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Virtual and Authentic Tennis: Similarities and Differences of Three Common Tennis Strokes

Kristy M. Noble
Winthrop University, noblek3@winthrop.edu

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To the Dean of the Graduate School:

We are submitting a thesis written by Kristy Noble entitled VIRTUAL AND AUTHENTIC TENNIS: SIMILARITES AND DIFFERENCES OF THREE COMMON TENNIS STROKES IN NCAA DIVISION I TENNIS PLAYERS.

We recommend acceptance in partial fulfillment of the requirements for the degree of Master of Science in Sport and Fitness Administration through the Richard W. Riley College of Education.

Dr. Seth E. Jenny, Thesis Advisor

Dr. David P. Schary, Committee Member

Dr. Shelley D. Hamill, Committee Member

Dr. Jennie Rakestraw, Dean, College of Education

Dr. Jack E. DeRochi, Dean, Graduate School

VIRTUAL AND AUTHENTIC TENNIS: SIMILARITIES AND DIFFERENCES OF THREE COMMON TENNIS STROKES IN NCAA DIVISION I TENNIS PLAYERS

A Thesis
Presented to the Faculty
Of the
Richard W. Riley College of Education
In Partial Fulfillment
Of the
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By

Kristy M. Noble

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Review of Literature Manuscript

The Educational Value of Motion-based Video Gaming

Kristy M. Noble

Seth E. Jenny

David P. Schary

Shelley D. Hamill

Winthrop University

Authors' Note

All authors teach within the Department of Physical Education, Sport and Human Performance at Winthrop University, Rock Hill, SC. Correspondence concerning this article should be addressed to Dr. Seth E. Jenny, Department of Physical Education, Sport and Human Performance, Winthrop University, 216B West Center, Rock Hill, SC 29733. Contact: jennys@winthrop.edu

Abstract

Technology growth affords innovative teaching techniques as video gaming within education has increased in popularity. Motion-based video gaming (MBVG) is a type of gaming that requires the individual playing the game to be physically interactive. Thus, whatever movements the individual playing the game does is picked up by motion sensors and is mimicked via the on-screen character. MBVG provides constant feedback to learners and has been found to help motivate students, replace sedentary with active gaming, and can facilitate social interactions with peers. This literature review reveals the current knowledge regarding the potential educational benefits of MBVG, particularly in physical education and sport pedagogy settings. Developments of video gaming in education as well as recent research regarding MBVG and its potential impact on physical skill development within educational environments are discussed.

Keywords: *Exergaming, active video gaming, physical education, Kinect, Wii*

Introduction

Today, video gaming has become one of the most popular hobbies across all age ranges. The Entertainment Software Association (2015) found that 155 million Americans play video games and 51% of all United States households own at least one video game system. Video games appear to be most popular among youth as 88% of the demographic plays video games (Gentile, 2009). In addition, 42% of American high school students play either video or computer games for at least 3 hours per day (Kann et al., 2014).

However, most video games are sedentary (i.e., the individual is not exerting significant energy in order to play the game). As a result, some correlate video game growth with the tremendous increase in obesity rates within America (Thompson et al., 2010). Studies in children and teens suggest that computer, video game, and Internet use are associated with excess weight (Ballard, Gray, Reilly, & Noggle, 2009; Vandewater, Shim, & Caplovitz, 2004). Conversely, a recent study found that trading sedentary video games for active video games may help children's BMI and body fat in overweight kids (Chan, 2017).

Unlike sedentary video gaming, motion-based video gaming (MBVG) require participants to be active in order to play the game. Also referred to as Exergaming or active video gaming, participants playing motion-based video games (MBVGs) manipulate their body while facing the motion-based technology (i.e., sensor and software), often without a handheld controller (Jenny, Hushman, & Hushman, 2013). The on-screen character (i.e., avatar) then mimics specific movements the participant makes.

Common systems employing this technology include the Xbox One Kinect (Microsoft, Redmond, WA) and the Nintendo Wii (Kyoto, Japan). For example, the MBVG version of tennis requires players to physically swing their arm in order for the on-screen character to execute the same movement. This type of gaming may become more popular for those who are trying to be more physically fit.

Since the early 1970's, classroom teachers have incorporated video games into instruction (Eakin, 2013; Papallo, 2015). Now, physical education (PE) experts are turning to MBVG to motivate and engage their students in their lessons. However, many PE instructors are unaware of how effective MBVGs can be to teach skill development. The purpose of this article is to provide a brief overview of video gaming in education, discuss the recent developments in MBVG research, and review the current literature regarding teaching motor skills through MBVG.

Video Gaming in Education

Video games have most recently been praised for allowing students to be engaged in learning content; whether it is in the classroom or in a gym (Gee, 2007). Some educators believe video games may be the future of education. Video games that are well designed can be very beneficial in learning environments, as they incorporate sound, theories and concepts that require players to learn and develop skills to succeed (Felicia, 2012). For example, Papallo (2015) has discussed in great detail that the goal of some video game developers is to introduce educational gaming into the common core of education. When discussing educational video games, O'Keefe (as cited by Papallo, 2015) stated:

> In the best [video] games, you are learning a subject like algebra in a way that you don't really know you're learning it. Students end up actually enjoying algebra because it's like a puzzle. You're untying a knot and there's something pleasurable about it. (p. 1).

Research has consistently shown that playing computer games produces reductions in reaction times, improved hand-eye coordination, and can raise players' self-esteem (Griffiths, 2002; Papallo, 2015). Today, video games in schools can be played with iPads (Apple, Cupertino, CA), smart phones, tablet computers, and gaming consoles (e.g., Sony PlayStation, etc.). However, video gaming in education has deep roots.

In 1974, a computer game called "The Oregon Trail" (Minnesota Educational Computing Consortium, Brooklyn Center, MN) was introduced to a class in Minnesota. The goal of the game was to educate and interest students on the history of U.S. western expansion. Shockingly, compared to today's standards, a game that originated with weak graphics and slow animation grew to massive popularity as it appeared to engage and teach students the realities of 19th century pioneer life on the Oregon Trail. Over the years, the game has had a number of developments, including a recent iPhone-based version that has been downloaded over 4 million times (Eakin, 2013). This game may be considered as the original video game that transformed education. From this start, technology such as video gaming has also evolved into PE settings.

Technology in PE. Today, technology is a "hot-button" topic within PE. Effective use of technology should not replace quality teaching, but augment and enhanced student learning. For instance, technology can be used to motivate students by showing a highlight video projected through a SmartBoard during the introduction of a class. Any technology used in PE should increase instructional effectiveness, support the curriculum, and/or facilitate assessment (Society for Health and Physical Educators [SHAPE] America, 2009). Oftentimes, physical educators view effective use of technology as extremely valuable in student assessment and feedback (National Association for Sport and Physical Education, 2009).

iPads are one of the most popular devices used to assess students, and can be considered the pioneer of this technology (Henderson, 2012). iPad applications (i.e., apps) can help both teachers and students throughout a PE lesson through, for example, assisting with classroom management, student assessment, peer assessment, playing music, and video recording and playback. In addition, other common technology equipment used in PE includes pedometers, heart rate monitors, and accelerometers, which assist in tracking step counts and measuring the intensity of physical activity. Each of these forms of technology can assist in assessing students' activity performed throughout a PE lesson, provide student accountability, and possibly enhance student motivation for physical activity, but none of these devices teach sport or motor skill movement. Sport video games also have an influence on student learning within the PE classroom.

