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Running Head: VIRTUAL REALITY SPORT PSYCHOLOGY

The Use of Virtual Reality Head-Mounted Displays within Applied Sport Psychology

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Abstract

Virtual reality (VR) technology has been employed within several domains such as medicine, education, and the military. Nonetheless, there is limited research examining how VR can supplement applied sport psychology practice. This article provides the reader with an understanding of key components and concepts associated with VR head-mounted displays (HMDs). Subsequently, a range of possible applications within applied sport psychology are discussed, such as the training of perceptual-cognitive skills, relaxation strategies, and injury rehabilitation. Thereafter, the practicalities of using VR HMDs are outlined, and recommendations are provided to applied sport psychology practitioners wishing to embed this technology within their practice.

Keywords: Head-mounted display, immersive virtual environments, sport psychology practice, virtual reality, virtual training.

The Use of Virtual Reality Head-Mounted Displays within Applied Sport Psychology

The term virtual reality (VR) was coined in 1987 by Jaron Lanier. Nonetheless, it is only recently that hardware and software developments have allowed VR to break out of the laboratory environment and enter the home (Bailenson, 2018). The year 2016 saw the release of multiple VR systems from companies including Oculus, HTC, Sony, Google, and Samsung. Opportunities to engage with VR content grew exponentially and fueled the assertion that mainstream VR had taken flight (Lin, 2017). Currently, a popular use of VR is for home entertainment (Bailenson, 2018). Within the sports sector, there are numerous opportunities for fans to experience content using VR systems (e.g., the National Basketball Association's League Pass VR[1]), allowing fans to get closer to the action than ever before. The rate at which individuals are engaging with VR doesn't appear to be slowing, with some reporting that the VR market will be worth over $33 billion by the year 2022.[2]

The application of VR extends far beyond the realm of home entertainment, with researchers examining the efficacy of this technology within education (Jensen & Konradsen, 2018), the military (Norr, Smolenski, & Reger, 2018), surgical training (Huber et al., 2017), rehabilitation (Cano Porras, Siemonsma, Inzelberg, Zeilig, & Plotnik, 2018) and the treatment of pain (Ambron, Miller, Kuchenbecker, Buxbaum, & Coslett, 2018). However, there is little research that explores how contemporary VR systems can enhance applied sport psychology practice. Accordingly, the author introduces the reader to key terminology and concepts associated with the experience of VR. Thereafter, the author discusses how VR can be employed to develop athletes' perceptual-cognitive skills, induce a state of relaxation, and facilitate rehabilitation from injury. Finally, the practicalities of using VR technology are expounded, with reference to input devices, output devices, virtual content, and health and safety.

Head-Mounted Displays

There are a range of VR hardware options available that can deliver immersive experiences. However, the present article focusses on VR head-mounted displays (HMDs), which represents the most common type of consumer VR system (Won et al., 2017). A HMD contains two screens that are presented in front of the individual's eyes. Digital images are delivered to each screen which are rendered with appropriate perspective to account for the position of each eye (Slater & Sanchez-Vives, 2016). The screens are housed within a case that contains sensors that constantly track an individual's head movements and alter the virtual environment accordingly.

Consciousness of our surroundings is dependent on information acquired by our senses (Slater & Sanchez-Vives, 2016). Critical to VR HMDs is the capacity to replace real sense perceptions with computer-generated ones, allowing individuals to perceive actively through natural sensorimotor contingencies (Slater & Sanchez-Vives, 2016). The term *presence* refers to the perceptual illusion of being in the virtual environment (Slater, 2018). VR HMDs provide real-time updates of sensory perception, stereoscopic visuals, and wide fields of view to ensure that individuals experience the virtual environment as their primary reality (Won et al., 2017). A product of presence is that individuals behave in similar ways during a VR experience as they would in reality (Bailenson, 2018).

