The Importance of Performance Feedback in Virtual Reality (VR) Training: A Table Tennis Coach Perspective

Kissinger Sunday
Faculty of Computer Science/VR Lab
Dalhousie University
Halifax, Nova Scotia, Canada
kissinger.sunday@dal.ca

Soraya S. Anvari
HCI4Good
Dalhousie University
Halifax, Nova Scotia, Canada
soraya.anvari@dal.ca

Yiwei Li
Computer Science
University of Western Ontario
Toronto, Ontario, Canada
yli922@uwo.ca

Junwei Sun
School of Interactive Arts and Technology
Simon Fraser University
Vancouver, British Columbia, Canada
junwei.s@yahoo.com

Rina R. Wehbe
HCI4Good, Faculty of Computer Science
Dalhousie University
Halifax, Nova Scotia, Canada
Rina.wehbe@dal.ca

Heather Neyedli
School Health & Human Performance
Dalhousie University
Halifax, Nova Scotia, Canada
hneyedli@dal.ca

Anil Ufuk Batmaz
Department of Computer Science & Software Engineering
Concordia University
Montreal, Quebec, Canada
ufuk.batmaz@concordia.ca

Mayra Donaji Barrera Machuca
Faculty of Computer Science
Dalhousie University
Halifax, Nova Scotia, Canada
mbarrera@dal.ca

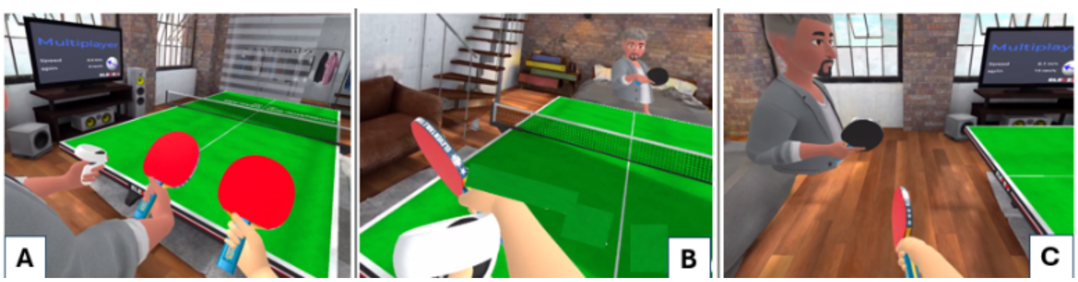

Figure 1: Visualization of the Virtual Reality Table Tennis environment used in the study. A) The coach demonstrates the correct paddle grip technique. B) The coach provides visual and verbal feedback on executing the backhand drive. C) The coach provides hands-on guidance to refine movement patterns.

Abstract

Advances in Virtual Reality (VR) technology have redefined sports training, offering a new modality for athletes to prepare for competitions. This paper explores the coaching strategies used to train novice table tennis players in VR. Through interviews with the coach and participant feedback, we identified key strategies such as personalized feedback, table division, and a structured training regimen for skill development in VR. Challenges include limited facial awareness and the absence of virtual cheering, which impacted the coach's ability to engage fully with participants. These findings offer valuable insights into coaching strategies in VR environments, contributing to developing more effective and engaging VR training systems.

CHI EA '25, Yokohama, Japan

ACM ISBN 979-8-4007-1395-8/25/04
https://doi.org/10.1145/3706599.3720204

CCS Concepts

• **Human-centered computing → Virtual reality**; *Empirical studies in HCI*.

Keywords

Virtual Reality (VR), Table Tennis, Training, Sports, Feedback

ACM Reference Format:

Kissinger Sunday, Soraya S. Anvari, Yiwei Li, Junwei Sun, Rina R. Wehbe, Heather Neyedli, Anil Ufuk Batmaz, and Mayra Donaji Barrera Machuca. 2025. The Importance of Performance Feedback in Virtual Reality (VR) Training: A Table Tennis Coach Perspective. In *Extended Abstracts of the CHI Conference on Human Factors in Computing Systems (CHI EA '25), April*

26–May 01, 2025, Yokohama, Japan. ACM, New York, NY, USA, 7 pages. https://doi.org/10.1145/3706599.3720204

1 Introduction

Virtual Reality (VR) has continued to gain widespread adoption thanks to the technological advancements that make it possible to offer immersive visuals and lifelike physics. The low cost of head-mounted displays (HMDs) has also made it possible to use VR in new application areas like sports. One of the most popular VR sports games is VR table tennis due to its minimal space requirement and the ability to closely mirror the real-environment (RE) playing experience [13]. Commercial VR table tennis games like Eleven Table Tennis (ETT) [1] offer an engaged player community with tournaments and cash prices [13], providing opportunities for players to compete at various skill levels.

