LeBlanc et al., 1997; Wardle, 1975).

This study represents the second known attempt to use virtual reality in a music performance environment with performing musicians. Based on the promising results of the initial study (Orman, in press), this study expanded the treatment period, number of subjects, and type of performance environments to include live performances. The purpose of this study was to examine the effects of computer-generated virtual reality graded exposure on heart rate and psychological ratings of performing musicians. Specifically, how would subjects respond to the different virtual environments? How would subjects respond to repeated exposure to the same virtual environments? How would the subjects react to the long-term, consistent use of virtual reality exposure? How would psychological and physiological responses to in vivo and virtual reality immersion compare?

METHOD

Eight of eleven saxophone studio class members in the school of music at a large university who volunteered to participate actually

completed the 16-week study. One of the eleven members did not participate in the study at all, one dropped out after completing a biographical information form, and one dropped out after completing half the study. The eight participants who completed the study consisted of five men and three women ranging from freshman through graduate level. During the first week, the study and proper use of the equipment were explained, and subjects completed both a consent form and a personal details form recording their age, sex, proficiency level, number of years of instrumental study, and number of public performances given as part of a group and as a soloist. Weeks 2 through 16 consisted of both live performances and practice sessions completed during immersion in various virtual environments.

Psychological and physiological measurements were obtained from each subject throughout the study. Psychological measurements were taken in the form of Subjective Units of Discomfort (Wolpe, 1958, 1982). A subjective unit of discomfort is a 0 to 100 self-reported anxiety measure in which 0 indicates no anxiety or discomfort and 100 represents extreme anxiety. Physiological measurements consisted of heart rate acquired using a Polar Vantage S-610 heart-rate monitor and T-31 noncoded electrode chest transmitters that recorded each subject's heart rate in beats per minute (bpm) at 5-second intervals. Earlier models of this device have been successfully used in studies of music performance anxiety (Brotons, 1994; LeBlanc, Campbell & Codding, 1993; LeBlanc et al., 1997). Electrode gel aided proper reception and recording of heart rate from the T-31 transmitters.

The virtual environments used in this study were the same environments previously found to be easily recognized and environments that gradually increased the subjects' expected anxiety levels (Orman, in press). Subjects "entered" the virtual environments by putting on a head-mounted display that allowed them to see the environment and hear sounds common to the environment they were visualizing. In addition, the sights and sounds changed naturally as each subject turned his or her head or body to face a different direction. The environment designed to create the lowest anxiety level was an empty practice room. A room with members of the saxophone studio class seated as an audience was the second environment. Third was a room with three school of music faculty members seated as if listening to and possibly judging a performance, and fourth was a room with the director of bands seated as if listening to and judging an audition for entry and placement in a major performing ensemble. An additional environment of a nature setting including a waterfall, stream, and forest was used shortly after the beginning of the study to obtain baseline heart rate and subjective unit of discomfort rating.

Virtual environments were created using digital audio and video software packages, a Pentium III desktop computer workstation and a Canon GL 1 mini digital video camera. A VFX-3D head-mounted display with head tracking and stereo audio was used for immersion.

Virtual reality sessions were conducted in a small storage room rearranged for the study.

Each subject completed three live performance sessions and 12 virtual reality performance sessions. Live performances included performing major scales in front of the saxophone studio class during the 2nd, 9th, and 16th week of the study. Heart rates were recorded every five seconds during performance and immediately following their performance, subjects completed written subjective units of discomfort ratings that represented their anxiety level before, during, and after each live performance.

Each subject completed six 15- to 20-minute weekly private virtual reality sessions between the first and second live studio performances and six additional 15- to 20-minute weekly virtual reality sessions between the second and third live studio performances. Virtual reality sessions consisted of six immersions in the practice room environment and two immersions in each of the audience environments in the following order: room with studio class members; room with three professors; and room with the director of bands. Half the subjects, randomly selected, experienced the practice room during the first six virtual reality sessions followed by 2 weeks in each of the studio class, faculty, and director of bands environments, while the other half of the subjects began virtual reality sessions with 2 weeks in each of the studio class, faculty, and director of bands environments followed by six sessions immersed in the practice room. During each session, subjects were told they could practice anything they wished but were unable to look at any printed music due to the restrictions of the head-mounted display. Heart-rate readings were obtained every 5 seconds, and subjective units of discomfort were verbally elicited every 5 minutes during immersion.

