Dancing with the Avatars: Minimal Avatar Customisation Enhances Learning in a Psychomotor Task

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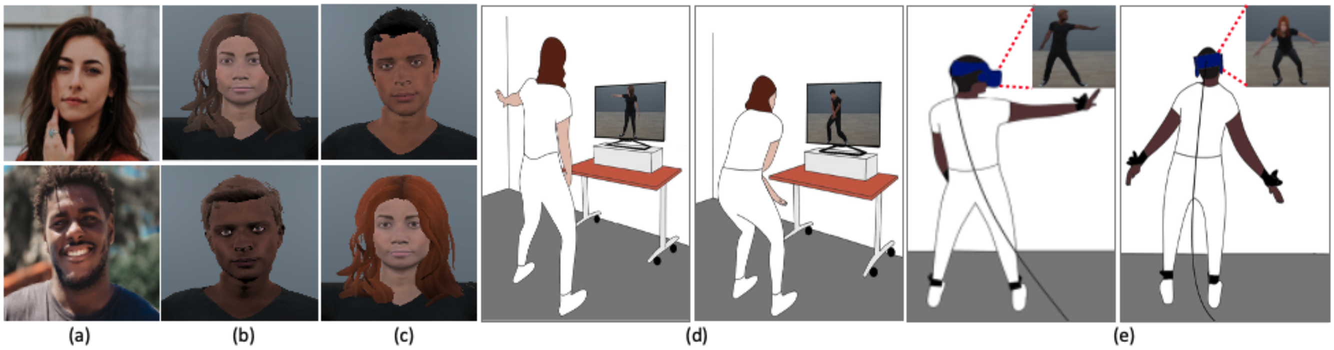

Figure 1: (a) Participants selected their gender, hair colour and skin-tone from a basic palette of options, leading to the automatic creation of a (b) matched feature avatar (MF) and (c) a dissimilar (D) avatar with different hair colour, skin-tone, and gender. Both avatars were animated to display 3-move Hip-Hop dance routines, which participants learned through observation and practice either from (d) a video on a screen or (e) in a corresponding immersive virtual environment.

ABSTRACT

Virtual environments can support psychomotor learning by allowing learners to observe instructor avatars. Instructor avatars that look like the learner hold promise in enhancing learning; however, it is unclear whether this works for psychomotor tasks and how similar avatars need to be. We investigated 'minimal' customisation of instructor avatars, approximating a learner's appearance by matching only key visual features: gender, skin-tone, and hair colour. These avatars can be created easily and avoid problems of highly similar avatars. Using modern dancing as a skill to learn, we compared the effects of visually similar and dissimilar avatars, considering both learning on a screen (n=59) and in VR (n=38). Our results indicate that minimal avatar customisation leads to significantly more vivid visual imagery of the dance moves than dissimilar avatars. We analyse variables affecting interindividual differences, discuss the results in relation to theory, and derive design implications for psychomotor training in virtual environments.

CCS CONCEPTS

• **Human-centered computing** → **Virtual reality**; **Laboratory experiments**; • **Applied computing** → **Education**.

KEYWORDS

Avatar Customisation, Skills Training, Psychomotor, Virtual Environments, Virtual Reality

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1 INTRODUCTION

Psychomotor tasks are physical activities which require both cognitive and motor processes [93]. These range from complex fine motor vocational skills involving instrument manipulation, such as

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surgery or sewing, to full-body gross psychomotor skills including sports and dancing. Various technologies can be used to support and enhance psychomotor learning including the use of virtual environments experienced on a screen [25, 153, 156], or through immersive virtual reality setups [27, 29, 57, 71, 72, 120]. Virtual environments are a compelling medium for psychomotor learning because the experience can be enhanced using additional features such as real-time augmented feedback [72, 145, 153] and gamification [119]. As a result, virtual environments form the foundation of digital interactive experiences for psychomotor learning.

Acquisition of psychomotor skills is commonly achieved through observational learning: a task is learned by observing someone else perform it [67, 107, 109, 148]. At the heart of observational learning in virtual environments are *avatars*: animated digital representations of an instructor that demonstrate a task [26, 27, 79, 150]. With the increasing popularity of virtual environments for learning – both through screens and VR headsets – and the advent of 'metaverse' technology, avatars are becoming more and more commonplace in training and education [96, 131]. Avatars can take many forms, with varying degrees of realism, which has been shown to affect user behaviour and cognition [96, 105, 131, 132, 154]. This crucial role of avatars raises the question of how instructor avatars should be designed, and whether their design can enhance psychomotor learning.

We know from learning in real environments that the likeness of the instructor to the learner can moderate learning effects [10, 11, 138–140, 161]. The neuroscientific basis for observational learning is thought to lie with mirror neurons, which activate both when performing a skill as well as when observing it [85, 111, 126]. If an instructor looks similar or is familiar to a learner, this has the potential to increase mirror neuron activity and therefore enhance learning [2, 33, 37, 100]. This has been utilised in *feedforward learning*, where a learner observes a model of themselves, typically through video which has been edited to give the impression of a better skill performance [39]. This has been shown to result in rapid improvements in performance across a range of activities, including motor tasks [36, 37, 39]. In consequence, making instructor avatars look like the learner is promising and has been studied for various forms of learning and behaviour change in virtual environments [3, 54, 57, 89, 92, 159]. However, apart from a comparison of skilled versus novice self-avatars [57], and a small exploratory study by Fitton et al. [48], it has not yet been investigated for learning psychomotor tasks.

Instructor avatars that closely resemble the learner are not always feasible or desirable. Creating a high-quality instructor avatar with a high resemblance typically requires specialised hardware [46, 57], significant computation time [7], and/or a time-consuming customisation process [42, 92]. Poor-quality avatars can lead to negative emotions and the uncanny valley effect [112], which can negatively affect user experience [159]. Moreover, some people dislike looking at themselves [20], making the proposition of a self-similar instructor avatar unattractive. Also, information about what learners look like may simply not be available, for example, to protect their privacy. Lastly, research on observational and feedforward learning suggests that instructor avatars with a high resemblance to the learner may also not be necessary [37, 85], as mirror neuron activity is thought to increase gradually with similarity [33, 100]. How much similarity is necessary to achieve meaningful enhancements in learning has not been investigated yet. This raises the following research questions:

RQ1 Can minimal avatar customisation enhance learning of a psychomotor skill?

RQ2 Do the effects of minimal avatar customisation differ when learning from a screen compared to learning in VR?

We address these gaps by demonstrating how minimal customisation of an instructor avatar can enhance learning of a complex psychomotor task – modern dancing. Rather than trying to make the instructor a digital clone of the learner, we customise only three basic properties to make it more similar to the learner: gender, skin colour and hair colour. Such minimal customisation mitigates concerns of highly-similar avatars: it is very easy to implement, requires minimal effort from the user, avoids negative effects of poorly designed avatars and strong self-similarity, and helps preserve the learner's privacy. Basic avatar customisation of gender, skin colour, and hair colour can be done in a matter of seconds and is commonplace in many virtual environments [19, 125, 129]. We demonstrate the effects of minimal avatar customisation in both a screen-based and immersive VR virtual environment. Learning enhancements on both platforms are particularly important because screen-based virtual environments are currently much more ubiquitous than VR and are commonly used for observational learning, while immersive VR is becoming increasingly popular and offers distinct possibilities for enhancing motor learning through immersion and embodiment [91, 147].