In this paper, we explore the role of an RE coach (i.e., in the same physical space as the player) and the strategies employed to prevent participants from learning incorrect techniques in VR, as highlighted in previous studies[6]. An RE coach can help mitigate VR limitations such as depth perception challenges, lack of haptic feedback, and the weightlessness of the virtual ball for players [13, 29]. By adapting training, reacting to mistakes, and providing personalized feedback through visual, verbal, and hands-on guidance, the coach adds a layer of precision that current automated systems cannot replicate [9, 19, 32]. The physical presence of a coach further allows them to assess a player's emotional state, offering tailored motivational feedback, building trust, and maintaining engagement [1, 12, 20]. Unlike remote or existing automated systems with artificial intelligence (AI) capabilities, a co-located RE coach avoids delays and can physically correct a player's wrist position or paddle angle [13, 29, 38].

While past work has already identified that training in VR should be adaptive for each player [10], the present paper provides the first empirical evidence of how a coach enhances VR table tennis training using different strategies based on the player's needs. We aim to inform future VR training systems that use robotic/AI-based coaching systems to go beyond using repetition to train players [39]. Thus, our first research question (**RQ1**) is *what strategies does a coach use to train novice table tennis participants in VR?*. We also aim to understand better the impact of VR technology on training players to design more useful VR training systems. Thus, our second research question (**RQ2**) is *what technological challenges do novice table tennis participants and a coach encounter during VR training?* We interviewed the coach to explore the strategies and technological challenges of training novice table tennis in VR to answer RQ1 and RQ2. Additionally, we administered an open-ended questionnaire to the participants to gather insights on their experience during VR training to help answer RQ2. Our findings provide valuable insights for sports researchers by identifying the challenges and advantages of incorporating a coach in VR training systems.

[1]https://elevenvr.com/en/

2 Related Work

2.1 Feedback in Sports Training

In sports, *'Feedback'* refers to the information, assessment, or correction a coach provides based on performance [11]. Effective feedback is when a coach tailors their feedback to the individual and the learning context [19, 23], playing a critical role in enhancing skill acquisition, motivation, and overall athletic success [1, 3]. The timing, frequency, and delivery method are key to its effectiveness [5]. In sports, success depends on the player executing skilled movements, and players develop these skills through effective feedback from a coach [16, 19]. There are multiple ways of feedback, including intrinsic, extrinsic, positive, and corrective feedback [37]. Other work classifies feedback as verbal (spoken corrections), visual (observing coach's gestures), and kinesthetic (hands-on guidance) [9, 33]. Our research explores coaching strategies in VR table tennis, offering insights that could inform and inspire future studies.

2.2 Coaching for Racket Sports

Several studies have investigated the use of technologies in coaching for racket sports [8, 15, 16, 21, 22]. For example, in Squash, Rose et al. [22] utilized an autonomous humanoid robotic coach to train individual players, which was perceived as more socially competent and enjoyable than the baseline condition. Yet, the coaching policy did not lead to significant performance improvements. In table tennis, Fuchino et al. [8] developed a robotic appendage system capable of guiding the user's hand movement in VR. The result of their evaluation demonstrates a potential in skill acquisition, albeit at the expense of the immersive fun typically associated with VR [8]. A similar study evaluated AI coaching in VR with the Eleven Table Tennis application [15] and demonstrated skill improvement, however, the authors were unable to determine the factors driving performance improvement and recommended further research involving an RE coach. This recommendation was supported by Oagaz et al. [16], who used robotic coaching to support skill acquisition [16]. While significant research exists on coaching for racket sports, understanding how feedback is administered in VR with a real-time coach is crucial for enhancing motivation [19], as well as mitigating frustration, particularly for underperforming players [29]. This approach also addresses the repetitive and monotonous nature of AI and robotic systems. The findings from the literature review highlight a notable gap in strategies used to train players, especially in the local context, emphasizing the need for solutions tailored to these challenges.

3 User Study

3.1 Participants

Through poster distribution and email advertising, we recruited 19 participants from Dalhousie University and the surrounding community. Participants were required to have minimal experience with VR table tennis and limited exposure to RE table tennis (less than once a month) and pass a skill test to show they were true novices. We selected novice participants for this study as they were in the awareness stage of Gallahue's model of motor skill development [24], where they were likely to benefit most from the coaching strategies explored within the study's timeframe [15].

Only 12 right-handed participants (4 female, 8 male) met the eligibility criteria and completed the training sessions. The participants' ages ranged from 18 to 34 years ($M = 22.7, SD = 3.4$), 58.3% reported having prior experience with sports, while 41.7% had never played any sports. For table tennis, no player had played table tennis in VR before, while 41.7% had previous experience playing in RE as this was independent of general sports. Still, their frequency of play was less than once a month, aligning with the definition of novice participants [25]. Additionally, all participants had prior experience with VR sports and were considered physically fit based on a self-reported physical fitness survey administered during the demographic assessment. See Appendix for the survey.

We recruited a Coach from a Halifax, Canada sports club to serve as an expert participant and train the novice players. The Coach has over 30 years of experience in professional table tennis coaching, primarily training novice and intermediate-level players. They are right-handed, which aligns with the right-handed participants in our study. The Coach specializes in skill-based and technique-oriented training, emphasizing foundational skills like serves, footwork, and spins. The Coach has actively engaged with VR technology for over a year, not only for training players but also for personal exploration of VR's potential in sports applications.