Sport video games and learning. Sport video games (SVGs) are video games that simulate the sporting experience. Example popular SVGs include FIFA Soccer (EA Sports, Redwood City, CA), NHL (EA Canada, Burnaby, British Columbia), UFC (EA Canada) and NBA 2k (2k Sports, Novato, CA). Some SVGs place the emphasis on the experience of playing the sport, while others focus on the strategy behind the sport (Hanna, 2015). The majority of these games are sedentary which only require a gaming console and controller to manipulate characters on the screen. SVGs have been found to increase knowledge of sport in an educational setting.

Recently, Jenny and Schary (2014) explored the effectiveness of learning American football through playing the sedentary SVG Madden NFL (EA Sports). This mixed-methods experiment also investigated whether playing the SVG influenced participants to want to watch or play "real life" football. Forty international students with little to no experience with American football took pre and posttests on football knowledge (i.e., rules, field layout, terminology, official signals, and player positions). Participants randomly assigned to the experimental group completed eight 30-minute video gaming sessions using the Xbox One or PlayStation 4 prior to taking the posttest. Subsequently, experimental participants also then partook in a focus group session discussing their gaming experiences. Results showed that playing the SVG increased total knowledge of the sport (compared to the control group), particularly regarding field layout and player positions, as well as facilitated intentions to want to watch or play the sport in a "real world" environment.

Likewise, Author, Author, Author, and Author (in review) mimicked Jenny and Schary's (2014) methods, but utilized American students with little to no knowledge of cricket playing the SVG Don Bradman Cricket (Big Ant Studios, Melbourne, Victoria, Australia). Compared to the control group, findings indicated that cricket knowledge significantly increased pre to posttest for the experimental group (principally concerning cricket rules, terminology, player positions, and field layout). Moreover, experimental group participants were found to be significantly more interested in playing cricket during the posttest compared to the control. Finally, focus group results indicated that the SVG motivated future intentions to watch and play the sport. Thus, SVGs have potential to teach individuals with little knowledge about a sport and may motivate intentions to play the sport in the future. However, longitudinal evidence of this is still lacking.

Video Gaming and Motivation

Motivation is one of the key components to learning and video games can support learners' intrinsic motivation (Felicia, 2012). Video game players often feel like they are in the game themselves (Granic, Lobel, & Engels, 2014). This engagement facilitates participants in creating goals and overcoming challenges within the game. Video games provide immediate reward during play (i.e., often in the form of points or advancing to a new level), paralleling instant praise from a teacher. This immediate feedback can continue to motivate players causing them to want to play more.

"Between their popularity and their efficient delivery of information, video games may help to enhance students motivation, understanding, and performance in sports" (Hayes, 2007, p. 18). MBVGs have been shown to provide stimulus for engagement to students who have lost interest in traditional physical activity (Widman, McDonald, & Abresch, 2006).

MBVG and motivation have also been studied. With students ages 8 to 14 years (*n* = 24), Finco, Reategui, Zaro, Sheehan, and Katz (2015) found that MBVG devices not only motivated students in PE, but also helped develop their social skills through collaboration and support. In addition, MVBG has been found to motivate students who have lost interest in traditional physical activity settings (Sheehan & Katz, 2010; Finco et al., 2015).

Moreover, Jenny and Schary (2015) conducted a study that focused on the ability of MBVG to motivate future authentic rock climbing with participants whom had never rock climbed before. While the game was found to be enjoyable by participants, results indicated that the rock climbing MBVG via the Xbox Kinect did not motivate participants to pursue future rock climbing; rather authentic rock climbing motivated future climbing. Thus, more longitudinal research is needed to determine the effectiveness of using video games to motivate future "real life" physical activity. However, MBVG has seen great success in the fields of physical therapy and rehabilitation.

MBVG and Rehabilitation

MBVG has also been utilized in the medical field for rehabilitation and exercise adherence purposes. Patients can buy their own MBVG equipment and continue rehab at home, which has been found to assist with increasing rehabilitative exercise program adherence both at home and in clinical settings. Many clinicians have introduced the Wii Balance Board (Nintendo, Kyoto, Japan) to their patients. The Wii Balance Board is an innovative accessory for the Nintendo Wii console; as you step onto the board, it interprets the movement of your feet and brings your motions to life. Wii Balance Boards have been found to enhance balance performance through visual feedback given by the

Nintendo Wii system, specifically motivating patients with previous injuries in accomplishing specific therapy tasks (Lange, Flynn, & Rizzo, 2009).

Moreover, Gerling, Mandryk, and Linehan (2015) investigated the long-term use of MBVGs in care home settings. Results showed that weekly MBVG (i.e., Xbox Ones Kinect Sports and Kinect Adventures) were found to be both empowering and enjoyable for patients in a long-term care facility. Furthermore, other research has found that MBVG systems Wii Fit (Nintendo, Kyoto, Japan), Sony EyeToy (Toyko, Japan), and Dance Dance Revolution (Konami, Osaka, Japan) can increase activity levels in users and effectively aid rehabilitation (Franco, Jacobs, Inzerillo, & Kluzik, 2012; Taylor, McCormick, Shawis, Impson, & Griffin, 2011). Other research as studied how much energy is expended while MBVG.

Caloric Expenditure in MBVG

Caloric expenditure is defined as the amount of kilocalories used during an activity or during a specific length of time – generally increasing with the intensity and duration of the activity. Sedentary screen time (i.e., watching television, using the computer, etc.) is seen as low caloric expenditure activities while MBVG is often viewed as a healthier alternative. For example, Lyons, Tate, Ward, and Wang (2012) studied the comparison of television time, sedentary video gaming, and MBVG with young adults and found that the caloric expenditure was higher (655 kcal) in those that performed MBVG. Moreover, MBVG has shown the potential to improve individual's aerobic fitness levels through increased heart rate and oxygen consumption while expending energy (Peng, Lin, & Crouse, 2011). Additionally, other studies have found a positive link to MBVG and health improvements (Warburton et al., 2007; Garn, Baker, Beasley, Solmon, 2012). More specifically, it has been found that MBVG increase heart rate and physical activity in youth; thus promoting both physical activity and health in adolescence (Boucher, Sorensen & Belamarich, 2015; Gao & Chen, 2013).

However, the authentic versions of the physical activities expend more energy, resulting in greater improvements in health-related fitness compared to the MBVG versions of the same activity (Warburton et al., 2007; Garn et al., 2012). Also, caloric expenditure varies depending on the game an individual chooses to play. Some games are more vigorous and require more full body movements, thus, fluctuating caloric expenditure (e.g., boxing versus bowling MBVGs). Overall, it appears MBVG is more beneficial than sedentary video gaming and has the potential to reach moderate levels of exercise intensity, but authentic versions of the sport expend more energy.