We demonstrate learning enhancements for modern dance, a full-body psychomotor task with widespread popular appeal that incorporates many psychomotor challenges, such as a wide variety of upper and lower body movements, coordination of simultaneous movements, timing and synchronisation (to music), and artistic expression. It is commonly taught using observation learning [142] and forms the basis for some of the most popular exergames (e.g., Just Dance[1], Zumba Burn It Up![2]). In line with a global trend towards micro-learning [69, 98], we focus on immediate learning effects of sessions lasting only a few minutes to learn a short, self-contained sequence of dance moves. It is difficult to reliably assess dance performance using exact motion matching for contemporary dance because of the individual stylistic variability [52, 75, 146], and performance quality ratings have been found not sensitive enough to discern learning improvements for short, simple dance tasks [48, 101]. Therefore, we demonstrate enhancements in learning using visual imagery, an important outcome measure of psychomotor learning. Visual imagery measures the immediate cognitive effects of learning and the correlation between imagery ability and performance is well-documented both for psychomotor skills [56, 87, 110] and specifically for dance [22, 30, 97].

We also analyse how interindividual differences influence the efficacy of minimal avatar customisation. That is, we investigate how demographic variables such as age and gender, and subjective variables such as perceived competence, similarity to the instructor avatar and presence in VR, are influencing the efficacy of avatar

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[1] Just Dance 2022 – https://www.ubisoft.com/en-gb/game/just-dance/2022

[2] Zumba Burn It Up! – https://www.nintendo.co.uk/Games/Nintendo-Switch-games/Zumba-Burn-It-Up--1662260.html

customisation using regression analyses. This is in contrast to most psychomotor learning studies, which consider only the overall effects of a learning intervention irrespective of the individual characteristics of the users [56, 57, 63, 97, 162].

To the best of our knowledge, our study is the first to investigate 1) the use of instructor avatars that resemble the learner for a complex psychomotor task, 2) the effects of 'minimal' avatar customisation on learning, and 3) the differences of instructor avatars in a screen-based vs. a fully-immersive VR environment. By contrast, the closest related works consider only single-action psychomotor tasks (e.g., squats [57]), and/or only highly-customised 'realistic' avatars [48, 57]. Only a few works [6, 160] compare screen versus VR for psychomotor learning, but they do not consider the effects of avatars.

In summary, we make the following contributions:

(1) Evidence that minimal avatar customisation can enhance the psychocognitive effects of learning in a psychomotor task.
(2) Evidence that minimal avatar customisation can be effective both in screen-based and immersive virtual environments, with potentially stronger effects in VR.
(3) Regression models describing how interindividual differences affect the efficacy of minimal avatar customisation.

2 RELATED WORK

Engaging with virtual environments, whether in the context of entertainment [92, 129], training and education [27, 57, 96], or data interaction [154], often includes interacting with avatars. Avatars are digital models with varying levels of appearance and behavioural realism used to represent people [8]. The appearance of avatars is known to influence human behaviour and cognition, such as creativity [105], motivation [19, 92, 132, 155], cognitive load [96], and performance [114, 129, 131]. Avatars which are more similar to the user behaviourally and aesthetically have been shown to elicit powerful effects [54, 55]. A high degree of avatar similarity is associated with greater engagement, reduced stress, and higher cognitive load in children playing educational games [96]. Similarly in adults, avatars which are most representative of the user are associated with greater positive affect [105] and self-efficacy [131] in online learning environments compared to dissimilar or idealised avatars. As virtual environments continue to emerge within education and training contexts the use and presentation of avatars used to represent the learner [16, 57, 96, 105], instructors [27, 118, 152], coaches [115], or peers [104] is an important consideration.

Virtual environments, both screen-based and immersive, have been used to support the acquisition of psychomotor skills through observational learning in a wide variety of tasks including martial arts [25, 28, 70], dance [1, 27, 44, 150], and sports [73, 118, 153, 164]. Mimicking traditional learning, this is achieved using a virtual instructor who demonstrates the psychomotor task for the learner to observe and imitate. The virtual instructor can take on different forms, from simplistic humanoid representations such as a stick figure [70, 72, 73, 150] to generic avatars modelled on an instructor for a given skill (i.e. dressed in appropriate clothing) [25, 27, 118]. In addition, the learner's kinematic data can be displayed as live feedback to the learner in the virtual environment to highlight incorrect limb and joint positions [1, 5, 27, 44], or to overlay a skilled model of the movement [1, 28, 70, 72, 73, 144]. In our work, we forego additional augmentation of the virtual environment and instead focus on how small modifications to the instructor's avatar can be used to enhance learning.

At the heart of observational learning is an instructor or model to learn from, and evidence suggests that more similar models (e.g. in terms of demographics, physical appearance, and interests) elicit feedforward learning effects and benefit the attentional and motivational processes involved. Individuals are more likely to pay closer attention to, and gain a stronger sense of self-belief from, a model they identify with [36] and this has been shown to improve observational learning [138–140, 161].

Similarity in terms of appearance and demographics are key factors driving the process of identification with an avatar [34, 92]. Feedforward posits that for learning to occur, an individual must be able to envisage themselves successfully performing the skill, by extracting a self-model and constructing a self-simulation [37, 39]. Maximising the physical similarity between the learner and the instructor avatar results in self-models of the user, and this has been shown to be an effective training technique for a variety of skills and situations [13, 37, 39, 40, 68, 149]. In virtual environments, creation of a self-model involves creating an avatar with photorealistic likeness to the learner, also known as 'self-avatars' [57, 89, 159]. Observational learning using self-avatars can reduce anxiety and improve performance in public speaking tasks [3, 89], motivate increased physical activity and exertion during and after virtual experiences [54, 114], and lead to perceptual-cognitive scaffolding in basic motor actions [57].

Despite their potential benefits, self-avatars are not always desirable. Minor defects in the appearance or animation of a self-avatar can become a severe distraction from the learning task [159] – for example in a public speaking task observing a self-avatar was only found to be effective for male participants, females did not feel the avatar was a realistic representation of themselves [3]. In addition to self-avatars being more at risk of producing the uncanny valley effect [112], even a 'perfect' self-avatar would not be desirable as an instructor avatar for all individuals, such as those lacking confidence [159], are anxious [4], or suffer from body dysmorphic disorder [20] or in all learning situations (e.g. for an anxiety-provoking task [4]). In this work, we move away from the extreme customisation required to produce self-avatars. High impact features tend to be those which are most visible, with hair colour and style reportedly more important than finer details which can be harder to distinguish, such as facial features [42]. Therefore, we focus on minimal customisation to understand if identification with avatars that are visibly similar in appearance, with matched characteristics such as gender, skin-tone and hair colour, elicit similar effects to enhance learning of a psychomotor skill.

Traditional screen-based displays and immersive VR setups are the two most popular technological platforms for psychomotor learning using virtual environments. However, it is unclear whether any effects of learning from a similar avatar will differ between these two technology platforms. Prior work has shown that VR, and the associated increase in presence and immersion, can elicit more beneficial effects than less immersive environments, resulting in improved performance, motivation, engagement, and enjoyment [6, 23, 113, 123, 143, 165]. In the context of skill acquisition, cognitive skills, such as decision making, have also been shown to improve when using immersive VR [53], and objective improvements in learning outcomes have been observed for VR compared to a screen [6, 143].