3.2 Equipment & Training Environment

Participants used a Meta Quest 2 VR HMD [14] with the AMVR Table Tennis Paddle Grip Handle for the Oculus Quest 2 controllers [2]. The training environment was the Eleven Table Tennis game v2.314 .12 [31] (see Figure 1). We chose this game due to its widespread popularity and substantial user community of over 298,000 players [18]. See Figure 2B for a picture of the room used to train participants in VR. During training, we enabled the avatar to help participants visually interpret the Coach's instructions and feedback (see Figure 1B). The presence of an avatar aids in the participants' understanding of spatial positioning, postures, and movements, facilitating the learning process [17, 35].

3.3 Procedure

3.3.1 Initial Skill Evaluation. Upon arriving at the lab, participants were given a brief overview of the study's objectives and procedures. They were also instructed to refrain from engaging in any table tennis activities outside the scheduled training sessions to prevent external factors from influencing the study results [34]. Participants were informed that the study would take place over six consecutive days, and missing any sessions would result in disqualification. They then reviewed and signed a consent form to confirm their participation. After the briefing, participants completed a pre-study questionnaire that gathered demographic information and self-reported physical fitness levels (see Appendix). Subsequently, Researcher A evaluated their RE table tennis skills on a physical table tennis table (see Figure 2) to confirm eligibility, ensuring only novice players were included in the study.

3.3.2 Training stage. The Coach trained the participants for 60 minutes per session throughout five sessions, resulting in a total of 300 minutes (60 minutes × 5 sessions) of training using a structured protocol by Sunday et al. [29], tailored for novice accessibility and skill progression. Each session included three participants to reduce the number of participants in the room (Figure 2). Researcher A supervised the sessions to ensure adherence to the protocol and assisted with VR setup and session recordings.

On the first training day, the Coach initiated the ETT game and started with a warm-up session to familiarize the participants with the VR environment. The participants then learned the game's rules, including basic serving (short and long) and return techniques. Figure 3 illustrates the complete protocol. During training sessions on days 1 to 4, the Coach and the participants wore their headsets. The Coach guided the participants by implementing various strategies and offering visual, verbal, and kinesthetic feedback to refine their skills and technique in VR. The participants were able to see the avatar representation of the coach in VR, observe the Coach's movements, and experience the various strategies the Coach applied. In some cases, the Coach removed their headset to provide RE adjustments, such as correcting participants' stance or wrist positioning, particularly for those who struggled to apply the feedback in the virtual environment. On the final day, the Coach's VR headset was removed so they could observe the participants as they played against each other while still wearing their headsets. As they played, the Coach watched from a distance, identifying struggling players through real-time voice interactions and video replays, which prompted the coach to wear the headset again and provide personalized feedback.

3.3.3 Qualitative Data Collection. After participants completed all training sessions, we administered a written open-ended questionnaire to assess their overall experience with the training. We also conducted a semi-structured, in-person interview with the Coach to ask them about their perspectives on training practices, dynamics, and feedback mechanisms, including feedback types, timing, and formats. The aim was to understand coaching strategies applicable to VR training environments, including the technological challenges encountered. The interview lasted approximately 80 minutes.

3.4 Data Analysis

We analyzed the Coach interview data and the participants' open-ended responses using a thematic analysis following Braun and Clarke's method [4]. Two authors (Researcher A and Researcher B) collaboratively conducted the analysis. Researcher A has over 10 years of playing experience. Researcher B is a co-author of the paper who has 2 years of experience in qualitative data thematic analysis and one year of playing experience. The thematic analysis process took approximately ten hours over two weeks, during which both researchers held regular meetings to discuss the data and collaboratively reviewed the resulting codes and themes to ensure the study's reliability.

First, Researcher A and Researcher B transcribed the audio recordings of the Coach interview for coding using Microsoft Teams. They then reviewed the transcribed text to identify and correct any potential errors. The interview consisted of three sections: perspectives on VR training, training practices and dynamics, and feedback mechanisms. Both researchers independently

[2]https://www.amvrshop.com/products/amvr-table-tennis-adaptor-for-quest-2-controllers?

