Humans or Haptics: A Deep-dive into Robots for Sports Training

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In a constantly evolving field such as sports training, keeping up with new techniques, such as the use of haptic devices is essential for those dedicated to optimizing their training processes in a particular sport. Haptic devices send force feedback to a user giving tactile information to the individual.It is not clear to what extent haptics have the capability to enhance training for athletes in comparison to traditional human-based techniques. In this work, we perform a literature review of studies using human-only training as well as studies which incorporate force feedback, tactile feedback, and kinesthetic feedback haptic devices. We examine the biomechanical and cognitive effects of these types of training on the athletes in order to understand the relative trade-offs of haptics vs. human-based training. We discover that haptics aid athletes in terms of increasing the usage of muscle memory, increasing efficiency of learning, improving the timing of the athletes motion, allowing the imitation of real world motions,focusing on a narrow aspect of training, and providing training opportunities for people who are not able to fully engage in the more social environment of traditional training. The downsides of haptics are less practice with sportsmanship, fewer social interactions, fewer opportunities to learn life skills, the potentially overwhelming process of multitasking, and negative emotions and stress that can grow from these effects. Overall, we find that haptics have the capacity to strengthen training regiments, but are not a complete substitute for human-based training.

Introduction

Learning is a different process for every person. We, as humans, have been developing new ways to make this task simpler in places such as sports. In this review paper, we will review the effects of using robots and haptic devices when used to make learning a sport or action simpler. The rules and skills of any sport are constantly advancing to make sports practice a healthier environment and making skill acquisition simpler and more efficient. One developing way of advancing the skills is using a haptic device or robot to train with. Haptic devices give out information in terms of the sense touch [1]. Understanding the effects of training with or without these devices is important, especially for athletes due to making informed choices about training based on the long run impacts on their body and mind.

Based on the literature body we reviewed, we found that the most frequently used robotic system used in sports training are haptic devices. Haptic devices are viewed as an effective tool and developing asset for newcomer athletes and people looking to get a healthy exercise into their daily schedule. Despite being an efficient tool for exercising, we must look at if they truly benefit the athlete. Haptic devices interact directly with the sense of touch. Based on the literature we compiled, we can conclude that there are two main types of haptic devices, kinesthetic and tactile. Kinesthetic feedback designs affect the muscular system of the body. Tactile feedback is given to a living thing through their sense of touch. A prime example of tactile feedback is vibrational feedback used in haptic devices. A model of a device that uses this type of feedback is a phone's vibrations used to notify us.

Training using haptic feedback is an alternative to training with humans only. Haptic feedback is a useful tool for efficient learning in terms of learning particular motions, but can have some down sides in the effect on a persons' mentality of the sport or their thought processes [2,3]. As we are only human, we have limitations to our motions and the ways we can help others, and robotic assistance can help us in ways we cannot help each other. Looking at different types of haptic devices can help us grasp how exactly the implementation of the devices work and predict whether the use of them will help a person rather than negatively affect them.

Research Question

How does sports training with only humans compare to training with robots in terms of the immediate cognitive and biomechanical impacts on an athlete's body?

Relevant Sports Metrics

Due to the expanse of papers we researched and the positive effects of haptics in training, we think that there is a strong possibility of increasing haptic technology usage in fields such as sports training. Due to this recent advancement, it is impor-

tant to understand the effects of the devices towards a person. Human training is a technique the majority of people have access to, but to understand the future of the field better, we should be well informed about upcoming techniques that may surpass the old ways of teaching. One of these techniques that is growing more popular is haptic training. To determine whether human-only training is more beneficial than training with haptics, there are two main metrics we will compare: Bio-mechanical metrics and cognitive metrics. When comparing haptic devices in the sports field, these two metrics are commonly used[4,5]. While looking into the cognitive aspect we will be discussing muscle memory and social aspects that are in play during the action of sports. We will also examine the biomechanical effects of these training styles on particular movements[5]. This entails understanding the results of several experiments or haptic devices that have been given the opportunity to change the way any given human moves.