A review of the heart-rate data for the first two sessions conducted revealed what seemed to be relatively high heart rates, since the virtual environment for both subjects was the empty practice room. Therefore, it was decided that all subsequent virtual environment sessions would begin by taking a 1-minute baseline heart rate. During baseline subjects were immersed into a waterfall, stream, and forest venue. Beginning with each subject's third session, one verbal baseline subjective unit of discomfort rating was also elicited during immersion in the waterfall, stream, and forest scene. Means of the psychological and physiological data from each live performance and immersive environment were subsequently graphed[1] in chronological order for each subject.

RESULTS

The following are individual presentations of results for each subject. Given the vast variability among people's psychological (subjective units of discomfort) and physiological (heart-rate) measures and the behavioral nature (eight case studies) of the design, the researcher decided that this would be the most appropriate means of presenting the data.

Subject 1 was an 18-year-old first-semester music major who had played saxophone for 7 years and piano for 9 years. She estimated having given 72 public performances as an ensemble member and 24 public solo performances. This subject was immersed in the empty room environment for her first six virtual reality sessions, followed by the graded audience environments for her last six sessions. Her heart rate remained fairly consistent during the first ($M = 89.76$, $SD = 7.25$) and second ($M = 87.86$, $SD = 6.48$) live studio performances and rose for the final studio performance ($M = 107.53$, $SD = 8.12$). In contrast, her subjective unit of discomfort ratings show a steady decline between the first ($M = 38.33$, $SD = 2.89$) and second ($M = 30.00$, $SD = 5.00$) performances and a marked decline for the last studio performance ($M = 20.00$, $SD = 0.00$). Heart rates during the virtual reality sessions varied, but a pattern was discernable. Heart rates were consistently higher than baseline throughout the practice-room sessions. The average difference between baseline and heart rates during the practice-room sessions ranged from 20 bpm to 36 bpm. In contrast, immersions into the audience environments had an average difference between baseline and immersive heart rates ranging from 14 bpm to 23 bpm. The average difference between baseline and immersion declined during the repeated exposure to each of the different audience environments. Subjective units of discomfort ratings during immersion appeared high during the second and third practice room immersions and remained relatively steady for Sessions 1 and 4 through 6. The difference between baseline and immersion subjective unit of discomfort ratings for Sessions 7 through 12 showed a decline during the second exposure to each audience environment except the faculty member environment, which showed an increase. Overall, this subject had higher heart rates and subjective units of discomfort ratings during audience virtual reality sessions compared to practice-room virtual reality sessions.

Subject 2, an 18-year-old first-semester music major who had played saxophone for 8 years, estimated having given 33 public performances as an ensemble member and 13 as a soloist. He spent his first six virtual reality sessions immersed in the practice-room environment and his last six sessions immersed in the graded audience environments. Heart-rate readings during live studio class performances dropped slightly from his first ($M = 113.83$, $SD = 9.29$) to his second ($M = 104.31$, $SD = 8.46$) performance and rose for his third ($M = 122.47$, $SD = 8.74$) performance. Subjective units of discomfort ratings rose steadily from his first ($M = 13.33$, $SD = 7.64$) to his second ($M = 16.67$, $SD = 2.89$) and to his third ($M = 20.00$, $SD = 0.00$) live studio performance. The average heart-rate difference between baseline and practice room immersion ranged from 4 bpm to 22 bpm. The largest increase occurred during Sessions 5 and 6. The average difference between baseline and heart-rate audience environments ranged from 6 bpm to 10 bpm. The average difference between baseline and heart-rate readings of the same audience environments showed a decline during the second exposure to the studio class, a

slight decline during the second exposure to the faculty, and an elevation during the second exposure to the director of bands. The difference between baseline and subjective units of discomfort ratings for practice room immersions were relatively steady, with a decline during second exposure to the studio class and a slight increase for the second exposure to the faculty and the director of bands. Overall, heart rates and subjective units of discomfort ratings were higher during audience exposure sessions as compared to the practice room environment.

Subject 3 was an 18-year-old first-semester music major who had played saxophone for 6 years. He estimated having given 49 public performances as an ensemble member and 5 public solo performances. His first six virtual reality immersions were in the audience graded exposure settings and his last six immersions were in the practice room. Heart rates during live studio performances were lowest for his first performance ($M = 120.12$, $SD = 20.49$), highest for his second performance ($M = 144.64$, $SD = 16.56$) and in between performances one and two for his third performance ($M = 132.56$, $SD = 19.51$). Subjective units of discomfort ratings remained relatively the same for live performances one ($M = 28.33$, $SD = 5.77$) and three ($M = 28.33$, $SD = 2.89$) but increased for the second studio performance ($M = 33.33$, $SD = 2.89$). Heart-rate readings during immersion showed a comparatively high overall heart rate for the practice room immersions with the average difference between baseline and immersion ranging from 16 bpm to 35 bpm. Average heart-rate difference between baseline and immersion in the audience settings ranged from 15 bpm to 30 bpm. His second exposure into the same environment produced a decline in the average difference between baseline and his heart rate during exposure to the faculty and the director of bands but a slight increase for the studio class environment. Subjective units of discomfort ratings during the practice room exposure were generally higher for Sessions 7, 8, and 12 and generally equal to baseline for Sessions 9, 10, and 11. Average difference between baseline and exposure of subjective units of discomfort ratings declined during the second faculty exposure as compared to the first but remained steady for the second exposure as compared to the first exposure to the director of bands. Overall, this subject's heart rate and subjective unit of discomfort ratings were higher during the practice room exposure as compared to the various audience exposures.