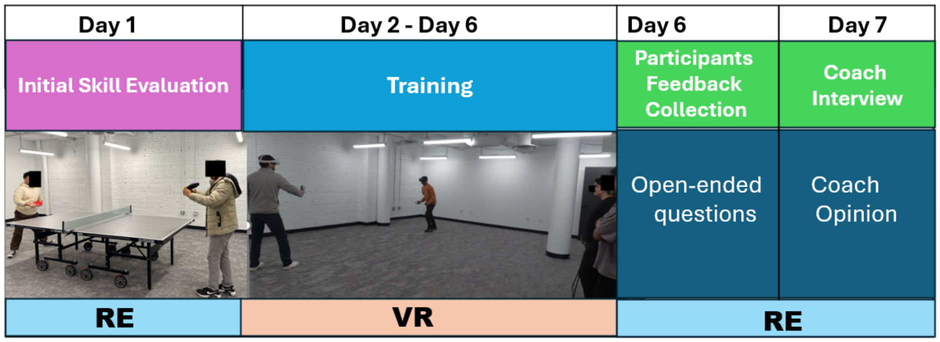

Figure 2: The user study procedure has three stages: A) Initial skill evaluation [Day 1], where we assessed each RE table tennis participant to ensure they were novices. B) Training [Days 2-6], where we trained groups of three participants in VR for five consecutive days. C) Participants Feedback Collection [Day 6], where we collected open-ended questions from the participants about their experience training in VR. D) Coach Interview [Day 7], where we collected the coach opinion about his training experience.

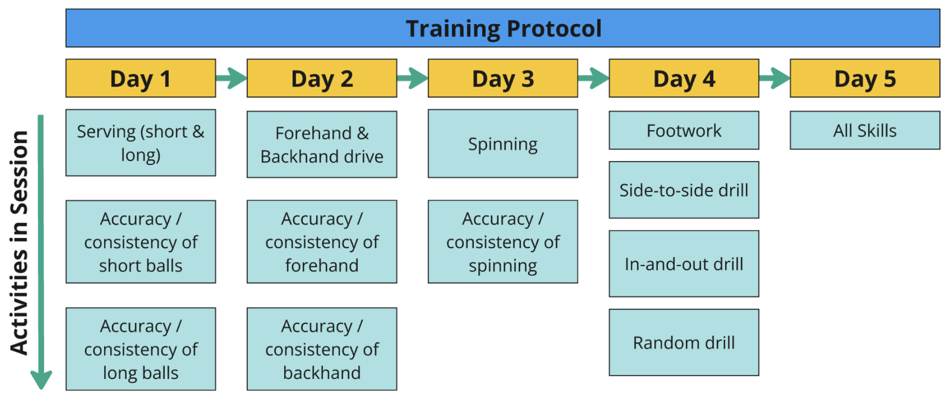

Figure 3: Training Protocol. The training was over five days, and each day had between one and three exercises focused on a specific skill. For activities about accuracy, the focus was for participants to consistently place the ball in a specific location using that skill. For activities about consistency, the focus was on the participants being able to do that particular skill consistently. The Coach trained all 16 skills using the protocol.

reviewed the data multiple times to deeply understand the content before initiating the coding process. For the sections on VR training perspective and training practices, the researchers used an inductive, bottom-up approach where themes emerged through repeated data readings. This method also followed the Fereday methodology of generating themes from raw data [7]. In contrast, the feedback mechanisms sections were coded using a deductive approach with pre-existing categories such as "verbal," "visual," "kinesthetic") based on previous empirical research [9, 19, 26, 33]. The next phase of analysis focused on open-ended responses from participants. Both researchers read and made themselves familiar with the data. Then, using the themes derived from the Coach interview as a framework, the researchers coded the participants' feedback through an inductive, bottom-up approach. Subsequently, the codes from the player data were mapped to the themes established during the coach interview analysis. The analysis revealed a coherence between the themes derived from the Coach interview and the participants' feedback.

4 Results

4.1 Theme 1: Structured Skill Development and Optimizing Strategies

The Coach attributed the success of participants' skill acquisition partly to the structured training protocol, which starts with the basics (e.g., serving) and progresses to more complex skills such as spinning and footwork. As the Coach noted, *"Following this progression [protocol] greatly contributed to enhancing participants' performance (C)."* While it might be harder for novice participants to grasp the skills initially as the result of the uncertain nature of VR environment with unfamiliar mechanics, those who persist show improvement and progress as the Coach explained: *"The key takeaway is that VR, while different from physical play, can still be a powerful tool for advancing skills and understanding in table tennis*

(C)." When talking about their experience, participants credited the effective training strategies employed during the sessions. One participant shared *"I got to learn so many skills like measuring distance of the ball, where to hit the ball, strategies to making lose the opponent (P10)"*. Participants consistently noted enhanced skills, including improved accuracy, positioning, and technique:*"it improved the accuracy of me placing the ball on the table (P16)."*

4.2 Theme 2: Enhancing Player Engagement and Confidence Through Immersive VR Experiences

The Coach said about the VR environment *"participants are often immersed in their practice without external distractions, creating a controlled environment where they feel more confident in their progress (C)."* To keep participants motivated, the Coach employed foundational techniques and a step-by-step progression strategy. For instance, the virtual table was divided into sections to short serve, long serve, left serve, and right serve—practiced individually before progressing to the full table: *"I start with foundational elements to avoid overwhelming them, dividing the table into sections and gradually expanding to the full table (C)."* This structured approach built participants' confidence, e.g., as they grew accustomed to VR controls, visuals, and feedback, their confidence increased, transforming initial hesitation into enthusiasm: *"Over time, participants become so engrossed in the game that they may not want to stop (C)."*