However, the benefits of immersive VR for psychomotor skills learning have only been realised in instances where the interactive capabilities of an immersive VR environment are leveraged [6]. In equivalent applications it has been found repeatedly that learning occurs at the same rate in both screen-based and immersive VR environments [6, 58, 81, 136]. Although the closer fidelity and dimensionality of an immersive VR environment to the real world is suggested to influence learning and transfer [51, 99]. We explore this further by comparing learning of a psychomotor skill from avatars both in a video on a screen and in an equivalent immersive environment experienced through a head-mounted display (HMD).

3 METHODOLOGY

This study investigates whether minimal avatar customisation can enhance psychomotor learning (RQ1), and explores any differences in learning outcomes between screen-based and immersive VR virtual environments (RQ2). In a mixed factorial design, display type (screen or VR) is a between-groups factor and instructor avatar type (matched-feature and dissimilar) is a within-subjects factor. Participants were recruited separately for the screen and VR groups. The screen based condition was conducted online via Zoom due to the COVID-19 pandemic, whereas the VR condition was carried out in a laboratory once restrictions were eased. Participants learned two different 3-move hip-hop dance sequences, one from a matched feature (MF) avatar with their selected gender, skin-tone, and hair colour and the other from a dissimilar (D) avatar with differing characteristics. Both sets of dance moves were categorised as 'beginner', and as a precaution we counterbalanced the order of learning sequence A and B in the event that some participants found one slightly easier or harder. To control order effects, the order of learning from a MF and D avatar were counterbalanced. This resulted in four permutations: half of participants learned sequence A first, the other half learned sequence B first. For each of these permutations half of participants learned sequence A from the MF avatar, the other half learned sequence B from the MF avatar.

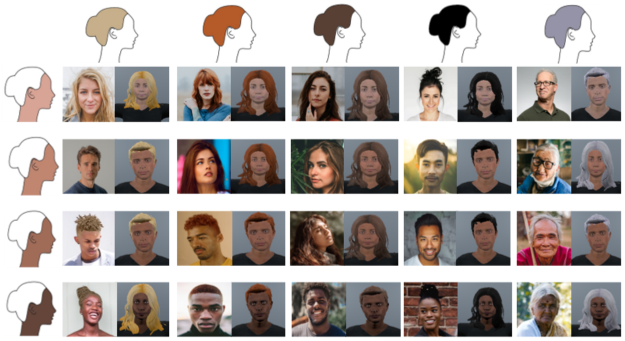

Figure 2: An individual chooses the skin-tone (4 options on the left) and hair colour (5 options on the top) closest to their own to determine the MF avatar appearance. Each combination is depicted here alongside photographs of real people to show how their MF avatar would appear in each case.

3.1 Minimal Avatar Creation

Matching user-avatar key features (those with the greatest visibility), such as gender, skin-tone, and hair colour has been shown to be sufficient for identification to occur [155]. Therefore, for matched feature (MF) avatars, users selected the gender, skin-tone, and hair colour which they identified with (see Figure 2). Dissimilar avatars (D) were then automatically created by applying contrasting features (e.g., male instead of female). Participants were not instructed to wear the same clothes as the avatar since clothing has not been shown to significantly affect whether people identify with avatars [157].

This research uses traditional associations between sex and gender [158], considering avatar gender as a binary characteristic. Participants were required to choose either male or female gender depending on which they identified with most. All participants in this study were aware of their right to withdraw at any point and none reported any discomfort in selecting a gender. A male and a female Adobe Fuse CC model were created from standard components, both wearing neutral, black clothing and trainers.

3.2 Dance

Participants were tasked with learning one of two 3-move dance sequences which were choreographed by Mihran Kirakosian[3] (see Figure 3). Avatars were fully rigged with animations of the dance sequences captured using data from two dancers (a male and a female) who were recruited from a university dance society. The dancers were given the Mihran Kirkosian tutorials to learn a week prior to the recording session. Their movements were captured in a professional motion capture studio and converted into an animation demonstrable by the avatars. This led to high-quality animations which were in time with the music. The male and female dancers' motions were applied to the male and female avatars respectively.

3.3 Apparatus & Set-up

3.3.1 Hardware. The screen condition was conducted online using Zoom and Qualtrics, and participants were required to join the Zoom meeting on a desktop PC or laptop. In the VR condition we used an HTC Vive Pro Eye HMD powered by a PC with an Intel

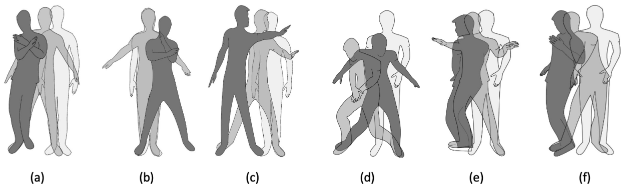

Figure 3: The simple 3-move dance sequences that participants were tasked with learning: (a – c) sequence A, and (d – f) sequence B

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[3] Mihran Kiakosian Dance Videos, Tutorials, and Vlogs YouTube channel - https://www.youtube.com/c/mihrankirakosian

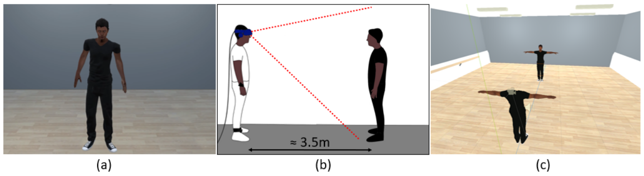

Figure 4: (a) In the virtual environment, presented on a screen or in an immersive HMD, participants observed an animated instructor avatar (MF or D). (b) In the immersive VR condition participants embodied a virtual body positioned approximately 3.5m away from the instructor avatar. (c) The virtual scene consisted of: a wooden floor, lights, and simplistic decoration to mimic a dance studio, an instructor avatar, and a virtual body with the camera positioned as the head.

i7-9900k processor, an RTX 2080Ti GPU and 32GB of RAM, running Windows 10. Participants wore four additional Vive trackers (one on each hand and ankle) secured using velcro straps. A UV cleanbox was used to disinfect all VR equipment between participants.

3.3.2 Virtual Reality Dance Studio. The virtual dance studio (See Figure 4A) was created using Unity version 2019.3.12f1, using simple 3D objects, textures, and materials to mimic a real-world dance studio. An audio source was added to play a track from Mihran Kirakosian's sound cloud page, matching the 8-beat timing of the dance moves. Unity Recorder was used to capture high-quality videos. A video was produced for every possible avatar skin-tone, hair colour, and gender combination for both dance sequences. The videos displayed the sequence (A or B) only once, the videos were looped and embedded into the Qualtrics survey used for participants in the screen condition. The videos auto-played and all navigational functionality (e.g. pause) was disabled.

For the VR condition, the same virtual dance studio was recreated in the Godot game engine version 3.3.1.stable and participants were provided with a VR-body to aid with presence and involvement in the virtual environment [141]. The VR-body that participants embodied was a copy of their MF avatar with their chosen gender and skin-tone, however the hair colour was not visible because the avatar's head was removed to prevent it from occluding the camera, that is, obstructing the participant's view. Participants embodied in the VR-body faced the MF/D avatar instructor (See Figure 4). The VR-body was scaled according to the participant's height. Participants wore an HMD and four Vive trackers (one on each ankle and hand) to detect their body movement. Their VR-body movement was mapped to their actual body movement using inverse kinematics to encourage feelings of body ownership [60]. The instructor avatar automatically cycled through the movements, participants were unable to pause or control the simulation themselves.