Perceptions of MBVG

Logic would say if individuals do not perceive something is useful they are less likely to adopt it. Thus is the case with MBVG in PE. Therefore, it is important to reveal how MBVG is perceived. In 2013, Jenny and colleagues conducted a study that investigated PE pre-service teachers' perception of MBVG. After the participants played several MBVGs, participants were asked their perceived limitations, benefits, and general opinions of MVBG in PE through Likert-style and open response questions. Results revealed that these participants felt that MBVGs are fun and enjoyable, would increase student motivation, and are a way to increase student physical activity, but MBVGs do not always mirror the same fundamental concepts or motor movements of the actual sport. This last finding certainly may impact learning motor skills through MBVG.

Motor Skill Development through MBVG

Learning physical skills in PE is vital for motor skill performance. SHAPE America's (2014) number one national physical education standard targets students' abilities to proficiently perform motor skills and movement patterns. With that said, lessons in PE may focus on motor skill drill practice too much and eliminate the complexity and excitement of game play.

Effective use of technology is enhancing the way teachers teach and the way that students receive information, both cognitively and physically. Hopper (2011) believes that game-play in video games as well as student-centered approaches in PE can draw on higher order student processing in order to inform the learning process in a fun and challenging environment. Many video games are designed by a game-as-teacher approach. Meaning, the game itself is designed to be able to teach an individual a skill, using that skill in a situation, and implementing that skill at the correct moment. In PE, beginners may feel de-motivated by the emphasis on isolated skill practice before even getting to experience the game/sport itself (Hopper, 2011). Breaking down skill by skill can be repetitive and boring for learners. Game-as-teacher within video gaming employs self-motivation as players modify game play in order to adapt skills to be successful within the game. However, the little research exists on the accuracy of the motor skills utilized within MBVGs compared to the authentic versions of the sport.

Jenny and Schary (2016) conducted a mixed-methods multiphase intervention study that investigated the similarities and differences between MBVGs (i.e., Xbox One Kinect Sports Rivals Rock Climbing) and "real-life" wall/rock climbing as well as determine the perceived usefulness of utilizing MBVGs when trying to teach someone how to authentically wall/rock climb. The college student participants (*n* = 24) had no prior wall/rock climbing experience in any environment. Findings revealed that the participants perceived MBVGs and "real life" wall/rock climbing had comparable arm movements and required tactics/strategies, but were dissimilar concerning leg, finger/grip and jumping movements as well as effort differences. However, both the virtual and authentic climbing experiences were needed for a significant difference occurred regarding the participants' self-perceived understanding of the tactics/strategies and motor skills required to wall/rock climb. Lastly, the participants perceived that MBVGs may be most useful to teach wall/rock climbing to beginners or those with physical limitations. However, the authors conclude that due to perceived effort and lower extremity motor movement differences, caution must be heeded for those wanting to use MBVGs to teach "real life" climbing.

In 2012, Sheehan and Katz conducted a six-week school-based study using a multi-factor, multi-variable repeated measures design employing Wii Balance Boards. Balance, strength, flexibility, and dance activities were targeted within the MBVGs with the third grade students (*n* = 67). Data collection occurred throughout regular PE schedules that were 34 minutes long, three times per week. Students were randomly assigned to one of three groups, the control group, the Wii Fit+ Group, or the Agility, Balance, and Coordination Group (ABC). Students who got assigned to the Wii Fit+ group enhanced their postural stability by 26%, while the ABC group had a 23% improvement. The control group had no significant difference in postural stability. Results indicated that MBVGs show promise in improving balance skill development in elementary children.

Other research results are mixed regarding improving motor skill development while utilizing MBVGs. For example, Johnson, Ridgers, Hulteen, Mellecker, and Barnett (2015) conducted a study looking at children's object control skills utilizing the Xbox with Kinect. Forty-three children between the ages of six and ten played variations of Kinect Sport Rivals. Over the six-week intervention period there was no significant findings of improved motor control.

Furthermore, Barnett, Hinkley, Okely, Hesketh, and Salmon (2012) investigated object control and locomotor skills of 3 to 5 year olds (n = 47) utilized within a variety of sedentary gaming systems. Participants' were video recorded while performing each skill by trained professionals across a 55 day period. Results showed that the video gaming did not improve object control or locomotor movements (Barnett et al., 2012). However, other studies have reported motor skill improvement through MBVG.

Hulteen, Johnson, Ridgers, Mellecker, and Barnett (2015) examined how sport-specific MBVGs may enhance real life motor movements of students ages 5 to 9 years old (n = 19). Participants' played sport MBVGs such as tennis, baseball, and golf, once a week for 50 minutes each session for six weeks. The authors reported that the skill components of catching were present 100% of the time and the one and two-handed strike skill components were present 38 to 42% of the time while playing the Xbox Kinect. Overall the studies results demonstrated that MBVGs have the potential to mirror motor movements.

Moreover, George, Rohr, & Byrne (2016) measured pre/post aiming and catching within an intervention study utilizing Nintendo Wii's Wii Sport, Wii Sport Resort, Wii Play and Just Dance 2. Seventeen males and females ages 6 to 12 years participated in the six-week intervention study. Results showed a near significant improvement in aiming and catching ($p = 0.06$). These two studies show the positive impact that MBVG can have on individuals motor movements.

Conclusion

Students have been found to be more engaged and motivated in learning when video games are present (Gee, 2007; Papallo, 2015). The purpose of this article was to provide an overview of sedentary and MBVG research in education, particularly regarding developing motor skills through MBVG. Based on the literature, MBVG may be most beneficial for beginners who are experiencing a sport for the first time as basic sport concepts and skills can be introduced through video gaming. Furthermore, those who have special needs may benefit from utilizing MBVG because of the games abilities to differentiate skill levels.

Moreover, with just one gaming console, individuals can experience a variety of sports which they may not have access to otherwise. This creates a diverse learning environment for those with diminished resources where students can participate in a wide range of activities. Along with motivating students, video gaming may support social interaction with peers as students are able to work together, play against each other, and interact with their classmates. MBVG can also assist in rehabilitation by increasing an individual's motivation and engagement.

Additionally, video games provide constant feedback as players hear in-game commentary such as game/sport-specific terminology, rules, and player positions. Thus, MBVG afford students to perform physical activity and develop their cognitive knowledge. However there are also negative aspects to MBVG in an educational setting.

Foremost, MBVG consoles can be expensive, not including purchasing games and accessories. Moreover, time on task can be reduced for students if multiple consoles are not available as not all students may be able to play at the same time. However, MBVG can increase overall physical activity by replacing sedentary video gaming with active gaming. Although MBVGs are more physically active than sedentary gaming they still do not burn as many calories as traditional sports (i.e., less energy required to play MBVGs). Finally, physical movements of MBVGs may not always mimic the authentic version of the sport. Thus, students may not be learning the correct form of a specific skill. In summary, practitioners must be wary of utilizing MBVGs in teaching sports skills as empirical evidence is lacking with supports authentic sport-specific motor skill development.