Participants described VR training as engaging and comprehensive. Many highlighted their growing confidence and enjoyment, such as P14: *"The study was good; now I'm able to play table tennis very well."* For some participants, the nature of the training was engaging *"Being totally involved in the game! (P17)."* Interestingly, one participant found the training with the Coach so engaging that they momentarily forgot the board was not real, highlighting immersion as a challenge:*"I was sometimes unable to remember that the board was not real, so I found that challenging at times (P1)."*

Technological issues occasionally disrupted gameplay, such as lag, limited haptic feedback, glitches, and depth perception challenges: *"Sometimes I misjudged the distance between the paddle and the ball (P5)."* Participants also noted the inability to feel a sense of touch: *"'In real life, touch is important, which limits VR's realism (P18)."* Moreover, the Coach 's feedback was constrained by VR's limitations, such as the inability to convey facial expressions or demonstrate techniques hands-on: *"My facial expressions, such as smiles, are not visible (C)"*. To address these issues, the Coach suggested displaying written instructions or bullet points on-screen to aid player understanding.

4.3 Theme 3: Foundational Techniques and Motivational Strategies in VR

Participants learned basic serving (short and long) skills on the first day of the training protocol. During the interview, the Coach justified this step of the training protocol by calling serving a fundamental and required skill to play table tennis: *"The starting point, which is the service, is key. This is like the driving wheel of the game, so if you're unable to serve for at least, then there's no way to proceed (C)."* By focusing on serving first, participants could progress to other skills like the forehand, backhand, and spinning easier, but only if they master these skills.

Another training element the coach emphasized was motivation: *"I share personal stories to provide encouragement and relate to their experiences. This strategy helps them feel more connected and supported, especially when they are not professional participants themselves (C)."* The Coach also mentioned encouraging participants to help them maintain a positive mindset and prevent frustration during gameplay: *"When participants face challenges and become frustrated because they can't perform as well as expected, I address their emotions by encouraging them to stay positive and reminding them that improvement comes with practice (C)."*

Furthermore, the Coach highlighted the potential benefits of incorporating a virtual spectator, e.g., *"adding virtual audience elements could be advantageous. Implementing virtual cheering or reactions could simulate the emotional feedback that participants receive from an audience, enhancing their motivation and performance (C).".* The Coach further noted that such features could also help players' confidence, *"as they experience the immediate support and celebration from others, enhancing their overall training experience (C)."* Conversely, the Coach highlighted a potential disadvantage of having a spectator presence:*"they can also create pressure, leading to self-consciousness and potential stress. These social dynamics can complicate the player's ability to stay focused and track their performance accurately (C).".*

4.4 Theme 4: Holistic Feedback and Experience Based Training

The Coach used a combination of visual, verbal, and hands-on feedback as part of the strategies in VR training. Visual feedback played a central role, with demonstrations helping clarify corrections and overcome communication barriers (*"I use visual feedback to help participants understand and apply the necessary corrections effectively (C)."*). Verbal feedback was provided continuously during gameplay to correct positioning and reinforce key points. For hands-on feedback, the Coach offers demonstrations, which may sometimes require stepping out of the VR environment: *"I also address errors by demonstrating the correct techniques, which may involve physically adjusting their stance or grip (C).".*

The Coach employed value, neutral, and corrective feedback tailored to participant needs. Value feedback highlighted progress and encouraged improvement in specific skills *"If we're focusing on serving, I offer feedback on that skill and continue to practice it until I see improvement. Only then do we move on to another skill (C).".* Neutral feedback was delivered consistently during gameplay to maintain focus and momentum *"Providing feedback throughout the game, rather than waiting until the end, is crucial for effective training (C).".* For difficult skills, the coach dedicated extra time to provide corrective feedback, e.g., *"Spinning with the backhand can be particularly challenging, so I provide targeted feedback tailored to each participant (C)."*).

The coach provided immediate feedback during gameplay, with additional observations shared afterward to guide future practice (*"I might say, 'You performed well today. Tomorrow, we should focus on this area (C)."*). The coach also delivered feedback at specific times (*"I focus on key moments where feedback is most needed, allowing* *participants to enjoy the game without constant interruptions (C)."*). The Coach also fostered a two-way communication channel by observing participants and asking targeted questions to identify individual challenges. This approach ensured feedback was personalized and aligned with participants' self-assessments (*"By focusing on areas they identify for improvement, I can motivate them to work on those aspects more intensively (C)."*).

5 Discussion

5.1 Coach Strategies to Train Novices in VR (RQ1)

The coach found that RE training strategies, such as a structured regimen and personalized feedback, were equally effective on VR platforms. The training protocol included warm-ups and progressive skill development, beginning with basic skills like serving and advancing to spinning and footwork, which prevented participants from feeling overwhelmed by VR-specific challenges like depth perception and ball weightlessness[13, 29]. The coach addressed technological issues in real-time, such as monitoring participants' movements to mitigate the lack of haptic feedback; the main feedback concerns identified in previous works[29], and adhering to real-world practices like calling for re-serves when necessary.