3.4 Outcome Variables

The primary outcome measure in this study is vividness of movement imagery, the ability to mentally simulate specific motor actions [77], to demonstrate long-term memory of the dance moves and hence learning [21, 41, 76, 87]. The correlation between action observation, imagery ability, and performance is well-documented [56, 87, 110], also specifically for dance [22, 30, 97], and has been backed up by neurological evidence to a degree that researchers posed a "functional equivalence" hypothesis stating that imagery and skill execution processes share structures and mechanisms [47, 62, 77, 78]. Action observation has been shown to contribute to improved movement imagery abilities [116, 162] and better visual movement imagery abilities have been shown to lead to improved performance [21, 41, 76], that is, those with better imagery display greater movement skill than those with poorer imagery (e.g. in trampolining [74], gymnastics [95], golf [122], tennis [135]).

We created the vividness of dance movement imagery questionnaire (VDMIQ), which is an adapted version of the revised vividness of movement imagery questionnaire (VMIQ-2) [134], to assess participants' ability to imagine the movements: from their own point of view (internal visual imagery, IVI), from someone else's point of view as if they were watching themselves (external visual imagery, EVI), and finally their ability to imagine the feeling of doing the movements (kinaesthetic visual imagery, KVI). Each scale item is rated in terms of the vividness of the movement imagery or feeling (1 = perfectly clear and vivid as normal vision, 5 = no image at all). In the VDMIQ we replaced the generic movements mentioned in the VMIQ-2 (e.g. walking, running, jumping) with the dance moves learned by specific body parts (arm, feet, and head), as well as rating imagery for the body as a whole. Such specific items are preferable because generic items do not always detect differences in task-specific imagery ability [106]. For each subscale (IVI, EVI, KVI) the items are averaged to produce a score from 1 (best) to 5 (worst). Moderately good visual imagery ability is indicated by scores lower than the midpoint of the scale (3; [106]). Based on related work [21, 41, 76, 95, 117, 134, 162], these scores are sensitive to differences in learning and provide valid estimates of psychomotor skill.

Secondary outcome measures included perceived competence, measured using the Perceived Competence (PC) subscale of the IMI [108], and kinaesthetic awareness. Kinaesthetic awareness, that is, one's ability to understand one's movements within space [18, 88], is arguably a key component of learning to dance [32, 128]. We included this as an exploratory measure to understand whether screen-based versus immersive VR training would affect kinaesthetic awareness differently [17] and therefore impact learning. Typically awareness of body movement is measured using physical tasks, such as balance tests, rather than validated questionnaire measures [14]. However, to better accommodate the remote nature of the screen-based condition, due to COVID-19 restrictions, we developed a kinaesthetic awareness questionnaire (KAQ) which contains four kinaesthetic awareness items related to dance (e.g. *'I could not tell when I did the moves wrong'*) and four kinaesthetic skill items (e.g. *'I was able to control my limbs to mirror the movement without difficulty'*). They are rated on a 7-point Likert scale yielding a total score between 1 (worst) and 7 (best).

Other measures included existing skill, motivation, and avatar liking. A baseline level of skill was determined using a single question that asked participants to rate their current level of dance skill (0 = Novice, 10 = Professional dancer), in addition to five items measuring their perception of their dancing abilities on a 5-point Likert scale (e.g. *'I am a good dancer'*). Intrinsic motivation (IM) was measured using the Interest/Enjoyment subscale of the IMI, and avatar liking was measured using the Liking subscale of the PAI [34].

We also used two VR specific measures: VR sickness, a commonly reported adverse effect of VR, and presence, which has been shown to interact with virtual imitation [54]. The Virtual Reality Sickness Questionnaire (VRSQ) [86], a recent adaptation of the well-known Simulator Sickness Questionnaire (SSQ) [84], measures general discomfort, eyestrain and disorientation, yielding a total VR sickness score (the higher, the worse). The iGroup presence questionnaire (IPQ) [137] was used to measure how present participants felt in the virtual environment, measuring spatial presence, involvement and realism, and yielding an overall average presence score between 1 (least presence) and 5 (most presence). To confirm whether our avatar similarity manipulation was successful, we used the Physical Similarity subscale of the PAI. Since the personalisation choices were restricted to rudimentary hair colour and skin-tone options (Figure 1A), participants were also asked to rate how closely they felt these features matched their own on a 5-point scale (5=most similar).

Qualitative feedback on the experience of learning dance moves and participants' feelings surrounding the avatars were gathered via a semi-structured interview. Five questions formed the basis of the interviews (*1. 'How was that? Did you manage to learn the moves?'; 2. 'Were you able to learn both routines equally well?'; 3. 'Do you feel as though having an avatar teaching you as opposed to a real person impacted the experience? In what way?'; 4. 'How did you feel about the avatars?'; 5. 'Which avatar did you prefer learning the moves from and why?'*), though participants were permitted to deviate from the questions if they had other comments, and were encouraged to elaborate their answers. Interviews lasted 5–10 minutes.

3.5 Procedure

Participants in the different display type conditions (Screen and VR) were supervised by the same experimenter and performed and engaged similarly in the learning tasks. They received the same instructions, tasks, and amount of time to practice the dance sequences.

3.5.1 Non-Immersive Condition (Screen). Non-immersive study sessions were conducted with remote participants due to COVID-19 restrictions in place at that time. The experimenter conducted the study sessions with each participant over Zoom, using a Qualtrics survey to provide participants with the information, instructions, dance videos, and questionnaires used throughout the experiment.

The experimenter introduced the study to participants and provided them with a link to the Qualtrics survey, the experimenter remained on the call to supervise participants and answer any questions. Qualtrics provided participants with information and a consent form before taking participants to a 'warm up' clip from Mihran Kirakosian's YouTube channel. Participants then completed the preliminary dance skill questionnaires and answered demographic questions, which involved selecting the gender they identify with most, hair colour, and skin-tone. Participants were encouraged to ask questions if they were unsure how to answer. Based on these answers, participants were automatically assigned MF and D avatars. Participants learned two different three-move dance sequences (A and B), one from each avatar (MF, D). The flow logic of the Qualtrics survey randomly assigned participants to one of the four permutations resulting from counterbalancing the order of the dance sequences (A, B) and instructor avatars (MF, D).

Participants were instructed to mirror the dance moves and practice with the video. After 3 minutes participants were directed to a post-training questionnaire, before repeating the process for the second avatar condition. After both conditions were complete, the experimenter conducted a semi-structured interview which lasted 5 - 10 minutes. Interviews were recorded using Zoom and later transcribed. The non-immersive (screen) condition sessions lasted approximately 40 minutes and participants were emailed a £5 Amazon voucher afterward as a reward.

3.5.2 Immersive Condition (VR). The immersive condition took place face-to-face in a University lab. Using the same Qualtrics survey, participants were guided through the experiment; in place of embedded videos, messages notified participants to start each task. After completing the initial questions, the experimenter recorded the participant's height and prepared the virtual scene whilst the participant completed the warm-up. Then, the experimenter manually selected the correct avatar with the correct dance animation.