Using VR HMDs Within Applied Practice

The following section offers several possibilities for how sport psychology practitioners can integrate VR HMDs within their applied practice, drawing upon relevant research and examples from real-world contexts.

Perceptual-cognitive skills training. Expert performers possess enhanced perceptual-cognitive skills when compared to their lesser skilled counterparts (Murphy, Jackson, & Williams, 2018). Superior perceptual-cognitive skills allow individuals to effectively use their vision to identify critical environmental information, in order to anticipate the behaviors of others (i.e., teammates and opponents) and to select and execute the most appropriate cause of action (Broadbent, Ford, O'Hara, Williams, & Causer, 2017). Encouragingly, perceptual-cognitive skills can be trained across a variety of sports (see Cotterill & Discombe, 2016 for a review).

Video-based methods have been used extensively to explore the perceptual-cognitive skills of athletes (Broadbent et al., 2017). However, there are several limitations with using two-dimensional video playback, such as the inability to extract stereoscopic information (Vignais, Kulpa, Brault, Presse, & Bideau, 2015). Moreover, the viewpoint is not fully egocentric as it does not automatically update to account for the athlete's movements, compromising the environment/actor relationship that is present during a sporting contest (Craig, 2014). Researchers adopting an ecological perspective, wherein perception and action are considered to be cyclical, have encouraged the use of VR HMDs to study perceptual-cognitive skills, owing to the technology's capacity to overcome such limitations and to preserve the perception/action loop (Correia, Araújo, Watson, & Craig, 2014).

Dessing and Craig (2010) used a virtual environment to examine the influence of ball spin on soccer goalkeepers' movements. Findings revealed that experts waited significantly longer than novices before commencing any movement, so that they could pick up more information about the ball's trajectory. It has also been demonstrated that expert rugby players using VR HMDs are more likely to attune to honest movement signals (e.g., center of mass) than novices when predicting the running direction of opponents (Brault, Bideau, Kulpa, & Craig, 2012). Accordingly, VR HMDs can offer sport psychology practitioners a useful means of training athletes to attend to relevant cues in the performance environment.

Perhaps the most recognizable company currently using VR HMDs to train athletes' perceptual-cognitive skills is STRIVR.[3] Derek Belch, the founder of STRIVR, recognized that the typical eye-in-the-sky video footage used to review football plays wasn't fully representative of the vantage point experienced by athletes in the competitive arena. Subsequently, STRIVR recorded 360-degree videos of specific plays being executed from the perspective of a quarterback. Thereafter, the athletes could use a VR HMD to review the footage, allowing them to scan the field of play, anticipate the pass rush, and to identify their receivers. It has been reported that quarterback Case Keenum watched over 2,500 plays using a VR HMD during his 2017 season with the Minnesota Vikings.[4] However, players from other positions can use VR HMDs to study blitz pickups and moves at the line of scrimmage.

Outside of a football setting, sport skills that require limited movement are particularly well suited to VR HMDs (Miles, Pop, Watt, Lawrence, & John, 2012). Accordingly, applied practitioners might seek to employ this technology when training the perceptual-cognitive skills of soccer players (e.g., defending set pieces), baseball players (e.g., hitting), and hockey players (e.g., goaltending). An advantage of using VR HMDs to train athletes' perceptual-cognitive skills is the ability to complete a large number of repetitions with reduced risk of physical injury (Düking, Holmberg, & Sperlich, 2018).

Relaxation. Success in sport requires athletes to continually manage a variety of changing demands (Swettenham, Eubank, Won, & Whitehead, 2018). Athletes are subjected to several stressors including high training loads, pressure to perform, organizational politics, and interpersonal conflict with teammates, coaches, officials, and opponents (Crocker, Tamminen, & Bennett, 2018). Stressors have the potential to damage an athlete's physical and mental well-being (Rumbold, Fletcher, & Daniels, 2018). Therefore, applied sport psychology practitioners often work alongside athletes to develop a range of strategies to help them cope with such demands.