Feedback was central to the coach's strategy, enhancing player performance with visual, verbal, and kinesthetic feedback [19]. Visual demonstrations of correct and incorrect techniques helped participants refine strokes, posture, and paddle angles. Verbal feedback identified errors, provided clear instructions, and included positive reinforcement to boost confidence. Kinesthetic feedback involved hands-on adjustments, such as correcting stances or paddle grips, sometimes requiring the removal of the VR headset for physical guidance—an approach not possible with remote coaching[30]. Although we acknowledge that presence and immersion, a key attribute of VR [28], may be compromised. This trade-off ensures that players receive comprehensive and effective feedback that would otherwise be difficult to achieve in VR thereby broadening our understanding of the limits of hands-on guidance in VR table tennis. The coach also used a two-way feedback system, incorporating participant input to improve the training experience, in contrast to the feedback modalities applied in other training experiments [2, 19, 33, 36].

Participants valued the physical presence of the coach, who quickly addressed technological challenges and offered personalized feedback. The coach's ability to provide real-time solutions and adapt to individual needs underscores the potential for developing adaptive AI systems that emulate these qualities in future VR-based sports training environments

5.2 Technological Challenges of Training in VR (RQ2)

Participants and the coach expressed concerns about the game physics in VR, particularly the impression that the ball's behavior was inconsistent with expectations and the occasional lag spikes during gameplay. Although latency affects VR training systems [13, 29], neither participants nor the coach identified it as a significant issue, possibly due to the immediate guidance provided by the coach. VR hardware limitations, e.g., inadequate haptic feedback, the ability to walk through the virtual table, and the weightlessness of the ball, were sources of frustration for both participants and the coach, which previous works also identified [13, 27, 29]. However, in our study, the coach mitigated these issues by enforcing rules and voiding serves when participants walked through the table. A notable concern was the inability to see the coach's facial expressions, which participants found to be a key disadvantage compared to RE gameplay. Despite these limitations, the coach's presence enhanced the participant's motivation by providing immediate feedback and guidance.

6 Conclusion, Limitation & Future Work

This paper presents a longitudinal study examining various coaching strategies for Virtual Reality (VR) table tennis training. We aimed to explore coaching strategies used in VR table tennis with novice players. From an interview with the coach, we identified different feedback types supported by VR, including visual, verbal, and kinesthetic feedback. The coach also adapted and personalized each feedback method to meet each player's needs. We also identified several limitations and challenges in VR table tennis from both the coach's and participants' perspectives.

During the training sessions, several participants were present in the same room. While this may not be too critical in this context, it may introduce bias as observing other participants may influence impressions beyond what would be experienced using the system independently. Although the coach trained participants and provided varied feedback modalities to enhance skill acquisition within and outside the VR environment, it is important to evaluate whether the skills transfer to RE performance. Hence, future research should focus on exploring the impact of these strategies on skill performance. We believe the insight derived from this study will enhance future training systems by informing the design of adaptive feedback mechanisms to enhance overall player engagement and skill acquisition.

References

[1] Anthony J. Amorose and Peter J.K. Smith. 2003. Feedback as a Source of Physical Competence Information: Effects of Age, Experience and Type of Feedback. *Journal of Sport and Exercise Psychology* 25, 3 (2003), 341 – 359. https://doi.org/10.1123/jsep.25.3.341

[2] Fraser Anderson, Tovi Grossman, Justin Matejka, and George Fitzmaurice. 2013. YouMove: enhancing movement training with an augmented reality mirror. In *Proceedings of the 26th Annual ACM Symposium on User Interface Software and Technology* (St. Andrews, Scotland, United Kingdom) *(UIST '13)*. Association for Computing Machinery, New York, NY, USA, 311–320. https://doi.org/10.1145/2501988.2502045

[3] S Jill Black and Maureen R Weiss. 1992. The relationship among perceived coaching behaviors, perceptions of ability, and motivation in competitive age-group swimmers. *Journal of sport and exercise psychology* 14, 3 (1992), 309–325. https://doi.org/10.1123/jsep.14.3.309

[4] Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative research in psychology* 3, 2 (2006), 77–101. https://doi.org/10.1191/1478088706qp063oa

[5] Florence D. DiGennaro Reed Denys Brand, Matthew D. Novak and Samara A. Tortolero. 2020. Examining the Effects of Feedback Accuracy and Timing on Skill Acquisition. *Journal of Organizational Behavior Management* 40, 1-2 (2020), 3–18. https://doi.org/10.1080/01608061.2020.1715319 arXiv:https://doi.org/10.1080/01608061.2020.1715319