Participants were equipped with the Vive trackers and the HMD was adjusted to fit comfortably. Participants were then informed that they could begin learning the dance moves and were given three minutes to mirror the avatar and practice the dance. Afterwards, they removed the headset and returned to the survey to complete the post-task questionnaire. This process was repeated for the second condition, followed by the semi-structured interview. The immersive (VR) condition sessions lasted 60 minutes due to equipment set-up and additional questionnaires (VRSQ, IPQ). Participants received a £10 voucher for their participation.

3.6 Hypotheses

Similarity between an observed model and the learner is known to enhance learning due to the feedforward effect [35–37]; therefore, we hypothesise that learning is enhanced when dance moves are demonstrated by the more similar avatar. We therefore pose the following a-priori hypotheses to address RQ1 (*Can minimal avatar customisation enhance learning of a psychomotor skill?*). Each hypothesis breaks down into three sub-hypotheses for the a) internal, b) external and c) kinaesthetic visual imagery measures:

H1 Internal (**H1a**), external (**H1b**) and kinaesthetic visual imagery (**H1c**) are stronger after learning from a matched-feature avatar compared with a dissimilar avatar overall.

H2 Internal (**H2a**), external (**H2b**) and kinaesthetic visual imagery (**H2c**) are stronger after learning from a matched-feature avatar compared with a dissimilar avatar when using a screen.

H3 Internal (**H3a**), external (**H3b**) and kinaesthetic visual imagery (**H3c**) are stronger after learning from a matched-feature avatar compared with a dissimilar avatar in VR.

3.7 Participants

A sample of 97 participants (42M, 55F), aged 18 - 60 (M = 31.660, SD = 10.544) were recruited through mailing lists and social media. Participants from around the world were able to take part in the remote screen based condition, whilst the immersive VR condition relied on the local participant pool. 59 participants (21M, 38F) learned dance through a screen and 38 participants (21M, 17F) in VR. Eligibility criteria excluded anyone under the age of 16 and anyone with uncorrected hearing or visual impairment, but welcomed any level of dance skill. The majority of participants were self-declared novice dancers (Table 1).

4 QUANTITATIVE RESULTS

The results are summarised in Table 1 and illustrated in Figure 5. The collected data satisfied the assumptions for analysis of variance (ANOVA). If Mauchly's test indicated a violation of sphericity, Huynh-Feldt correction was applied. If a Shapiro-Wilk test indicated a violation of normality for a pairwise comparison, a non-parametric Wilcoxon test was used instead of a t-test (for existing dance experience and ability ratings). Power analyses indicated that our study was able to detect small-to-medium main effects between D and MF and interaction effects with display type overall (Cohen's $d = 0.287$), small-to-medium effects between D and MF when using a screen ($d = 0.328$), and medium effects between D and MF in VR ($d = 0.411$), all at $\alpha = .05$ with a power of 0.8.

4.1 Manipulation Check and Scale Reliability

Our manipulation of avatar similarity worked as intended, and matched feature avatars resulted in significantly higher avatar similarity scores. A two-way mixed ANOVA found a significant main effect of avatar type on avatar similarity ($F(1, 95) = 195.229, p < .001^{**}, eta_p^2 = 0.398$), with MF avatars ($M = 5.011, SD = 1.311$) being more similar than D avatars ($M = 2.315, SD = 1.697$). There was also a significant main effect of display type on avatar similarity ($F(1, 95) = 21.497, p < .001^{**}, eta_p^2 = 0.045$) with higher avatar similarity in VR ($M = 6.852, SD = 1.669$) compared to a screen ($M = 5.729, SD = 1.594$). We found no significant difference in existing dance experience rating ($M_{diff} = 0.556, Z = 1277.500, p = .245, r = 0.140$) or dance ability ($M_{diff} = 0.103, Z = 1195.500, p = .584, r = 0.066$) between the two participant groups.

We also assessed the reliability of the kinaesthetic awareness scale (KAQ) that was created for this study, and also the internal visual imagery (IVI), external visual imagery (EVI), and kinaesthetic visual imagery (KVI) measures. The McDonald's omega score [66] suggested that all of the scales were highly reliable, and in the acceptable range (interpretation is similar to Cronbach's alpha) [151] (KAQ ω = .826, IVI ω = .835, EVI ω = .858, KVI ω = .814). The scales used for other measures indicative of avatar identification (PAI Physical similarity ω = .927, PAI Liking ω = .891), perceived competence (IMI Perceived Competence ω = .947), intrinsic motivation (IMI Interest/Enjoyment ω = .929), presence (IPQ ω = .856), and VR sickness (VRSQ ω = .817) were also highly reliable.

4.2 Learning Efficacy Overall

To test **H1a**, a two-way mixed ANOVA was conducted testing the effect of avatar type and display on internal visual imagery (IVI). A significant main effect of avatar type was found ($F(1, 95) = 9.224, p = .003^{**}, d = 0.308$) with MF avatars ($M = 2.446, SD = 0.842$) resulting in clearer IVI than D avatars ($M = 2.670, SD = 0.913$) overall, so we accept **H1a**. The main effect of display type was not significant ($F(1, 95) = 3.744, p = .056, d = 0.196$) and there was no significant interaction between display and avatar types ($F(1, 95) = 2.248, p = .137, eta_p^2 = 0.023$).

A similar ANOVA for external visual imagery (EVI) revealed a significant main effect of avatar type ($F(1, 95) = 3.976, p = .049^{*}, d = 0.202$), once again with clearer imagery for MF avatars ($M = 2.701, SD = 0.831$) compared with a D avatar ($M = 2.840, SD = 0.913$) overall, so we accept **H1b**. The main effect of display type was not significant ($F(1, 95) = 3.832, p = .053, d = 0.199$) nor was there any interaction effect ($F(1, 95) = 0.697, p = .406, eta_p^2 = 0.007$).

Finally, a similar ANOVA for kinaesthetic visual imagery (KVI) revealed a significant main effect of avatar type ($F(1, 95) = 5.948, p = .017^{*}, d = 0.248$), again with clearer imagery for MF avatars ($M = 2.260, SD = 0.793$) compared to D avatars ($M = 2.418, SD = 0.887$), so we accept **H1c**. No other main ($F(1, 95) = 3.174, p = .078, d = 0.181$) or interaction effects were found ($F(1, 95) = 1.297, p = .258, eta_p^2 = 0.013$).

4.3 Learning Efficacy Using a Screen or VR

Directed paired-samples t-tests comparing IVI ($t(58) = 1.152, p = .127, d = 0.150$), EVI ($t(58) = 0.853, p = .199, d = 0.111$) and KVI ($t(58) = 0.982, p = .165, d = 0.128$) between MF and D when using a screen were not significant, so we reject **H2**. Directed paired-samples t-test comparing IVI ($t(37) = 3.283, p = .002^{**}, d = 0.533$), EVI ($t(58) = -2.136, p = .020^{**}, d = 0.347$) and KVI ($t(37) = 2.543, p = .008^{**}, d = 0.413$) between MF and D in VR were all significant, so we accept **H3**.