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Main Study Manuscript

Virtual and Authentic Tennis: Similarities and Differences of Three Common Tennis Strokes in NCAA Division I Tennis Players

Kristy M. Noble

Seth E. Jenny

Shelley D. Hamill

David P. Schary

Winthrop University

Authors' Note

All authors teach within the Department of Physical Education, Sport and Human Performance at Winthrop University, Rock Hill, SC. Correspondence concerning this article should be addressed to Dr. Seth E. Jenny, Department of Physical Education, Sport and Human Performance, Winthrop University, 216B West Center, Rock Hill, SC 29733. Contact: jennys@winthrop.edu

Abstract

The purpose of this mixed-methods multi-phase study was to compare the similarities and differences of three common tennis strokes performed by National Collegiate Athletic Association Division I tennis players in an authentic and motion-based video game (MBVG) environment. Moreover, the perceived effectiveness of using MBVGs as a pedagogical tool was also examined. Statistical analyses revealed that the forehand, backhand, and serve were performed significantly different in the authentic and MBVG environments. However, the participants perceived that the MBVG forehand and serve were similar to the authentic environment. In addition, the participants perceived several positives and negatives of utilizing MBVGs when teaching sports skills, particularly in reference to beginner and experienced tennis athletes. Implications of these findings for physical educators and coaches are discussed.

Keywords: Exergaming, Xbox Kinect, virtual, motion-based video gaming, active gaming

Introduction

Youth obesity is a rising concern around the developed world, particularly within the United States. According to the Centers for Disease and Prevention (CDC, 2015a), 12.7 million American children from the ages of 2 to 19 years are obese. Obesity can lead to severe health issues such as heart disease, high cholesterol, diabetes, orthopedic issues, or fatty liver disease (Daniels, 2014). Children who suffer from obesity are also 50% more likely to continue to suffer from obesity in their adult life (Hardy, 2004). However, a healthy diet and regular exercise (i.e., at least 60 minutes of daily physical activity) have been shown to help decrease obesity within children (CDC, 2015b; CDC, 2015c).

Recently, sedentary video games have been blamed as part of the increase in obesity due to the lack of physical activity involved (Loop, 2015). For example, past research claims that each hour a child watches television or plays a video game doubles the likelihood of that child becoming obese (Stettler, 2004). However, this negative outlook on video games may be starting to change.

Traditional sedentary video gaming is very popular within America. Video games are found to be most popular in adolescence as 88% of youth play video games (Gentile, 2009). In addition, 41.3% of American high school students play either video or computer games for at least three hours per day (Kann et al., 2014). Moreover, 63% of Americans play video games on a regular basis while at least 65% of all American homes own at least one video game system (Entertainment Software Association, 2016). It is clear that youth may be spending an abundant amount of time playing video games, which may be replacing physical activity time.

Motion-based Video Games

The introduction of motion-based video games (MBVGs) has somewhat altered the negative outlook toward video gaming for some. MBVGs are interactive video games that use sensors to manipulate the on-screen character in order to mimic the movement of the individual playing the game, thus requiring physical movement of the player (Jenny, Hushman, & Hushman, 2013). Following the craze of the interactive dance MBVG *Dance Dance Revolution* (Kanomi, Redwood City, CA), the first popular retail MBVG console, the Nintendo Wii (Nintendo, Kyoto, Japan), was released in 2006 (Rouse, 2011). Today, popular MBVG consoles include the Nintendo Wii Fit and Balance Board and the Xbox One with Kinect (Microsoft, Redmond, WA). MBVGs have been found to be helpful in several areas, including, for example, rehabilitating sport injuries (Lange, Flynn, & Rizzo, 2009) and motivating physical activity in elderly populations within a long-term care setting (Gerling, Mandryk, & Linehan, 2015).

Recently, interactive technology, such as video gaming, has been suggested for educational purposes (Papallo, 2015). For example, Chrome Books, iPads, smartphones, and SMART Boards have all been shown to enhanced student learning when used effectively (Hasan, 2014). Introduced in the 1970's, *The Oregon Trail* (Minnesota Educational Computing Consortium, Northfield, MN) was first widely used video game in classrooms, targeting student learning about the western expansion (Eakin, 2013). Today, much more technologically advanced educational video games are utilized to increase student learning, motivation, and improve social skills (Finco, Reategui, Zaro, Sheehan, & Katz, 2015). Current research has investigated video gaming and its role in teaching and learning within physical education (Jenny & Schary, 2014; Jenny & Schary, 2016; Finco et al., 2015).

MBVGs in Physical Education

Fundamental aspects of physical education include increasing student physical activity and promoting lifelong fitness (Society of Health and Physical Educators [SHAPE] America, 2014). Common MBVGs that have been employed by physical educators as pedagogical aids include the Nintendo Wii, Xbox One with Kinect, and Dance Dance revolution Classroom Edition (Sheehan & Katz, 2012; Staiano & Calvert, 2011; Quennerstedt et al., 2014). Past studies have explored possible relationships between MBVGs and many physical education-related factors, including motivation (Granic, Lobel, & Engels, 2014; Jenny & Schary, 2015), caloric expenditure (Lyons, Tate, Ward, & Wang, 2012), social skills (Finco et al., 2015), learning sport tactics/strategies (Jenny & Schary, 2016), and perceptions of MBVG skill difficulty (Jenny & Schary, 2015). However, SHAPE America’s (2014) national physical education Standards 1 and 2 state that physically literate individuals exhibit motor skill competency as they effectively apply movement concepts, principles, tactics, and strategies. MBVG can also incorporate all three learning domains, including the psychomotor (i.e., fundamental motor movements), cognitive (e.g., rules, scoring, etc.), and affective domains (e.g., motivation, peer interaction, etc.) (SHAPE, 2015). Physical educators must break down sports skills into simple steps called skill cues, often striving to find exciting new ways to teach these fundamental skills (Graham, 2012). However, few studies have investigated the effectiveness of using MBVGs for physical skill development, particularly regarding empirically comparing authentic and MBVG sport movements.

The purpose of this study was to explore the similarities and differences of three common tennis strokes (serve, forehand, backhand) employed in MBVG and authentic tennis environments. The primary questions which guided this research included: 1) How closely do the physical actions involved in a tennis MBVG mirror the same fundamental motor movements of authentic tennis?, and 2) What is the perceived effectiveness of using a tennis MBVG as a teaching tool? Understanding the motor movements required in authentic versus MBVG environments assists physical educators and coaches in determining the possible benefits and detriments in utilizing MBVGs for instruction.

Method

Design and Participants

A mixed-methods multi-phase approach with one women's (n = 9) and one men's (n = 6) National Collegiate Athletic Association (NCAA) Division I tennis team was used in this study. NCAA tennis athletes were utilized in order to get an accurate assessment of the tennis strokes, which may not be attained from a recreational players or within general physical education classes. All participants had immense tennis experience and were student-athletes who attended the same mid-major liberal arts state university located in the southeast United States. Most recently, the women's team won the conference championship the previous year prior to the study, while the men's team won the conference championship two years prior – with both teams attaining national recognition by the Intercollegiate Tennis Association (ITA) for academic excellence the year prior. Additional participant demographic information is listed in Table 1. Prior to the start of the study, Institutional Review Board approval and participant consent were attained.