[6] Forouzan Farzinnejad, Javad Rasti, Navid Khezrian, and Jens Grubert. 2023. The Effect of an Exergame on the Shadow Play Skill Based on Muscle Memory for Young Female Participants: The Case of Forehand Drive in Table Tennis. In *2023 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*. IEEE, IEEE, Sydney, Australia, 1152–1160. https://doi.org/10.48550/arXiv.2308.14404

[7] Jennifer Fereday and Eimear Muir-Cochrane. 2006. Demonstrating rigor using thematic analysis: A hybrid approach of inductive and deductive coding and theme development. *International journal of qualitative methods* 5, 1 (2006), 80–92. https://doi.org/10.1177/160940690600500

[8] Kodai Fuchino, Mohammed Al-Sada, Tamon Miyake, and Tatsuo Nakajima. 2022. T2snaker: a robotic coach for table tennis. In *Proceedings of the Augmented Humans International Conference 2022*. Association for Computing Machinery, New York, NY, USA, 305–308.

[9] Elizabeth Gibbons. 2004. Feedback in the dance studio. *Journal of Physical Education, Recreation & Dance* 75, 7 (2004), 38–43. https://doi.org/10.1080/07303084.2004.10607273

[10] Rob Gray. 2017. Transfer of training from virtual to real baseball batting. *Frontiers in psychology* 8 (2017), 2183. https://doi.org/10.3389/fpsyg.2017.02183

[11] John Hattie and Helen Timperley. 2007. The Power of Feedback. *Review of Educational Research* 77, 1 (2007), 81–112. https://doi.org/10.3102/003465430298487

[12] Thelma S Horn. 2008. *Advances in sport psychology.* Human kinetics, Champaign.

[13] Eren Karatas, Kissinger Sunday, Sude Erva Apak, Yiwei Li, Junwei Sun, Anil Ufuk Batmaz, and Mayra Donaji Barrera Machuca. 2023. I consider VR Table Tennis to be my secret weapon!: An Analysis of the VR Table Tennis Players' Experiences Outside the Lab. In *Proceedings of the 2023 ACM Symposium on Spatial User Interaction* (Sydney, NSW, Australia) *(SUI '23)*. Association for Computing Machinery, New York, NY, USA, Article 29, 12 pages. https://doi.org/10.1145/3607822.3614539

[14] Meta. 2024. https://www.meta.com/ca/quest/products/quest-2/ Accessed:2024-03-09.

[15] Stefan Carlo Michalski, Ancret Szpak, Dimitrios Saredakis, Tyler James Ross, Mark Billinghurst, and Tobias Loetscher. 2019. Getting your game on: Using virtual reality to improve real table tennis skills. *PloS one* 14, 9 (2019), e0222351. https://doi.org/10.1371/journal.pone.0222351

[16] Hawkar Oagaz, Breawn Schoun, and Min-Hyung Choi. 2021. Performance improvement and skill transfer in table tennis through training in virtual reality. *IEEE Transactions on Visualization and Computer Graphics* 28, 12 (2021), 4332–4343. https://doi.org/10.1109/TVCG.2021.3086403

[17] Dhaval Parmar, Lorraine Lin, Nikeetha DSouza, Sophie Jörg, Alison E Leonard, Shaundra B Daily, and Sabarish V Babu. 2022. How immersion and self-avatars in VR affect learning programming and computational thinking in middle school education. *IEEE Transactions on Visualization and Computer Graphics* 29, 8 (2022), 3698–3713. https://doi.org/10.1109/TVCG.2022.3169426

[18] PlayTracker. 2023. Eleven: Table Tennis VR stats by Playtracker Insight. https://playtracker.net/insight/game/8608

[19] Leonor Portugal da Fonseca, Francisco Nunes, and Paula Alexandra Silva. 2024. Understanding Feedback in Rhythmic Gymnastics Training: An Ethnographic-Informed Study of a Competition Class. In *Proceedings of the CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI '24)*. Association for Computing Machinery, New York, NY, USA, Article 892, 16 pages. https://doi.org/10.1145/3613904.3642434

[20] Maria Rato Barrio, Clemens Ley, Anne Schomöller, and Detlef Dumon. 2021. Mental well-being or ill-being through coaching in adult grassroots sport: A systematic mapping review. *International journal of environmental research and public health* 18, 12 (2021), 6543. https://doi.org/10.3390/ijerph18126543

[21] Martin Keith Ross et al. 2024. *An adaptive robot for sports and rehabilitation coaching.* Ph. D. Dissertation. Heriot-Watt University.