4.4 Other Measures

A two-way mixed ANOVA to investigate whether avatar type or display had any effect on kinaesthetic awareness scores revealed no significant main effects of avatar type ($F(1, 95) = 1.716, p = .193, d = 0.133$) or display type ($F(1, 95) = 0.012, p = .914, d = 0.011$). There was no significant interaction effect ($F(1, 95) = 0.307, p = .581, eta_p^2 = 0.003$). However, a similar ANOVA revealed that there was a significant main effect of display type on perceived competence ($F(1, 95) = 10.023, p = .002^{**}, d = 0.321$) with those in the screen condition reporting greater perceived competence ($M = 4.306, SD = 1.484$) than those in the VR condition ($M = 3.375, SD = 1.299$), regardless of avatar type. No other significant main or interaction effects were found. There were no significant main or interaction effects of avatar type and display on IMI Interest/Enjoyment, indicating that levels of intrinsic motivation did not change. Avatar liking was also unchanged between avatar types and display types, with no significant main effects or interaction effects.

4.5 Effects of Interindividual Differences

To investigate how interindividual differences influence the learning enhancements of minimal avatar customisation, we conducted multiple linear regression analyses to predict learning enhancements based on the following covariates: Age, Gender, Perceived Competence (in D, as a baseline measure of a person's dance skill), and Avatar Similarity (in MF, where learning enhancements are observed). In order to present a cohesive, integrated analysis, we formalised the overall *learning enhancement* for a participant as an average of the effects of our three main outcome measures (EVI, IVI

Table 1: Summary of demographics and results of the main study (M ± SD).

Condition	n	Demographics	Variable	Similarity	
				D	MF
Screen	59	21 M, 38 F Age = 33.203 ±11.462 Dance Experience Rating = 3.898 ±2.234 Dance Ability Score = 2.908 ±1.077	AS	1.580 ±0.939	4.939 ±1.469
			AL	4.619 ±1.267	4.661 ±1.296
			IVI	2.500 ±0.934	2.373 ±0.905
			EVI	2.691 ±0.939	2.602 ±0.876
			KVI	2.275 ±0.893	2.182 ±0.849
			PC	4.410 ±1.569	4.203 ±1.613
			IMI Interest	5.012 ±1.487	5.075 ±1.353
			KAQ	4.898 ±1.104	4.972 ±1.060
VR	38	21M, 17F Age = 29.263 ±8.535 Dance Experience Rating = 3.342 ±2.529 Dance Ability Score = 2.805 ±1.027	AS	3.457 ±1.972	5.124 ±1.025
			AL	4.822 ±4.964	4.728 ±3.668
			IVI	2.934 ±0.823	2.559 ±0.729
			EVI	3.072 ±0.830	2.855 ±0.741
			KVI	2.638 ±0.842	2.382 ±0.690
			PC	3.276 ±1.541	3.474 ±1.408
			IMI Interest	5.138 ±1.173	5.028 ±1.169
			KAQ	4.822 ±1.134	5.005 ±0.955
			IPQ	1.335 ±1.824	1.476 ±1.689
			VRSQ	11.509 ±8.683	12.943 ±10.310

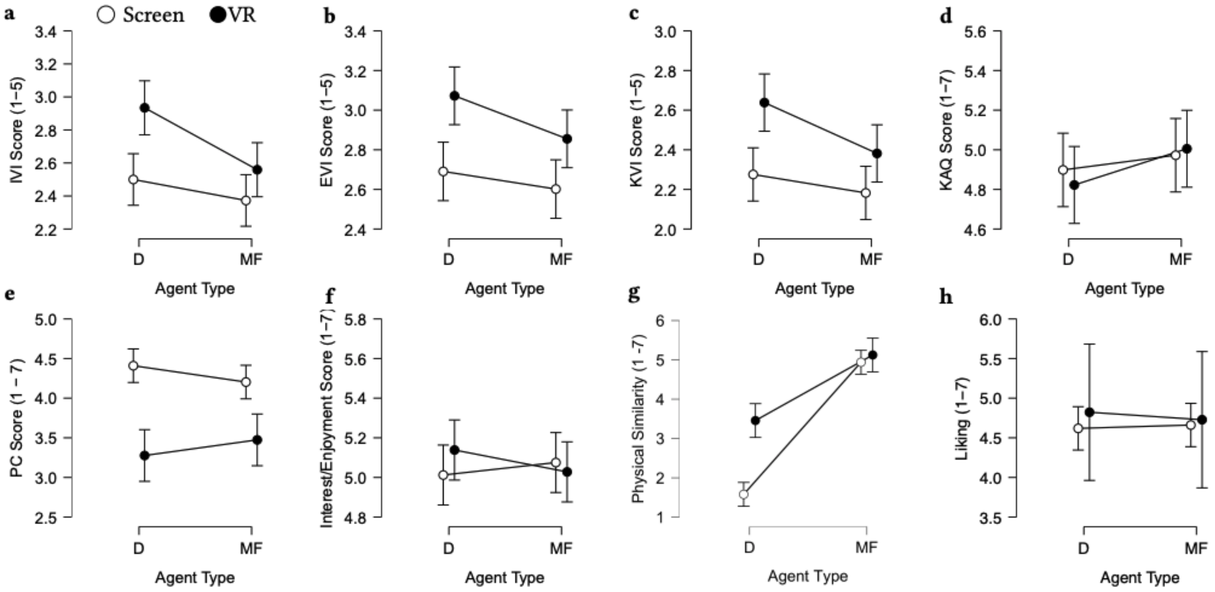

Figure 5: Effects of D and MF avatars in the screen and VR conditions on a) Internal Visual Imagery (IVI), b) External Visual Imagery (EVI), c) Kinaesthetic Visual Imagery (KVI), d) Kinaesthetic Awareness (KAQ), e) Perceived Competence (PC), f) Interest/Enjoyment (IM), g) Avatar Similarity (AS) and h) Avatar Liking (AL). For IVI, EVI, and KVI lower scores = more vivid imagery, for all other scales higher scores are better. Dots represent means and error bars show their 95% confidence intervals.

and KVI) as follows: We first calculated ΔEVI, ΔIVI and ΔKVI as the respective differences observed between the conditions D-MF. Then we normalised ΔEVI, ΔIVI and ΔKVI using standard z-transforms, i.e. subtracting their sample mean and dividing by their standard deviation. This made the ΔEVI, ΔIVI and ΔKVI values comparable to each other, allowing us to combine them by averaging to yield a measure of the overall learning enhancement – across EVI, IVI and KVI – observed for each participant. We hypothesised that people with higher Perceived Competence would show lower learning enhancement, as they already come equipped with dance skills and hence have less to learn; and that Avatar Similarity would positively influence learning enhancement as predicted by feedforward learning theory [37, 38].

For the overall results including VR and Screen, a significant regression equation was found ($F(4, 92) = 3.755, p = .007^{**}$), with an adjusted $R^2 = 0.140$. Participants' predicted learning enhancement is equal to $-0.010 \times$ Age $- 0.219 \times$ Gender $- 0.094 \times$ Competence $+ 0.180 \times$ Similarity, where Age is measured in years and Gender is coded as 0 for male and 1 for female. Perceived Competence ($p = .036^{*}$) and Avatar Similarity ($p = .004^{**}$) were significant predictors of learning enhancement, with learning enhancement decreasing with Perceived Competence and increasing with Avatar Similarity. Age ($p = .241$) and Gender ($p = .213$) were not significant predictors. For the results in VR, we also considered the overall IPQ Presence score (in D, as a baseline measure of how present a participant feels in VR). A significant regression equation was found ($F(5, 32) = 2.607, p = .044^{*}$), with an adjusted $R^2 = 0.178$. Participants' predicted learning enhancement is equal to $-0.018 \times$ Age $- 0.348 \times$ Gender $- 0.158 \times$ Competence $+ 0.148 \times$ Similarity $+ 0.072$ Presence. Perceived Competence ($p = .024^{*}$) and Presence ($p = .048^{*}$) were significant predictors of learning enhancement, with learning enhancement decreasing with Perceived Competence and increasing with Presence. Age, Gender and Avatar Similarity were not significant predictors ($p \geq .142$).