A coping strategy that can alleviate emotional distress is relaxation (Kellmann, Pelka, & Beckmann, 2018). For example, Karageorghis and Terry (2011) suggested an exercise entitled the relaxing place, wherein athletes visualize a real or imaginary location that conveys strong associations of relaxation. The effectiveness of this technique is enhanced when the athlete is able to fully immerse themselves in their favored place of relaxation (Karageorghis & Terry, 2011). Hence, applied sport psychology practitioners might use VR HMDs to supplement this exercise, by systematically immersing athletes into a range of environments in order to determine an athlete's preferred location. Videos depicting natural environments such as mountain ranges and beaches might prove effective, as they have been shown to significantly reduce participants' heart rate and blood pressure when viewed through a VR HMD (Gerber et al., 2017). Applied practitioners might also take advantage of the in-built audio contained within many VR HMDs by employing recuperative music to further induce a state of relaxation (Karageorghis et al., 2018).

Another relaxation strategy that is frequently employed by athletes is systematic breathing exercises (Kellmann et al., 2018). It has been suggested that VR HMDs can facilitate the practice of breathing exercises, owing to the technology's capacity to provide biofeedback to the participant (Kitson, Prpa, & Riecke, 2018). For example, the VR application DEEP[5] makes use of a custom controller that measures diaphragm expansion, which subsequently updates the visuals displayed via the VR HMD (van Rooij, Lobel, Harris, Smit, & Granic, 2016). Given that an athlete's preference for relaxation techniques is personal (Karageorghis & Terry, 2011), practitioners can use VR HMDs as a tool to showcase a variety of breathing techniques designed to alleviate emotional distress.

A strength of VR HMDs is the ability to facilitate feelings of presence and a useful side effect of this perceptual illusion is absence from the physical reality (Bailenson, 2018; Slater, 2018). Indeed, researchers have suggested that participants are largely unaware of their surroundings when using VR HMDs to encourage a state of relaxation (Gerber et al., 2017). Accordingly, a benefit of using VR HMDs within an applied sport psychology context is the potential to provide athletes with respite, on demand, from an environment that contains numerous stressors (Rumbold et al., 2018). Practitioners might employ this intervention to good effect in the days leading up to competition, as a state of relaxation can enhance sleep quality (Karageorghis & Terry, 2011). However, it is not recommended to employ relaxation strategies on the day of competition, as it might jeopardize the necessary activation for optimal performance (Kellmann et al., 2018).

Injury rehabilitation. Sport injuries can be considered an inevitable part of most athletes' careers. Given that sport injury represents a traumatic event that can serve as a catalyst for a series of competitive and organizational stressors (Mitchell, Evans, Rees, & Hardy, 2014), it is vital to understand the process of rehabilitation in order to enhance the likelihood of successful outcomes. The stressors that athletes face when injured can be classified according to three distinct time phases: onset, rehabilitation, and return to sport (Evans, Wadey, Hanton, & Mitchell, 2012). Frequently reported stressors at onset include a lack of knowledge pertaining to the injury/recovery process, during rehabilitation, a lack progress toward their program, and when returning to sport, a risk of re-injury. Moreover, there is evidence to suggest that some stressors, such as isolation, are experienced across multiple time phases (Evans et al., 2012).

Applied sport psychology practitioners can use VR HMDs with injured athletes across each of the three aforementioned time phases. To illustrate, virtual environments can be used at the onset of injury to enhance the athlete's understanding of the injury/recovery process (Won et al., 2017). Moreover, 360-degree video footage can be used as a means of reducing perceptions of isolation, by immersing athletes into environments that they might not be able to attend physically, such as the training ground. It is plausible that maintaining contact with the team environment could reduce negative affective states, which have been postulated to negatively impact athletes' post-injury behaviors (Wiese-Bjornstal, 2010).