Measures

Questionnaire and survey. The questionnaire consisted of 12 demographic questions concerning the participants' gender, race, age, first language, year(s) in university, as well as prior tennis, video gaming, and MBVG experience. The survey included six questions regarding the participants' interest and intentions to play MBVGs, perceived effort of MBVG tennis and authentic tennis, and perceived comparisons of the forehand, backhand, and serve of MBVG and authentic tennis measured on a ten point Likert scale (e.g., "The motion of the tennis forehand is the same in the video game as in real life.").

Tennis skill rubrics. Based on the textbook *Tennis: Steps to Success* (Brown & Soulier, 2013), three rubrics were created and used to analyze three tennis strokes (i.e., serve, forehand, and backhand) performed by the participants' in authentic and MBVG environments – see Table 2. Participants utilized their preferred backhand technique (one-handed or two-handed) throughout the study. Three content matter experts critiqued and validated each rubric for accuracy – a current head men's NCAA Division I tennis coach, a former National Association of Intercollegiate Athletics (NAIA) tennis player, and a former NCAA Division II tennis player.

Equipment

Xbox One with Kinect. Four Xbox One with Kinect (Microsoft, Redmond, WA) MBVG consoles were utilized in this study. The Kinect, a motion-capturing camera, requires players to use body movements to control the character on the screen, where the player's body acts as the "controller".

Kinect Sports Rivals Tennis. The MBVG used in this study was *Kinect Sports Rivals Tennis* (KSRT, Microsoft Studios, Redmond, WA). Players had the option to choose which hand they would like to play with and are able to put topspin or backspin on the ball, as well as utilize a variety of advanced shots such as the volley, lob, overhead and drop shot.

Tennis equipment. During authentic tennis skill evaluation, participants used their own racket. Moreover, to ensure consistency across participants, a Wilson tennis ball dispenser was used to assess forehand and backhand returns.

Motion-analysis. Dartfish (SimulCam, Switzerland) computer software, video motion-analysis used by professional athletes and Olympians (Dartfish, 2017), was used in analyzing the recorded MBVG and authentic tennis skills performed by the participants.

Procedure

Table 3 provides an overview of the study's six-phase schedule. Phase 1 entailed participants taking the questionnaire and pre-survey. Then, during phase 2, participants were video recorded at the end of a tennis practice performing the serve, forehand, and preferred backhand (one-handed or two-handed). Coaches delivered all balls to the athletes via a ball machine. Each stroke was performed three times. All participants' strokes were then analyzed independently by 2 qualified researchers utilizing Dartfish and the rubrics seen in Table 2.

Next, phase 3 involved participants exploring the KSRT video game through participating in a 45 minute practice session. The session started with the video game's short tutorial of how to play the MBVG, including how to make different shots and move around the court successfully. Then, the participants were randomly grouped into pairs and each played against one another for the remainder of the session.

Phase 4 involved the participants playing another 45 minute gaming session where two participants occupied one console and played two complete sets against one another. During this session, the researcher video recorded the participants performing the same tennis strokes mentioned above while playing the MBVG. Then, following the same protocol, each participant's tennis strokes were analyzed. Scores for each stroke within the authentic and MBVG environments were then compared.

During phase 5, participants took the post-survey. Finally, phase 6 consisted of two separate one-hour focus group sessions, one with the men's team and one with the women's team. Using a semi-structured interview schedule similar to the one used by Jenny and Schary (2016), participants were asked about their overall study experiences, focusing on their perceived comparisons of the differences and similarities of authentic and MBVG tennis (e.g., "*How close was your forehand stroke while playing the video game compared to in real life?*"). In addition, participants were asked about their perceptions of using tennis MBVGs as a teaching tool (e.g., *"To what extent could others learn about the physical skills necessary to perform tennis from playing the video* *game?"*). A digital audio recorder was used to record the focus group sessions and the data were later transcribed verbatim.

Data Analysis

Quantitative analysis. Descriptive statistics were calculated for the sample. Participant rubric scores for each tennis stroke were analyzed. During the scoring phase, two content experts analyzed the motor movements of the athletes independently. Then, if there was any differentiation between scores, they came to an agreement on the final score. This process was completed for the authentic tennis session and the MBVG sessions. Both a paired *t*-test and a two-tailed *t*-test were used to compare survey and rubric data. These tests were utilized due to the small sample size and study design. All quantitative analyses were conducted using SPSS Statistics (IBM, Armonk, NY). Significance was set at $p < .05$.

Qualitative analysis. *Atlas.ti 7.0* (Scientific Software Development, Gmbh, Germany) was utilized to organize and categorize the qualitative data. The transcribed data were first open coded in order to find primary themes. Then, the data were re-analyzed to finalize the major themes through cross-referencing the interrelationships of the major coded primary themes (Creswell & Poth, 2018).

Results

Research Question 1

As seen in Table 4, quantitative results supported that the tennis strokes employed with the tennis MBVG did not mirror the same fundamental motor movements as those utilized while playing authentic tennis. On average, the participant's overall scores of the forehand, backhand, and serve decreased significantly while participating in the MBVG compared to playing authentic tennis ($p = 0.001$). Conversely, quantitative results revealed that the participants perceived all of the strokes to be similar to authentic tennis (see Table 5). However, perceived similarities only increased slightly from pre to post test. Although participants perceived that the strokes were similar in both environments the results were still not significant. The small sample size of the study may have had an impact on the significance of the results.

Qualitative findings (seen in Table 6), revealed that the participants perceived that the MBVG forehand and serve involved similar motor movements compared to authentic tennis, while the backhand was perceived to be dissimilar.

Research Question 2

As seen in Table 7, the participants perceived that the tennis MBVG would be a beneficial tool to teach tennis to beginners. In addition to teaching motor movements, participants also perceived that it would be beneficial in teaching basic rules and scoring and to motivate individuals. However, the participants perceived several negatives of MBVG tennis for experienced players, including that the MBVG did not require them to use their authentic two-handed backhand swing, nor was it realistic to their success on the tennis court. In addition, the rules, sets, and scoring was not similar to NCAA tennis. Moreover, utilizing the Modified Borg Rating of Perceived Exertion (Borg, 1998; 0 = very easy; 10 = extremely hard), participants perceived that authentic tennis ($M = 7.80$, SD = 2.15) required significantly more effort than MBVG tennis ($M = 4.16$, SD = 1.85; $t(14) = 8.73$; $p = 0.001$).

Discussion and Implications

Research Question 1

This study empirically examined the similarities and differences of three tennis strokes while performing both authentic and MBVG tennis.

Forehand. The forehand stroke was found to be significantly different in the MBVG compared to the authentic environment (p = 0.001). As seen in Table 4, the average score of the forehand decreased significantly during the MBVG session. Video analysis revealed little to no lower body movement during MBVG tennis play. Participants' stroke movements became minimal with slight follow-through during MBVG tennis. Likewise, Bryant (2010) found that participants playing Nintendo Wii Tennis only used their wrist to perform the tennis stroke rather than their entire forearm. In the current study, participants also noted that it was difficult to aim their shots to where they wanted to place the ball, paralleling Bryant's (2010) results.