5 QUALITATIVE RESULTS

A reflexive thematic analysis was conducted to gain further insight into the effects of minimal avatar customisation (RQ1). Common themes and sub-themes emerged through a data-driven inductive coding process conducted by the primary researcher [24]. The overarching themes and sub-themes are discussed using participant quotes as illustrative examples; text in square brackets is used to add context to a quote to make it easier to understand.

5.1 Learning Efficacy

Avatars are effective digital models to learn from, providing a simplified ("*it doesn't look as complicated.*"; "*It was more simplistic movements on a more simplistic character.*") and engaging learning experience ("*It was a really fun, really good, interactive, engaging, loving it.*"). Evidence that minimally customised avatars can elicit feedforward effects emerged as **matched-feature avatars make it easier** with participants more able to imitate the avatar that looked similar to them compared to the dissimilar avatar ("*I think the first one was just easier to mimic there the* [MF] *Avatar*"; "*he didn't move in the way I thought I could, so it felt different and harder to learn yeah* [with the D avatar]"). They identified with the MF avatar to a greater extent ("*I felt like I was able to connect more with the* [MF] *avatar versus the second one* [D avatar]"), which made it easier to learn ("[with the MF avatar] *I felt like it was easier to naturally replicate moves, whereas in the second one it was a female*") and imagine their own performance ("*since it looked like me it was easier to imagine me doing those moves. I think.*"; "*it was easier for me to kind of imagine that what I see is my body*"), in turn enhancing their perceived competence ("*because the avatar looked somehow like me and made me feel like I could do it too.*").

Matched-feature avatars provide a more enjoyable learning experience ("*I preferred learning it from the one that looks like me.*"; "*The one that looks more like me, I think, was better.*"), and there was a preference for that condition because it made the dance training more relatable:

> *Preferably one* [MF avatar] *you would see yourself in the eyes of the avatar. Like more relatable if that makes sense.*; *I think I prefer one looked more like me, it is easier to kind of relate to and you can follow the moves better*

and having a relatable avatar was valued by participants:

> *I want to have something that I can relate to. yeah it certainly helps.*; *I think what's important to me personally* [female participant] *is that it was a female.*; *I appreciated that* [MF avatar] *kind of more from the perspective of just having a representation of a woman of about my age and body type represented there.*

5.2 Effects of Interindividual Differences

Identification with the instructor avatars was not the same for all participants. Some participants found that the MF avatar exhibiting the same gender, hair colour, and skin-tone was sufficient for them to identify with the avatar ("*once you get used to the routine and and the moves it was just like you're watching yourself in the mirror*"; "*when I saw that Avatar that looked more like me, I was like hey you know not bad.*"). Some others expressed frustration that it was not fully representative of themselves:

> *I'd rather it just be a completely different person than, look, or have the same characteristics as me, but not be me in a weird way*; *I didn't really feel like it was me or anything like that, they just happen to have Ginger hair and be a white male.*

Key features for identification include gender, with many participants commenting on whether the avatar was male or female and how this impacted their level of identification more so than the other customised characteristics:

> *I think what's important to me personally is that it was a female.*; *I felt more comfortable with the second one, because I guess it's a girl*; *Of course I relate more to the women characters than than men*; *I think things like hair colour or skin colour didn't make a difference to me but gender I can read a slight difference.*

The binary gender association meant that gender and physique were directly related in this study, however participants revealed that physique is a separate key characteristic that was not considered in the present study ("*her build was bigger than mine so it's just it's just her body shape wasn't consistent*"). In particular age, body shape, and height are important factors for identification:

> *I appreciated that kind of more from the perspective of just having a representation of a woman of about my age and body type represented there.*; *To be honest, because like someone has the same hair colour and skin colour but none of them look the same due to facial features, physique or height.*; *Probably age, because,* [the avatar] *looks kind of my age*; *although I'm female...*

> *I kind of have a male shaped body. Right. I'm quite slim as well..*

Hair colour and skin tone were mentioned less, with participants accepting a basic level of similarity ("*The second one was more of my resemblance in terms of skin colour or maybe the hair colour*"; "*her hair was really similar to mine when it's down*; "*Picked the right hair colour*"). However, there was a general **desire for greater similarity** in terms of the physical appearance of the avatar:

> *I think it would be interesting to have more I don't know more skin colours, more hairstyles.*; *I feel like they should add more like beard or hairstyle or physique. I think that would be a class.*; *I think my hair it's lighter the colour and I'm more white and I'm taller*

User ability impacts speed of learning with some participants finding it naturally easier to learn the dance moves quickly, indicating that 3 minutes was sufficient ("*I didn't necessarily need those 3 minutes to get it*"; "*Yeah, I found it quite easy. Picked up quite quickly.*"), while others indicated that they would need to rehearse over a longer period ("*I needed more time to be able to do it exactly the same.*"). Additionally, **'ability can lead to avatar ability preconceptions'** ("*You know your biases are still the same towards an avatar, than to a real person*"; "*You're having some subconscious impressions of what's going on quite quickly*"). Some participants felt as though the D avatar looked more like a dance instructor:

> *The first one* [D avatar] *looked more like someone like in a dance studio I guess*; *it* [D avatar] *felt more like an avatar that would teach you how to dance*; *The first one* [D avatar] *was more like a dance instructor*

and assumed that this avatar must therefore be performing better and is a better model for them to learn from:

> *So I actually thought that the one that looked different than me* [D avatar] *was going to be a better dancer like as a me as a teacher, a better teacher*; *maybe it has a negative impact if I don't think I can do it and then well this one's* [D avatar] *different to me, so I can copy them*

6 DISCUSSION

Overall, our findings demonstrate how minimal avatar customisation can enhance learning in virtual environments, with matched feature avatars eliciting immediate cognitive benefits that support psychomotor learning (RQ1). Participants' ability to mentally simulate the dance moves, indicated by the vividness of movement imagery, was significantly and meaningfully higher when observing a matched feature avatar. To contextualise the differences observed, prior work has shown how high-performing athletes competing at national level score an average of 8% higher across IVI, EVI, and KVI compared with recreational athletes [134]. Similarly, observing a video of a gymnastic routine 20 times per day for two weeks can lead to a 4% improvement in VMIQ-2 scores [95]. The improvements observed in this study (IVI = 5.6%, EVI = 3.5%, KVI = 4%) suggest that manipulating avatar similarity and minimal customisation can produce similar results instantly.