Subject 4 was an 18-year-old third-semester music major. He had played saxophone for 10 years and estimated having given 50 public ensemble performances and 8 public solo performances. This subject was exposed to the graded audience environments for his first six immersions followed by the practice room environment for his final six immersions. His live studio performance heart-rate readings increased for the second ($M = 125.17$, $SD = 8.24$) as compared to the first ($M = 95.67$, $SD = 8.57$) and remained relatively the same for the third ($M = 123.62$, $SD = 11.32$) performance. Studio performance

subjective unit of discomfort ratings also increased from the first performance (M = 36.67, SD = 5.77) to the second (M = 40.00, SD = 10.00); however, the lowest subjective unit of discomfort rating was reported for the third performance (M = 30.00, SD = 5.00). The average difference between baseline and immersive heart-rate reading during practice room sessions ranged from 9 bpm to 23 bpm. Heart-rate average differences during audience exposures ranged from 8 bpm to 27 bpm and dropped for the second studio class but increased for the second faculty and director of bands exposure as compared to the first exposure in each setting. Average differences in subjective unit of discomfort ratings from baseline to practice room exposure were generally higher than baseline throughout. These differences decreased for the second faculty exposure and remained steady for the second director of bands exposure as contrasted with the first exposure in these settings. Overall this subject had lower heart-rate but higher subjective unit of discomfort ratings during the various audience exposures than during practice room exposures.

Subject 5, a 21-year-old ninth-semester music major, had played saxophone for 13 years. He estimated having given 98 public ensemble performances and 2 public solo performances. The graded audience exposure settings made up the first six virtual reality sessions for this subject, followed by six sessions immersed in the practice room environment. This subject's heart-rate readings during live studio performances declined slightly but steadily from the first (M = 152.00, SD = 10.13) to the second (M = 145.47, SD = 6.94) and again from the second to the third (M = 134.66, SD = 10.33). Likewise, his subjective unit of discomfort ratings for live studio performances declined from the first (M = 48.33, SD = 27.54) to the second (M = 45.00, SD = 5.00) and again to the third performance (M = 41.67, SD = 12.58). The average difference between baseline and immersion heart rates during exposure to the practice room ranged from 12 bpm to 19 bpm and was lowest for the eighth session. The average difference between baseline and heart rate during the various audience exposures ranged from 7 bpm to 20 bpm and declined during the repeat studio class exposure but increased for the repeat exposure to the faculty and remained relatively the same for the director of bands when compared to the first exposure in each of these settings. Subjective unit of discomfort ratings were higher than baseline for all practice room exposures with the least difference occurring during Sessions 7 and 12. A decline occurred in the average difference between baseline and immersion for repeated exposures to faculty and director of bands. Overall this subject had higher heart rates during the practice room exposure than during the various audience immersions but overall higher subjective unit of discomfort ratings during audience as contrasted with practice room exposures.

Subject 6 was a 22-year-old ninth-semester music major who had played saxophone for 13 years and piano for 8 years. She estimated having given 106 public performances as an ensemble member and

11 public performances as a soloist. She was immersed in the graded audience environments for her first six virtual reality sessions followed by six sessions immersed in the practice room environment. Live studio performance heart-rate readings for this subject were relatively steady from the first ($M = 166.83$, $SD = 6.72$) to the second performance ($M = 169.29$, $SD = 4.84$) and declined for the third performance ($M = 150.96$, $SD = 5.48$). Subjective unit of discomfort ratings remained the same from the first to the second studio performance ($M = 56.67$, $SD = 15.28$) but showed a marked decline for the third performance ($M = 23.33$, $SD = 10.41$). Average difference between baseline and immersion heart rates for the practice room environments ranged from 13 bpm to 24 bpm with the highest differences occurring during the eleventh and twelfth sessions. Baseline and immersion average heart-rate differences for the various audience environments ranged from 12 bpm to 31 bpm and declined for the second exposure to the studio class and faculty but increased for the second exposure to the director of bands. Subjective unit of discomfort ratings during practice room exposures were lower than or slightly above baseline for all sessions. The average difference between baseline and subjective unit of discomfort ratings during immersion in the audience settings increased during the second exposure to the faculty but showed a marked decline for the second exposure to the director of bands. Overall, heart rates for this subject were somewhat higher for the practice room than the audience exposure environments; however, overall subjective unit of discomfort ratings were higher for audience immersions.