Moreover, participants in the current study perceived that teaching the forehand to beginners would be a good introduction to tennis however just the basics of the stroke would be demonstrated during gameplay (i.e. not including aiming, top/back spin, etc.). Likewise, Pedersen, Cooley and Cruichshank (2016) found that children practicing with Nintendo Wii Tennis and Bowling did not improve reaction time in lateral motor movement processing. Thus, MBVGs may not provide accurate enough body movement tracking and therefore may not precisely improve sport-specific motor movements. However, in the current study, qualitative findings revealed that the participants perceived that the forehand stroke was similar in both environments, but careful observation revealed critical motor movements such as footwork, shoulder rotation and follow-through was lacking in the MBVG environment.

Backhand. The backhand showed the most variation when comparing the authentic to MVBG environment. The mean score of the authentic tennis forehand was 8.40, while the mean score while playing the tennis MBVG was 5.13 (see Table 4). As seen by the researchers and noted by the participants in the focus groups, all participants used the two-handed backhand in an authentic environment, but all used a one-handed backhand while playing MBVG tennis. Also noted was that the visually showed the on-screen character performing a one-handed backhand, this may have influenced the participants to also use a one-handed backhand. A two-handed backhand is used more commonly in authentic tennis because it adds power, helps control the swing, and provides better top-spin when hitting the ball (Brown & Soulier, 2013). Study participants did not need to generate much power behind their stroke during MBVG play, which may have inadvertently impacted their decision to move to the less effortful one-handed backhand. Analyses also noted that key critical elements such as footwork and follow-through were not present while performing the MBVG backhand.

Past research has reported that minimal motor movements are required while playing MBVGs, including MBVG baseball, bowling, American football, golf, soccer table tennis, tennis, and volleyball (Barnett, Hinkley, Okely, Hesketh, & Salmon, 2012; Bryant, 2010; Pedersen, et al., 2016; Johnson, Ridgers, Hulteen, Mellecker, & Barnett, 2015). Regarding the current study, it appears participants physically moved the minimal amount needed to be successful while playing MBVGs, despite being highly trained in the sport.

Serve. Lastly, the MBVG tennis serve was significantly different compared to the authentic tennis serve (see Table 4). While participants felt that the MBVG serve was the most similar to the authentic tennis serve, it was perceived to be the most difficult stroke to be successful within the MBVG. In other words, the serves critical elements performed by the participants were the most similar to the authentic environment (i.e., foot position, toss, contact point, follow-through, etc.), but the success rate of the serve was low within the MBVG. This may have been a result of the Kinect camera sometimes not picking up arm-movements movements during MBVG serving as it appeared the system often recognized the toss, but not the serve contact.

Similarly, Jenny et al. (2013) found that pre-service physical education teachers perceived that the MBVG movements did not always correlate accurately to the actual sporting activity and that “glitches in the game” (p. 104) can make results unrealistic. For example, in this study, the participants were required to perform a five-step bowling approach and their “normal” strides were shortened to accommodate the limited Xbox Kinect sensing area. Therefore, sport-specific MBVG movements tracked by motion-sensing cameras are limited to the camera sensing area afforded to players, which can impact skill performance.

Research Question 2

The second purpose of this study was to determine whether MBVGs are perceived to be a beneficial tool to teach tennis. Certainly, the discussion above must be considered when deciding on the usefulness of MBVGs to teach sports skills. It is important that the physical movements are similar in a MBVG environment compared to an authentic setting because if not, negative transfer may occur when playing the authentic version of the sport. Negative transfer occurs when learners' past experiences hinder performing a sport skill under different conditions because the learner is forced to learn a new response to a well-learned stimulus (Coker, 2013). In other words, if students repetitively practice an incorrect forearm tennis stroke in a MBVG environment, they may tend to repeat this learned response in an authentic environment, which may impede skill development.

Effort differences between authentic and virtual sport environments have been researched in past studies, all finding that the authentic versions of the sport requires more effort/energy (e.g., Hulteen, Johnson, Ridger, Mellecker, & Barnett, 2015; Jenny & Schary, 2016; Reynolds, Thornton, Lay, Braham, & Rosenberg, 2014). In the present study, the participants' perceived the effort of playing MBVG tennis to be "weak" to "somewhat strong" while authentic tennis required "very strong" to "maximum" effort, resulting in a significant difference (see Table 4). As the amount of perceived effort between the two environments is significantly different, participants mentioned in the focus groups that an individual may be good at MBVG tennis, but poor in an authentic environment. Thus, utilizing MBVG tennis may be beneficial for educators attempting to boost confidence in unexperienced players, but may not be useful to act as an adequate cardiovascular stimulus when training for authentic tennis.

Perceived positives. Moreover, as seen in Table 7, the participants perceived several beneficial areas in which the tennis MBVG could be used as a teaching tool.

Learning rules and scoring for beginners. The participants perceived that beginners might benefit from playing in order to learn basic tennis rules and scoring. This may include learning the progression of scoring terms (i.e., love, 15, 30, 40, etc.), serving rules (i.e., number of serves, order of service, service positioning, etc.), court layout, out-of-bounds, etc. Similarly, Jenny and Schary (2014) found that participants with little prior knowledge of American football increased their knowledge by 7.2% after playing eight 30-minute sessions of the video game *Madden NFL* compared to a control group, but the results were not statistically significant. It appears that sport video games have the potential to increase sport knowledge, but more research is needed. However, at the same time, the participants in the current study also noted that the rules and scoring of KSRT were dissimilar to NCAA tennis, which will be discussed later.

Motivation for beginners. The majority of participants also felt that MBVGs could potentially help engage and motivate students to be physically active as well as be a great way to introduce tennis to beginners prior to introducing them to the authentic sport. The results mimic past studies that support that MBVGs may assist in motivating physical activity, particularly for beginners in the MBVG sport (Jenny et al., 2013; Jenny & Schary, 2015; Granic, Lobel, & Engels, 2014, Finco et al., 2015). Similarly, Fogel (2010) reported that introducing MBVGs in physical education increased motivation and activity time compared to a non-MBVG infused class. While longitudinal research is lacking, MBVGs have great promise in motivating students in physical education.

Teach basic motor movements for beginners. The participants perceived that individuals who have little prior knowledge of tennis would be able to experience the basic skills necessary to play tennis through playing the MBVG. However, the participants also noted that during MBVG tennis gameplay they were more focused on contact than the correct motion of their swing. Past literature supports that MBVG represent enough of the motor skills in order to get a general introduction of the sport being played (Hulteen et al., 2015; Jenny & Schary, 2016). However, noted previously, not all motor movements are the same. Using MBVGs to teach specific motor movements should be used with caution.

Still, the fact that highly experienced players perceived that the MBVG forehand and serve were similar to authentic tennis could be dangerous. Simply because physical educators (with likely less tennis experience) may incorrectly think they can use MBVGs as an aid to teach these skills.

Fun recreational outlet for experienced tennis players. As NCAA Division I tennis athletes, the participants perceived that the tennis MBVG could act as a fun outlet and become a recreational activity for them. The majority of participants perceived that playing the tennis MBVG would be more of a hobby rather than a training device. More empirical research is needed regarding the possible recreational benefits of using MBVGs for experienced athletes and their potential use for mental training.

Perceived negatives. Table 7 illustrates the perceived negatives of using the tennis MBVG as a teaching tool.