Human vs. Robotic Training: Biomechanical Impact

In sports, a person's physique and limitations to their movement must be accounted for while training. Robots have the capability to help individuals learn motions that may be more difficult to comprehend and mimic. Their job is to ensure that the athlete is able to build upon particular movements without large delays, efficiently, and in a beneficial physical manner.

In the literature we read through in this review, experiments often use either vibrational feedback, physical real world simulation, or a virtual reality device[6–11]. For example, in the table tennis experiment done by Wu et al.[6] there were vibrations placed directly onto the paddle which allowed for direct communication between the device and human. In this study, both visualization of images and sense of touch using a haptic device were used. This was intended to allow for a more memorable motion to be induced into the person. In this paper it was also stated that when distancing from other people in times of sickness one can still train using robots, allowing less time to be wasted under such circumstances[6].

An example of a physical real world simulation device would be a horseback riding simulation, which mimics the motion done by a horse while in motion[7]. This simulation works due to muscle memory, or the way bodies can automatically remember certain motions with a certain amount of repetition. This repetition can be mimicked to teach one how to ride a horse by teaching their body or can take the place of a horse to give the person a quality workout. The device was developed for exercise and therapeutic reasons.

A study on Chinese sports basketball teaching combined a multimedia interactive model and virtual reality technology to not only give feedback to someone playing, but analyze the movement using multimedia 3D technology[8]. The feedback given seems to be indirect and is not given to the athlete through a sense of touch. The machine deciphers the movement of a training athlete and gives feedback after information has been fed to it. It seems less efficient to use an indirect tactic, but it can identify unnoticed factors and thus improve the skill of an athlete.

The previous study was one using both visual feedback and sense of touch. One way of learning might be more beneficial than another when compared. A study was done on perceptual motion learning with haptic devices in which both visual cues and haptic cues were studied[9]. The researcher's goal was to uncover whether haptic learning would benefit the subject more than visual cues in terms of repeating a taught action. Visual cues can be considered a stand-in for observing other peoples skill set and motions. This study showed that haptic cues aided in the timing of the motion significantly more than visual cues, assuming that visual cues are stand-in for visual learning. Since precise and well-timed strokes are required for effectiveness in sport, the use of haptics seems beneficial. It states in the paper that a mix of both visual and haptic designs make a skill ingrained into the subject with more timing and motion coherence.

Another haptic device was made to signal the runner a desired direction and power of their running using vibrations[10]. No gestures or voice was needed to communicate the idea of running to the athletes. This could be a benefit in large fields and for hearing or visually impaired people. The research papers writers still plan on making it so the directions given to the runner are not fogged up by other engagements the athlete is in. This includes distracting obstacles on the field.

Similar to this haptic device, another device was developed for a more targeted purpose. Haptic technology was implemented in a sport training scenario in soccer sprinting with vibrotactile feedback[11]. This shows that haptic technology can be modified to fit certain purposes and needs accurately. With little room for unnecessary error, and a very straightforward right answer is presented to someone while sprinting, their muscles must soak up this new information very smoothly. In simple words, the feedback is direct, simple, and easy to get a grasp of. A device is placed on the bottom of the feet and on the calves and sends information through vibrotactile feedback, with little to no delay. With no other factors such as miscommunication between the coach and the athlete, the athlete understands what is required immediately based on haptic feedback, making this an efficient way of processing skill sets. Muscle memory is a major factor in learning replayed actions using a simulation[1].

Along with gaining a boost in timing of stroke, athletes can also benefit from the more efficient time management when it comes to learning a new motion. As stated in Lieberman et. al, we may eventually be able to learn these motions faster and more accurately without even realizing that we are doing so[12]. Using this technology can reduce the time athletes

spend learning new skills and help them hone down on issues with their movement more productively. In the study he researched they developed a wearable vibrotactile feedback suit and with the suit, the learning rate of the subject increases by 23%, and there are less real time errors with a change of 27%. An increasing amount of papers are showing up with positive response to haptic feedback in terms of biomechanical fitness. This is one of the reasons much of the sports training literature relies on haptics as a path to excelling.