[22] Martin K Ross, Frank Broz, and Lynne Baillie. 2023. Individual Squash Training is More Effective and Social with a Humanoid Robotic Coach. In *2023 32nd IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*. IEEE, Busan, Korea, 621–626. https://doi.org/10.1109/RO-MAN57019.2023.10309567

[23] D. Royce Sadler. 1989. Formative Assessment and the Design of Instructional Systems. *Instructional Science* 18, 2 (June 1989), 119–144. https://doi.org/10.1007/BF00117714

[24] Sayed Kavos Salehi, Farshid Tahmasebi, and Fateme Sadat Talebrokni. 2021. A different look at featured motor learning models: comparison exam of Gallahue's, Fitts and Posner's and Ann Gentile's motor learning models. *Movement & Sport Sciences* 112, 2 (2021), 53–63. https://doi.org/10.1051/sm/2021012

[25] Sabine Schaefer and David Scornaienchi. 2020. Table tennis experts outperform novices in a demanding cognitive-motor dual-task situation. *Journal of motor behavior* 52, 2 (2020), 204–213. https://doi.org/10.1080/00222895.2019.1602506

[26] Roland Sigrist, Georg Rauter, Robert Riener, and Peter Wolf. 2013. Augmented visual, auditory, haptic, and multimodal feedback in motor learning: a review. *Psychonomic bulletin & review* 20 (2013), 21–53. https://doi.org/10.3758/s13423-012-0333-8

[27] MARTIN Skopek, Josef Heidler, Jan Hnizdil, Jan Kresta, and Karolina Vysocka. 2023. The use of virtual reality in table tennis training: a comparison of selected muscle activation in upper limbs during strokes in virtual reality and normal environments. *Journal of Physical Education and Sport* 23, 7 (2023), 1736–1741. https://doi.org/10.7752/jpes.2023.07213

[28] Mel Slater and Sylvia Wilbur. 1997. A framework for immersive virtual environments (FIVE): Speculations on the role of presence in virtual environments. *Presence: Teleoperators & Virtual Environments* 6, 6 (1997), 603–616.

[29] Kissinger Sunday, Yiwei Li, Junwei Sun, Rina Wehbe, Heather Neyedli, Anil Ufuk Batmaz, and Mayra Donaji Barrera Machuca. 2024. Pinging Between Worlds: Training Table Tennis Novice Players in Real Environment for Virtual Reality Competitions. In *2024 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*. IEEE, USA, 652–661. https://doi.org/10.1109/ISMAR62088.2024.00080

[30] Sarah Taylor, Ian Renshaw, Ross Pinder, Remco Polman, and Scott Russell. 2023. Coaches' Use of Remote Coaching: Experiences From Paralympic Sport. *International Sport Coaching Journal* 10, 3 (2023), 316–327. https://doi.org/10.1123/iscj.2022-0073

[31] Eleven VR Table Tennis Tournaments. 2023. Official Tournament Announcement. https://web.archive.org/web/20210323200035/https://www.reddit.com/r/oculus/comments/mam989/official_eleven_table_tennis_tournaments_are_here/

[32] Milka Trajkova and Francesco Cafaro. 2018. Takes Tutu to ballet: designing visual and verbal feedback for augmented mirrors. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 2, 1 (2018), 1–30. https://doi.org/10.1145/3191770

[33] Milka Trajkova, Francesco Cafaro, and Lynn Dombrowski. 2019. Designing for ballet classes: Identifying and mitigating communication challenges between dancers and teachers. In *Proceedings of the 2019 on Designing Interactive Systems Conference* (San Diego, CA, USA) *(DIS '19)*. Association for Computing Machinery, New York, NY, USA, 265–277. https://doi.org/10.1145/3322276.3322312

[34] WMK Trochim. 2001. The research methods knowledge base. *Atomic Dog* 2 (2001).

[35] Sachiyo Ueda, Kazuya Nagamachi, Junya Nakamura, Maki Sugimoto, Masahiko Inami, and Michiteru Kitazaki. 2021. The effects of body direction and posture on taking the perspective of a humanoid avatar in a virtual environment. *PloS one* 16, 12 (2021), e0261063. https://doi.org/10.1371/journal.pone.0261063

[36] Eduardo Velloso, Andreas Bulling, and Hans Gellersen. 2013. MotionMA: Motion modelling and analysis by demonstration. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Paris, France) *(CHI '13)*. Association for Computing Machinery, New York, NY, USA, 1309–1318. https://doi.org/10.1145/2470654.2466171

[37] Jonathon Weakley, Kyle Wilson, Kevin Till, Harry Banyard, James Dyson, Padraic Phibbs, Dale Read, and Ben Jones. 2020. Show Me, Tell Me, Encourage Me: The Effect of Different Forms of Feedback on Resistance Training Performance. *Journal of Strength and Conditioning Research* 34, 11 (2020), 3157–3163. https://doi.org/10.1519/JSC.0000000000002887

[38] Inge Werner and Peter Federolf. 2023. Focus of Attention in Coach Instructions for Technique Training in Sports: A Scrutinized Review of Review Studies. *Journal of functional morphology and kinesiology* 8, 1 (2023), 7. https://doi.org/10.3390/jfmk8010007

[39] Erwin Wu, Mitski Piekenbrock, Takuto Nakumura, and Hideki Koike. 2021. Spinpong-virtual reality table tennis skill acquisition using visual, haptic and temporal cues. *IEEE Transactions on Visualization and Computer Graphics* 27, 5 (2021), 2566–2576. https://doi.org/10.1109/TVCG.2021.3067761