Dissimilar stroke pattern and backhand grip. Participants perceived that the strategies and tactics experienced in the tennis MBVG were not very similar to authentic tennis. Participants' noted how they tended to shorten their forehand and backhand stroke path.

In addition, as already noted, all participants converted from a two-handed to one-handed backhand. Similarly, Bryant (2010) reported that while playing Wii Tennis participants controlled the game by just moving the remote with wrist movements rather than demonstrating a legitimate swing. The same situation occurred when using the Xbox with Kinect which does not use a controller. Participants expressed that their motor movements were different than when they played authentic tennis. They were able to just slightly move their arms in order to hit the ball.

Dissimilar success levels. Participants expressed that during gameplay they got frustrated with the MBVG. Participants are experienced tennis players and therefore know the game and their skill level well. Participants' expressed that they became frustrated with the game and that strokes they were generally proficient at were unsuccessful in the MBVG game. Furthermore, participants noted that the game did not recognize their movements at times throughout game play. On the contrary, Daley (2009) found that MBVG benefited the confidence of the player, which helped motivate them to continue playing. On the other hand, Jenny and Schary (2015) found that playing a rock climbing MBVG did not motivate a minority of participants to want to authentically rock climb because the game made it appear rock climbing would be too difficult. For example, one participant noted, "I was terrible at the game which would make me think I'd be terrible in real life" (Jenny and Schary, 2015, p. 8). Therefore, not performing well in the virtual environment may impact motivation to participate in the authentic activity.

Physical educators must be cognizant of the motivational impact of MBVG, making sure that virtual experiences do not inhibit intentions for future authentic activity. However, in the current study, these experienced tennis players felt they could see themselves playing the tennis MBVG as a hobby (not focused on the success they experience in the video game), it is undetermined the potential ramifications for experienced players not finding success in a video game designed for their sport of expertise. Research is need to see the potential negative psychological impacts of this.

Dissimilar NCAA tennis set/rules/scoring. The participants expressed that the scoring and match length did not represent the same as in NCAA tennis. For example, participants articulated that the MBVG had "advantage" scoring (i.e., winning a game by two points), but within NCAA tennis rules there is no "advantage" scoring.

Participants also noted that matches were shorter than authentic tennis. Video game developers may shorten authentic versions of games in order to maintain player interest. Reduced tennis match times may be beneficial for beginners or less fit individuals, but it does not mimic the demands of the authentic sport. MBVG players should be aware of their fitness levels prior to attempting to play authentic versions of sports games. Moreover, educators should be aware of the rules and scoring as well as fitness levels of students prior to teaching. Particularly, in the current study, the scoring and rules varied from that of which the participants were accustom to playing (i.e., NCAA).

Limitations and Future Research

This study's results may not generalize well outside of NCAA Division I tennis players or beyond the specific MBVG used in this study (i.e., *Kinect Sports Rivals Tennis*). Future research may incorporate a larger sample, a differing sample (i.e., novice or beginner tennis players), or a different MBVG system or sport video game. Furthermore, researchers could change the format of game play, having participants' play against the computer or utilizing a racket during gameplay. However, using a racket may interfere with the space required for the MBVG camera range. Finally, future studies could investigate the benefits of using MBVG within an adapted physical education environment.

Conclusion

Within this study, sport-specific motor movements performed by experienced athletes in an authentic setting were not mimicked in a MBVG environment. In other words, critical elements of the tennis forehand, backhand, and serve performed by NCAA Division I tennis players were significantly different when demonstrated in an authentic environment versus a MBVG setting. However, the participant's perceived that the MBVG forehand was the most similar to an authentic environment. Furthermore, it was perceived that the effort needed to play MBVG tennis was not comparable to the effort needed to play authentic tennis.

In addition, it was perceived that using MBVGs to teach a sport (i.e., tennis) may be most beneficial for beginners in order to learn basic rules and scoring, motivate authentic game play, and teach basic sport-specific motor movements. However, participants perceived that the MBVG environment encouraged dissimilar (i.e., shortened) stroke patterns, a different backhand grip, unrealistic success levels, and contrary rules compared to the participants' authentic version of the sport (e.g., NCAA tennis).

In summary, using MBVGs to enhance motor skills may not be useful as they do not always mirror the same fundamental movements found in the authentic sport. Educators should use caution when using MBVGs to teach critical elements of a skill. However, MBVGs may be beneficial in introducing a sport or motivating novice players.

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Table 1

Participant Demographics

Variable	Results
Gender (*n*)	
Male	40.0% (6)
Female	60.0% (9)
Race/ethnicity (*n*)	
African American	0.0%
Asian/Pacific Islander	6.6% (1)
Caucasian	53.4% (8)
Hispanic/Latino	26.6% (4)
Multi-Racial	0.0%
American Indian/ Alaskan Native	0.0%
Other (European and Indian)	13.4% (2)
Age in years	18.9 (mean) (SD= 1.28)
Type of Student (*n*)	
Undergraduate	100.0% (15)
Graduate	0.0%
College Major (*n*)	
College of Education	13.4% (2)
College of Arts and Sciences	33.4% (5)
College of Business Administration	46.6% (7)
College of Visual & Performing Arts	0.0%
Other	6.6% (1)
Citizenship (*n*)	
United States Citizen	6.6% (1)
International (Not U.S. citizen)	93.4% (14)
First Language (*n*)	
English	33.4% (5)
Other	66.6% (10)
Self-reported Highest Level of Tennis Played	
International Tennis Federation (ITF)	53.3% (8)
Professional (As an amateur player)	40.0% (6)
Futures ITF	6.7% (1)
Tennis Experience in Years	
6-8	13.4% (2)
9-11	26.6% (4)
12-14	40.0% (6)
15+	20.0% (3)
Prior Xbox Video Game Experience	
Yes	40.0% (6)
No	60.0%(9)
Hours of Video Gaming per Week (prior to study)	1.2 (SD = 2.2)
Nintendo Wii Tennis Experience	
Yes	66.7% (10)
No	33.3% (5)

Table 2

Tennis Skill Rubrics – Serve, Forehand, and Backhand

1 Point	2 Points	3 Points
	Serve Preparation	
○ Grip on racket is not consistent ○ Body facing sideways ○ Tossing arm is bent ○ Racket is in front of the head ○ Weight is on both feet ○ Ball toss is low	○ Grip on racket is not consistent ○ Body is not completely facing the net ○ Tossing are isn't consistently extended ○ Racket is not behind the head ○ Weight on back foot ○ Ball toss is behind the head	○ Grip on racket is consistent ○ Body facing the net (front foot at a 45 degree angle, back foot straight) ○ Tossing arm extended forward ○ Racket behind the head ○ Weight on back foot ○ Ball toss OUT and FORWARD
	Serve Swing	
○ Body is upright ○ Contact is below the shoulder ○ No pronation present	○ Forward lean ○ Contact is not high ○ No pronation	○ Forward lean ○ High reach to contact ○ Pronation of the wrist
	Serve Follow- Through	
○ Swing stops after contact ○ Contact is eye level ○ No finish is present	○ Swing stops at the waist ○ Fishing swing: • Out • Down	○ Continued swing after contact ○ Finishing swing: • Out • Down • Across
	Forehand Preparation / Approach	
○ No crossover and/or shuffle step towards the ball ○ Shoulders are not turned towards the target ○ Racket is not in a backswing position ○ Athlete is standing straight up	○ Minimal footwork towards the ball ○ Shoulder turned towards the target ○ Racket in a backswing position ○ Athletic stance	○ Quick crossover and/or shuffle step towards the ball ○ Shoulder turned towards the target ○ Racket in a backswing position ○ Square athletic stance
	Forehand Swing	
○ Minimal racket motion ○ Swing path is not low-to-high ○ Contact is behind the body	○ Horizontal racket motion ○ Swing path is not low-to-high ○ Contact is parallel to the body	○ Upward and forward motion ○ Low-to-high swing path (waistline to shoulder height) ○ Early contact in front of the body
	Forehand Follow- Through	
○ Racket does not move past the waist line ○ Racket does not cross the mid-line	○ No movement across the body ○ Finish below the ear	○ Following through the ball ○ Finish behind the ear OR at the waist
	Backhand Preparation / Approach	