Human vs. Robotic Training: Cognitive Impact

Despite the popularity of the haptic approach, there are factors to consider which it performs less well on. People invested in effective sports training need to consider how much one has the ability to succeed by learning basic actions. The effects of not training with other humans, having social interactions, or being taught by a coach can affect an athlete's mind negatively[2]. If sports training approaches with haptics are highly optimized and provide precise feedback, some individuals might not have reason to work with others in a team setting. However, the social aspect of sports should not be overlooked. A lot of sports, such as soccer, basketball, and water polo are sports in which communication and team companionship are essential in order to win. Even for individual sports, it's important to use the social aspect of sports to an advantage while learning a sport. Sportsmanship is relevant in both team and individual sports. Social interaction allows athletes to better understand how to conduct themselves in a competition.

Many of the athletes today have opportunities to start from an earlier age, and along with that younger athletes are preferred in sports such as American football. For this reason it is sensible to use evidence gathered about the mentality of children and what benefits are reaped in a social athletic setting for them. The social setting of physical education classes provides an opportunity for student athletes to learn about themselves. This is supported by the World Health Organization's statement, Psychosocial competence is defined as a person's ability to deal effectively with the demands and challenges of everyday life[2]. Many life lessons such as self perseverance and how to carry oneself in group situations can be taught by simply existing around others. Students in the PE classes had a higher sense of personal and social responsibility and higher respect for others[2]. One possible interpretation of this is that the effects were all due to how classes went, or in other words how one's peers along with the coaches. Without being surrounded with humans while training and exercising the children would not have been given the opportunity to gain the social skills of respect and responsibility.

A research study by Shiraishi mentioned in the section "Human vs. Robotic Training: Biomechanical Impact", they highlight that haptic devices are effective when the athlete or exerciser is focused on the output the device displays[10]. However, many sports have more than one task to be achieved. A study by Mehterem and another study done by Se-Hoon Jeong both show negative effects by overdoing multitasking[13,14]. Adding a haptic device that gives even more information to the athlete may be overwhelming and cause stress.

As we look deeper into the social aspect of sports, we find evidence of the impact of social anxiety on the choice of training style. A study done on Japanese participants revolved around the topic of social anxiety[3]. They were asked whether they would prefer training in sports or exercises with robots rather than a human. It was shown that higher amounts of people with social anxiety choose to train with a robot indicating a lack of human interaction. This outcome seems unsurprising- it would be helpful for people with high anxiety to be given the option of training with a haptic device instead or being pushed into social situations. However, there might be repercussions to the avoidance of the social aspects of these kinds of tasks. People who have high social anxiety like to train with robots. We hypothesize that the lack of social interactions leads to a depletion of self esteem, making it harder for individuals to communicate in the future. The loss of motivation and will to do certain tasks can be caused by lack of social interactions.

Conclusion

The work of several sources demonstrates that robots helping athletes can have a positive impact on an athlete's body and training schedule. This seems to be a very intuitive approach to building a skill quicker while focusing more on the body's muscle memory. Although there is a hefty positive effect for the athletes training in the short term, the psychological downsides shown might take a toll in the process of training solitarily in the long run. Children starting sports young with less social interactions can lead to higher social anxiety and deprive them from valuable experiences and development as an individual[2]. Some training alongside haptic devices and robots can help athletes excel in the future, but an overemphasis could prevent them from developing the psychological skills of a full athlete. Based on the evidence, a mix of both training types should be implemented into one's training. The evidence supports the ideas of Feygin et al. For future works in this field we would suggest delving into the negative side effects of haptics and finding a way in which these side effects can be avoided. Another field of work that can be done based on our research is a look into a hybrid model of training in which both human-based training and haptic devices can be implemented. More work in relation to the direct comparison of these two types of training would be ideal. In the future, we hope that haptic training will be used in conjunction with current training methods to train skills beyond simple perceptual

motor skills[9].

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