During rehabilitation, VR environments that simulate training drills can be developed so that injured athletes can begin training with reduced risk of physical injury. A benefit of using VR environments in this manner concerns the potential to gamify elements of the rehabilitation process. Hence, an injured athlete might perform a set of rehabilitation exercises administered through a VR HMD and have the VR system record an objective measure of success (e.g., completion time). A personal leader board might be used, which could reinforce feelings of progression toward the athlete's rehabilitation program. Readers are referred to a video[6] illustrating how the company Mi Hiepa Sports are currently using VR HMDs to assist the rehabilitation of soccer players in the United Kingdom (VRFocus, 2018).

When returning to sport, practitioners might work alongside injured athletes to reduce fears of re-injury, which represents a significant source of stress (Covassin, McAllister-Deitrick, Bleecker, Heiden, & Yang, 2015). For example, a sport psychology practitioner might expose an athlete to a series of scenarios that they are likely to face when competing. Commencing with footage that lacks physical contact (e.g., walking out onto the field of play) and progressing onto footage that includes physical contact (e.g., tackling an opponent) might offer a useful means of desensitization training. However, it is noteworthy that athletes and the injuries they sustain are highly idiosyncratic (Bennett, Czech, Harris, & Todd, 2016). Thus, sport psychology practitioners are urged to consider the use of VR HMDs alongside more conventional methods, such as rational emotive behavioral therapy (Artiran, 2018).

Practical Considerations

The remainder of the present article focuses on the practicalities that bear consideration when integrating VR HMDs within applied sport psychology practice. The main components of a VR system are input devices, output devices, and virtual content. Thereafter, attention is drawn to relevant health and safety recommendations.

Input devices. Suitable input devices allow participants to interact with the virtual environment by tracking their movements. VR HMDs contain sensors that are capable of two forms of tracking: orientation and position (Won et al., 2017). Orientation is tracked by accelerometers, which provide feedback concerning the pitch (i.e., nodding), yaw (i.e., turns), and roll (i.e., lateral inclinations) of the participant's head movements. Orientation tracking allows the participant to freely look around their virtual environment. More powerful VR HMDs (see Output devices) have the option of positional tracking, which is achieved by placing external sensors within the participant's physical environment. Subsequently, the sensors capture the position of the headset. When using such HMDs, if the participant walks forward in physical space, the movement is translated in the virtual environment. A technical limitation of using VR HMDs within a sporting context was that the area of effective tracking was significantly smaller than the space required to recreate a typical sporting scenario (Slater & Sanchez-Vives, 2016). However, VR systems can now track an individual within an area of 10 m^2, making this technology more feasible for applied sport psychology practice.

Additional input devices can be used with VR HMDs. Handheld controllers contain orientation and positional tracking sensors, allowing participants to interact with virtual objects using their hands. Moreover, tracking sensors[7] can be attached to physical objects (e.g., sporting equipment) so that when an action is performed in the physical world, it is replicated virtually, which ultimately enhances task fidelity (Broadbent et al., 2017). Several companies provide full-body motion capture with integrated support for VR,[8,9] allowing practitioners to accurately record participants' movements within virtual environments. The obtained footage can be replayed from any angle, representing an advantage over traditional video playback (Miles et al., 2012). However, extra input devices require additional investments of time and cost for the applied sport psychology practitioner.

Output devices. There are numerous factors to consider when selecting a VR HMD for applied practice (see Table 1). It is possible to classify VR HMDs according to how they are powered; mobile, standalone, and tethered. Mobile VR systems require participants to place a compatible smartphone, which provides the computing power, within the HMD in order to view content. Two popular choices include Google Daydream View and the Samsung Gear VR, which offer advanced controls, tracking sensors, and dedicated content stores. Standalone VR HMDs, such as the Oculus Go, contain an in-built display which circumvents the requirement of a smartphone when using the device.