○ Racket grip is incorrect ○ Shoulders are not turned towards the target ○ Racket is not in a backswing position ○ Athlete is standing straight up ○ *Non-Dominant hand is not utilized correctly	○ Grip on the racket is not consistent ○ Shoulder somewhat turned towards the target ○ Racket in a backswing position ○ Athletic stance ○ *Non-dominant hand is near the racket	○ Grip on the racket is consistent ○ Shoulder turned towards the target ○ Racket in a backswing position early ○ Square athletic stance ○ *Non-dominant hand holds the racket using an eastern grip ○ *Quick upper body turn
	Backhand Swing	
○ No weight shift ○ Swing path is not low-to-high or Parallel ○ Contact is behind the body ○ *Non-dominant hand does not stay in contact with the racket ○ *Legs are not utilized correctly	○ Weight is not shifted forward ○ Swing path is inconsistent ○ Contact is parallel to the body, NOT in front ○ *Non-dominant hand is on the racket but does not create additional power ○ *Legs are bent but not uses for power	○ Weight shifts forward ○ Parallel OR Low-to-high swing path (waistline to shoulder height) ○ Early contact in front of the body ○ *Non-dominant hand pushes through the ball ○ *Utilizes legs to push for power
	Backhand Follow- Through	
○ Athlete does not push through the ball ○ Racket does not cross the mid-line ○ *Non dominant hand releases after contact	○ Athlete pushes through the ball but stops at contact ○ Racket finishes at the waist or low ○ *Non dominant hand releases after contact	○ Athlete follows through… ○ Outward ○ Across the body ○ Upward ○ *Both hands finish behind the ear

Note. Items marked with a "*" notate a two-handed backhand. The highest possible score for each stroke was nine.

Table 3

Study Schedule

Phase	Tasks	Content
Phase 1	Questionnaire and Pre-survey	Questions consisted of: Demographics, video game experience, perceived effort and perceived similarities of strokes
Phase 2	Authentic Tennis Video Recording	Participants were filmed performing the three tennis strokes during a practice session
Phase 3	MBVG Practice	Participants watched MBVG tutorial and played the MBVG (45 minutes)
Phase 4	MBVG Session	45 minute MBVG tennis game play with video recording
Phase 5	Post-survey	Questions consisted of: Perceived effort and perceived similarities of strokes
Phase 6	Focus Group	One hour focus group sessions with men's and women's tennis teams separately

Note. MBVG = motion-based video game (i.e., *Kinect Sports Rivals Tennis*)

Table 4

Tennis Stroke Rubric Analyses

Variable	Authentic Tennis	MBVG Tennis	*t*-Test	Significance
Forehand	7.87	5.07	37.52	.0001*
Backhand	8.40	5.13	29.88	.0001*
Serve	7.83	5.90	21.14	.0001*

Note. See Table 2 for scoring rubric. Highest possible score per stroke = 9. $*p<.05$

Table 5

*Comparing MBVG and Authentic Tennis Perceptions (**means**)*

Variable	**Pre-Survey**	**Post-Survey**	**Std. Dev**	**Paired *t*-test**	**Significance**
Forehand	4.13	5.06	2.34	-1.54	.145
Backhand	4.13	4.60	2.10	-0.86	.404
Serve	3.93	4.93	2.73	-1.42	.177
Strategies and Tactics	3.73	4.73	2.78	-1.39	.185

Note. Sample response item: "*The motion of the tennis forehand is the same in the video game as in real life*." Likert scale (1 = strongly disagree; 10 = strongly agree). $*p<.05$

Table 6

Research Question 1: Qualitative Results with Representative Quotes

Perceived Similarities of MBVG Tennis and Authentic Tennis
Forehand "[The forehand stroke is] similar because you're not just moving the hand, you actually need to [perform] all the swing and the technique. Not the same, but similar to what you will do in [authentic tennis]."
Serve "I ended up using [the serve] like I was literally doing the full actual swing on [the MBVG]." "The idea of the [MBVG] serve is also similar to [authentic] tennis because you need to toss the ball and you need to hit when the ball is [at] the top. So it's really similar."
Perceived Differences between MBVG Tennis and Authentic Tennis
Backhand "There's less leg [movements] than in real life…In [the MBVG] it's more just an arm motion." "I [perform] the [backhand] with two-hands [in authentic tennis, but the MBVG]…character was doing it one-handed."

Note. MBVG = motion-based video game.

Table 7

Research Question 2: Qualitative Results with Representative Quotes

Perceived Positives of using MBVGs as a Tennis Teaching Tool
Learning Rules and Scoring for Beginners "I think if you haven't played before, it would be a good way to develop some skills and know the scoring." "[Using the MBVG would be beneficial] to teach like scores, rules, how to move a little bit."
Motivation for Beginners "You could [use the MBVG as an introduction]. They could understand a little bit more. Then, you could almost get them excited, to…do it for real."
Teach Basic Motor Movements for Beginners "Maybe [with people who] don't know how to play tennis…[the MBVG would] help them to get their skills." "I think [the MBVG] would bring the skill up to a certain level, like once they understand how to hit the ball [in the MBVG] there's not much they can do after that."
Fun Recreational Outlet for Experienced Tennis Players "Not as a practice thing, but maybe [play MBVGs] like as a hobby" "I think the idea of the video game is just to have fun, not to improve the tennis. As we practice for like ten years, for example, it's hard to improve some things. We prefer to play in the court."
Perceived Negatives of using MBVGs as a Tennis Teaching Tool
Dissimilar Stroke Pattern and Backhand Grip "I made my swings shorter, and I did a one-hand backhand [in MBVG tennis compared to authentic tennis]."
Dissimilar Success Levels "I got frustrated… because I was losing [in KSRT, compared to authentic tennis]." "For me, personally, I have more confidence in my forehand side in real tennis, but in the video game I couldn't hit a forehand"
Dissimilar NCAA Tennis Rules/Sets/Scoring **"**There's no advantage [scoring in KSRT]." "[The KSRT matches were] short…very short."

Note. MBVGs = motion-based video games; KSRT = Kinect Sports Rivals Tennis.