Subject 7 was a 22-year-old first-semester master's-level music major who had played saxophone for 13 years. He estimated having given 57 public performances as an ensemble member and 77 public performances as a soloist. This subject was immersed in the practice room environment for his first six virtual reality sessions and in the graded audience environments for his final six exposures. Heart-rate readings remained relatively steady for his first ($M = 137.79$, $SD = 10.16$), second ($M = 140.37$, $SD = 8.96$), and third ($M = 136.13$, $SD = 11.25$) live studio performance but his subjective unit of discomfort ratings increased slightly from the first ($M = 43.33$, $SD = 27.54$) to the second performance ($M = 45.00$, $SD = 5.00$) and had a large interval of decline for the third performance ($M = 30.00$, $SD = 5.00$). His heart-rate readings during immersion into the practice room setting were highest during the second session with an average difference between baseline and subsequent immersion ranging from 25 bpm to 33 bpm. The average difference between baseline and immersion heart rates during the various audience settings ranged from 14 bpm to 37 bpm with an increase for the second exposure in every repeated setting. Subjective unit of discomfort readings were higher than baseline for all practice room immersions. The average difference between baseline and immersion subjective units of discomfort increased during the second exposure to the studio class and faculty environments but showed a marked decline during the repeated

exposure to the director of bands. Overall, his heart rate and subjective unit of discomfort ratings were higher during the various audience exposures as compared to the practice room exposures after his first two immersion experiences.

Subject 8 was a 28-year-old first-semester doctoral-level music major who had played saxophone for 17 years. She estimated having given 64 public performances as an ensemble member and 22 public performances as a soloist. This subject spent her first six virtual reality sessions immersed in the empty room environment followed by six sessions in the graded audience exposure settings. Heart rates during the three live studio performances remained relatively steady from the first (M = 139.45, SD = 4.87) to the second (M = 141.11, SD = 4.70) with a slight decline for the third performance (M = 135.14, SD = 7.66). Subjective unit of discomfort ratings decreased from the first (M = 68.33, SD = 7.64) to the second (M = 63.33, SD = 15.28) live studio performance and dropped to the lowest rating for the third performance (M = 48.33, SD = 5.77). The average difference between baseline and heart-rate readings while immersed in the practice room environment ranged from –4 bpm to 11 bpm with the largest average difference occurring during Sessions 3 and 6. Average difference in baseline and heart-rate readings while immersed in the various audience settings ranged from 16 bpm to 22 bpm. The average differences declined for the repeated exposure to the studio class and faculty but increased during the second exposure to the director of bands when compared to the first exposure. Her subjective unit of discomfort ratings were lower than baseline during the third session but relatively equal to or higher than baseline for Sessions 4 through 6. Average difference between baseline and exposure subjective unit of discomfort ratings declined for the second exposure to the studio class and director of bands environments but increased slightly for the second exposure to the faculty. This subject's overall heart rates were higher during the various audience settings than the practice room immersions. In contrast, her overall subjective unit of discomfort ratings were higher during the practice room immersions than during the various audience environments.

DISCUSSION

While extreme caution must be exercised in interpreting the results of this study, a few commonalities were apparent. First, regardless of performance environment, heart rates increased from baseline during performance, which may be an indication of the physical exertion that takes place when performing on a wind instrument. However, subjective unit of discomfort ratings did not always increase from baseline during performance which may suggest that performing was psychologically calming at times for some subjects. Secondly, increased or high heart-rate readings did not always correspond to self-rated anxiety levels in either the live performance or the immersive environments. There were numerous instances of increased or

high heart-rate readings and a decreased or low subjective unit of discomfort rating. Third, the majority of the subjects reported higher subjective unit of discomfort ratings and half of the subjects had higher heart-rate readings during virtual reality sessions while immersed in an audience environment as compared to the practice room setting. Finally, 54% of combined heart-rate readings and 55% of combined subjective units of discomfort ratings among all subjects decreased during the second exposure as compared to the first exposure to identical virtual audience environments. These results could be consequential especially when one considers the only criterion used to select the subjects for this study was that they were current members of the saxophone studio; therefore, the subjects were not representative of a population that had been predetermined to suffer from music performance anxiety. In addition, during virtual reality sessions each subject was acutely aware that what he or she was experiencing was not real. Each subject walked into a converted storage room with a computer workstation, put on a head-mounted display unit with stereo headphones, and proceeded to practice while immersed in different environments.