More powerful VR HMDs such as the PlayStation VR, Oculus Rift, HTC Vive, and HTC Vive Pro require tethering to a secondary device that is capable of generating and displaying VR content. This is usually achieved by a "VR ready" desktop or laptop computer (Won et al., 2017). The PlayStation VR provides the notable exception, which is powered by a Sony PlayStation 4 games console. Tethered VR HMDs can create the most immersive experiences, achieved through a culmination of advanced positional tracking, motion controllers and high frame rates. Nonetheless, tethered devices are more cumbersome and require more time to set up when compared to mobile or standalone VR HMDs.

The individual use cases of applied practitioners will help decide which VR HMD is the most appropriate. Those employed on a full-time basis with one sport team might wish to employ a tethered VR HMD, especially if they perform the majority of their consultancy at one training facility. Alternatively, practitioners that work with several athletes in a variety of settings may wish to employ a mobile or standalone VR HMD, due to its enhanced transportability and ease of implementation. The demands of the task also bear consideration when selecting a VR HMD, with tethered devices suiting applications that require limited mobility.

Table 1 about here

Virtual content. Applied sport psychology practitioners can develop their own content for use with VR HMDs or draw upon existing consumer content. Virtual content can be created using platforms such as Unity[10] or Unreal Engine.[11] Both platforms are free to download and contain tutorials that teach the basics of navigation and content creation. However, a challenge for practitioners is that Unity and Unreal Engine require familiarity with computer programming languages.[12,13] Indeed, it is seldom that effective content is developed without the aid of software engineers (Cipresso, Serino, & Riva, 2016).

With respect to training perceptual-cognitive skills, it appears that even simple animated point-light figures can be effective (Vignais et al., 2010). However, it is paramount that the virtual environment uses appropriate physics models as a means of providing realistic simulations to minimize the likelihood of incorrect learning (Miles et al., 2012; Slater & Sanchez-Vives, 2016). Hence, practitioners that work within academia might consider collaborating with relevant university departments, such as computer sciences, to develop customized content. Otherwise, practitioners are encouraged to explore platforms that facilitate the creation of VR content without extensive programming expertise, such as Amazon Sumerian.[14]

Practitioners can use 360-degree spherical cameras in order to capture live action footage for use with VR HMDs. Spherical cameras range in price from the hundreds (e.g., GoPro Fusion) to the thousands (e.g., Insta360 Pro) and can be positioned to represent the perspective of an athlete. An advantage of 360-degree videos is that they are far less time-intensive to create when compared to virtual environments. However, a shortcoming is that practitioners require access to the athletes needed to recreate sporting scenarios. Furthermore, participants are not able to move within the scene when viewing such footage through a VR HMD, instead they are active observers (Craig, 2014).

There is a significant amount of existing content that sport psychology practitioners can use with VR HMDs. An extensive collection of applications can be perused via online stores and range from free downloads to paid content that typically requires a one-off payment. [15,16] Although it is unlikely that there will ever be one application that can accommodate every type of use within applied sport psychology practice, a range of applications that might be of interest to applied sport psychology practitioners are presented in Table 2. Applications are usually intuitive and require little time to install on VR HMDs or tethered devices. However, practitioners can draw upon user reviews to help ascertain whether the application is viable to their individual consultancy requirements.

A range of existing 360-degree videos can be streamed and/or downloaded directly onto VR HMDs. Most devices include a dedicated application for this purpose. In addition, practitioners can use cross-compatible libraries such as YouTube Virtual Reality and Jaunt when searching for relevant content. When using VR HMDs to encourage relaxation, practitioners are directed toward libraries that contain content specifically designed for this purpose.[17,18] Moreover, practitioners can browse a public database of immersive 360-degree videos assembled by Li, Bailenson, Pines, Greenleaf, and Williams (2017).[19] Videos with a high valence and low arousal score (e.g., Mountain Stillness) are recommended to induce a state of relaxation. A strength of using existing content pertains to the ease of implementation and access to vast libraries. Nevertheless, participants are less likely to identify with generic content. Ultimately, the purpose of the intervention will decide whether employing such stimuli is appropriate on a case-by-case basis.

Table 2 about here

Health and safety. Despite the vast appeal of using VR HMDs within applied practice, there are a range of health and safety considerations that deserve attention. For example, practitioners should prioritize appropriate hygiene as VR HMDs are likely to come into contact with numerous individuals (Düking et al., 2018). Additional foam covers can also be purchased and applied to HMDs, allowing practitioners to use the same device with multiple individuals over a short time span (Won et al., 2017). A reported side-effect of using VR HMDs is simulation sickness (Bailenson, 2018). Engaging with VR content for a pre-determined time (e.g., up to 20 min) and scheduling regular breaks can help reduce the likelihood of simulation sickness occurring. Moreover, it is recommended that participants complete relevant tutorials that are pre-loaded onto the device before engaging with additional virtual content. VR systems allow the participant to set virtual boundaries which are indicative of their physical confines, in order to reduce the likelihood of accidents occurring. However, there is still the potential for individuals to collide with objects in the physical world when using VR HMDs. Therefore, practitioners are advised to monitor athletes at all times in order to maintain safety. Official documentation from VR HMD manufacturers pertaining to best practices represent useful resources for practitioners.[20]

Summary

The present article has introduced the use of VR HMDs as a tool for improved applied practice within sport psychology. VR HMDs allow practitioners to create and immerse individuals into countless scenarios on demand. This is lucrative because VR technology can provide a platform for individuals to engage in a variety of training when they might not be able to otherwise. The author has suggested that VR HMDs can be used as a means to enhance athletes' perceptual-cognitive skills, prompt a state of relaxation, and improve rehabilitation from injury. Nonetheless, future research should focus on ascertaining the effectiveness of sport psychology interventions that are delivered through VR HMDs. As this technology becomes more accessible, it is hoped that practitioners will be motivated to adopt VR HMDs within their practice and devise creative solutions for its implementation. After all, the applications are only limited by one's imagination.

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Footnotes

[1] https://watch.nba.com/page/vr

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Table 1

Virtual Reality Head-Mounted Display Output Devices

Product Name	Type	Price	Resolution (Per eye)	Refresh Rate (Hz)	Field of View (Degrees)	Tracking	Controls
Google Daydream View	Mobile	$99	Native to mobile device	Native to mobile device	100	Orientation	Daydream View Controller
Samsung Gear VR	Mobile	$129	1280 x 1440	60	101	Orientation	Gear VR Controller
Oculus Go	Standalone	From $199	1280 x 1440	60/72	110	Orientation	Go Controller
Lenovo Mirage Solo	Standalone	$399	1280 x 1440	75	110	Orientation and positional (head tracking only)	Daydream Motion Controller
Sony PlayStation VR	Tethered	$299	960 x 1080	120	100	Orientation and positional	DualShock 4
Oculus Rift	Tethered	$399	1080 x 1200	90	110	Orientation and positional	Oculus Touch
HTC Vive	Tethered	$499	1080 x 1200	90	110	Orientation and positional	Vive Controller
HTC Vive Pro	Tethered	From $799	1440 x 1600	90	110	Orientation and positional	Vive Controller

Table 2

Suggested Virtual Reality Applications for Applied Sport Psychology Practitioners

Application	Price	Compatible Devices	Potential Uses
Goaltender VR	Free	HV; HVP; OR	Perceptual-cognitive skills training
Final Soccer VR	$19.99	HV; HVP; OR	Perceptual-cognitive skills training
Lumen VR	$4.99	HV; HVP; OR	Relaxation
Relax VR	$2.99	GDV; SGVR	Relaxation
3D Organon VR Anatomy	$29.99	HV; HVP; OR	Injury rehabilitation (enhancing knowledge)

Note. GDV = Google Daydream View; HV = HTC Vive; HVP = HTC Vive Pro; OR = Oculus Rift; SGVR = Samsung Gear VR.