Several observations throughout the study may need to be considered for future research in this area. Many times, heart rate and subjective unit of discomfort readings may have been elevated for outside reasons. For example, Subject 1 had what appeared to be an unusually high heart rate during her fourth virtual reality session in the practice room environment; however, she was physically ill during this session. What seemed to be an unusual increase in subjective unit of discomfort ratings occurred for Subject 2 during Sessions 8 through 11 coincided with increased pressure exerted by several of his professors, as they perceived he had not worked up to his potential by midterm. Subject 3 had what seemed to be unusually high heart rates during Sessions 7 through 10; however, these were sessions in which this subject elected to practice circular breathing since this was something he could work on for 20 minutes without having to look at any written music. Subject 7 had elevated heart-rate readings and subjective unit of discomfort ratings for his first two virtual reality sessions in which he was immersed into a practice room. During the first session, he may have had a claustrophobic reaction to the head-mounted display unit, a reaction that had been found to be a common occurrence for some people during initial virtual reality experience.

Additionally, some of the subjects were taking prescription medication that most likely influenced their heart rate and possibly their subjective unit of discomfort ratings at various times throughout the study. Though not anticipated, it became apparent as the study progressed that not all of the subjects were familiar with all of the people or the settings used during immersion. For example, some of the subjects had never auditioned for an ensemble conducted by the director of bands and the freshman subjects had never experienced a jury and were therefore not as aware of the implications of the three-faculty-member setting.

Conditions related to equipment were also noted. At the conclusion of the first 20-minute virtual reality session, most subjects commented on how physically heavy the head-mounted display became during the session. Currently under development are head-mounted displays with the same features and improved video quality that are considerably smaller and lighter than the one used in this study. It is hoped these units will be sufficiently cost-effective so they may be used in future studies. Another frequent complaint was that the studio-quality headphones that are a part of the head-mounted display restricted acoustic sound, thereby not allowing the subjects to hear themselves practicing in the same manner as they would in a live practice or performance environment. While the headphones may be essential to creating the presence of the immersive environment by providing the sounds that would normally occur in the environment in 44.1 KHz stereo quality, future studies could use a mixer and microphone so live acoustic performance can be mixed with the prerecorded digital audio file and heard through the headphones on the head-mounted display or use a live surround-sound system. This would eliminate the need for the headphones on the head-mounted display unit.

While observational data were not a part of this study, it was interesting to note several common occurrences across subjects during virtual reality exposure. Since the researcher was present in the room at all times and could monitor on a computer screen exactly what individual subjects were observing during immersion, it became immediately apparent that all subjects elected to avoid looking at their saxophone professor while immersed in the studio class audience setting. While not by design, the saxophone professor happened to be sitting on one side of the room when the virtual environment was captured. During immersion all subjects elected to view the other half of the room, even though at one time the saxophone professor coughs on the audio track. Most subjects turned and looked at the saxophone professor after they heard the cough but then immediately moved their visual focus so that he was no longer in view. A couple of subjects also avoided having the faculty and director of bands in their field of vision as they were immersed in these environments. A second commonality was that subjects were reluctant to physically move around in the room while wearing the head-mounted display. A brief orientation period to new virtual environments seemed to enhance physical movement during immersion.

Interestingly, virtual environments do seem to elicit a sense of presence for performing musicians. The degree of presence and the possible benefits of this condition remain unanswered; however, results of this study seem to indicate that desensitization may be a possible outcome. Findings of this study can be used to improve the virtual environments and experimental conditions of future studies. It is yet unclear how much emphasis should be placed on the physiological or psychological results of this type of study. It seems pru-

dent that investigators in future studies consider the effect of virtual environments on the quality of musical performance.

Although any suggestions at this point are purely speculative, given the positive results in virtual reality research, it is interesting to consider the variety of virtual environments that may be possible for music teaching and learning. For example, students might be able to practice their teaching and rehearsal skills while standing on a podium in front of various virtual performing ensembles, practice "teaching" while immersed in different virtual classroom music venues, try their skill at "working" in an assortment of virtual private-lesson settings, or even learn how to instruct while "working" in a virtual marching band rehearsal. Again, one must be judicious with any speculation of this type; however, if empirically verified, many of these transfers do seem to be within reason.

NOTE

1. Graphs are available from the author on request.

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