Action observation facilitates movement imagery by providing an example of what the individual should imagine, our findings indicate that a more visually self-similar avatar provides a more clear and vivid example [94], resulting in improved task representation in long-term memory and contributing to greater performance [62, 78, 87]. These findings are in line with prior work on peer models and feedforward learning theory [9–12, 37, 38], and demonstrate the importance of having representative and relatable instructors. These results have important implications for the designers of virtual training applications: it suggests that even minimal customisation of an avatar can enhance learning outcomes. This basic, cost–effective measure requires little time on the user's behalf (inputting basic physical characteristics) that can significantly enhance the user's learning experience. Not only does this have implications for applications directly aiming to teach users, it reinforces the importance of having representative peers in exergaming and other applications involving psychomotor tasks in virtual environments, and wider relevance for other areas where avatar type might be impactful (e.g. human data interaction [154]).

Certain characteristics are more important to participants when creating minimally customised avatars. Of the features that we customised, gender can be considered the most important characteristic that influences avatar identification [43, 82, 129, 133], with many participants – especially females, highlighting the importance of having a same-gendered avatar as a relatable model. However, in this study, a binary gender association meant that participants were not only selecting a 'gender' but also a body type for the MF instructor avatar. Based on participant comments the avatar's physique (e.g. body shape, height, and age) is a separate characteristic that could be equally important for avatar identification. This raises questions about the minimal level of body type customisation required to elicit further meaningful identification which could contribute to the feedforward effect, without overburdening the user during the avatar creation process. Comparatively rudimentary skin-tone and hair colour options proved satisfactory for identification purposes, and participants accepted a low level of hairstyle similarity (non-customised) indicating that hairstyle may be a less prominent factor for avatar identification than previously suggested [42]. Whilst a desire for greater similarity is generally evident, our results indicate that it is not essential and highlights the importance of minimal customisation of key features: gender, physique, skin-tone, and hair colour, rather than generic avatars which can be dissimilar to the user.

Our results show how individual differences affect the efficacy of minimal avatar customisation. Our regression analyses suggest that neither age nor gender impacts the efficacy of this training technique, but that baseline skill is a limiting factor – with those who report high levels of perceived competence following the dissimilar avatar training benefiting less from the matched feature avatar training. This suggests that feedforward learning as a technique is most efficacious when the user is less skilled and has more to learn. Interestingly, a user's feelings of presence become an important factor in the efficacy of feedforward learning in VR, with presence positively correlating with feedforward learning effects. Other research has also identified a positive relationship between presence and learning outcomes [123, 143], indicating that virtual environments which elicit presence are capable of producing stronger self-modelling effects and imitation [54].

Matched feature avatars resulted in more vivid imagery, however not all participants reported the positive effects of learning, with some believing that the dissimilar avatar was a better dancer and therefore a better teacher. Based on qualitative feedback, another explanation as to why some participants preferred the dissimilar avatar is the Proteus effect [166], which typically describes situations where a user embodies or acts as the avatar. Physical characteristics of an avatar can give an impression of their capabilities, impacting how users behave and feel [130], e.g. by playing better as an athletic avatar [125, 127], perceiving physical tasks as less arduous with muscular avatars [90], or displaying greater confidence with a taller avatar [166]. This offers an explanation in the context of our study as some novice dancers may have attributed better dance skills to the dissimilar avatar and felt they learned better than from the matched feature avatar which they may have perceived to be a 'novice' similar to themselves.

Understanding the underlying mechanisms as to why learning benefits arise still remains unclear, and may stem from sub-conscious processes. There were no significant effects of avatar type on intrinsic motivation. However, it has been established that the use of imagery in novices is primarily a cognitive skill to aid learning and improve performance and that only experts will use imagery as a motivational tool [64, 121]. Therefore, despite matched feature avatars leading to significantly stronger visual imagery, it is unlikely that this contained a motivational aspect. Additionally, participants were not personally creating an avatar, but just selecting a skin-tone and hair colour. Previous research has shown that customisation of a self-model can lead to improvements in intrinsic motivation [92]; however, this may not be true where participants are not involved in the avatar creation process or where customisation is minimal.

Similarly, we found no significant effect of avatar type on perceived competence which contradicts the findings of other work which showed that more similar avatars resulted in greater self-efficacy [83]. This could have been due to strong self-identification with the avatar that they embodied, and levels of self-identification, whilst higher with the matched feature than dissimilar avatars, may not have been strong enough to affect perceived competence in our study. Nevertheless, our findings indicate that feedforward learning techniques using matched feature avatars provide a scalable solution for efficacious training in virtual environments. There has been evidence that there are underlying neurocognitive mechanisms at play [45]. Prior work suggests the feedforward effect is continuous, and that greater identification with a model will increase the effect due to superior mirror neuron response [2, 33, 37, 100]. It is these sub-conscious processes that may underpin the enhanced learning benefits of learning from a physically similar instructor.

The technological platform used for learning may affect the potential learning enhancements derived from minimal avatar customisation. VR training simulations are growing in popularity [31, 61, 79], and prior work has suggested that VR may improve learning of psychomotor skills compared with screen-based conditions when interactive capabilities are leveraged [6, 143, 165]. Our results provide evidence to suggest that VR may lead to greater learning effects with minimal avatar customisation compared with screen conditions even without interactive capabilities (RQ2).

Vividness of visual imagery seems to be more strongly related to avatar type in the VR condition than for the screen, and the effect size of avatar type is greater in VR, with medium-sized effects on IVI, KVI, and EVI when comparing dissimilar and matched feature avatars, compared with only small effects for screen-based video. Minimal avatar customisation may add more value in immersive virtual environments than in more traditional forms of media, possibly due to being more clearly visible, making them a worthwhile consideration for VR designers.

On the other hand, perceived competence following training was significantly higher for those who learned in the screen condition compared to the VR condition. A first possible explanation is that the two groups were simply different, possibly due to selecting from a global versus local participant pool. The screen based experiments took place remotely and attracted a global audience, thus it is possible that we attracted participants who were more interested in the dance task and had greater belief in their ability. However, according to baseline measures, there were no significant differences in self-reported dance experience or ability between the two groups. We speculate that this difference in perceived competence may instead be due to participants in the screen condition being able to see their own body, enabling better judgement of their accuracy. Many participants in the VR condition indeed reported that they were not sure how well they performed the moves because they could not see themselves, limiting their learning [63]. This could also explain why visual imagery following screen based training tended to be more vivid, and may be a confounding factor which hides the interaction effect between avatar and display types on IVI, EVI, and KVI.

Nevertheless, kinaesthetic awareness [18, 88] did not change with avatar type or display type according to our Kinaesthetic Awareness Questionnaire (KAQ). This suggests that the feeling of doing the moves did not differ between conditions – an important finding as it has been shown that immersive virtual environments can lead to confused proprioception [17]. Seemingly, wearing the VR equipment and not being able to see one's own real body in the immersive condition did not hinder participants' ability to practice the moves or their kinaesthetic awareness in our study [23]. Therefore, we agree that feedforward learning of motor skills, for which kinaesthetic and proprioceptive awareness is a key aspect [15, 163], is feasible and effective when replicating a real-world scenario in immersive VR [28].

6.1 Limitations and Future Work

Whilst one of the aims of this study was to approach feedforward using minimally customised avatars – matching only gender, hair colour, and skin-tone – the avatar creation process could be improved. We allowed participants to select either gender, asking them to select the gender that they identify with most at that time, accommodating dynamic gender identity. However, this process did not accommodate gender identities falling outside of gender binary, therefore to be more inclusive of gender identity, future work should involve participants in the creation of their avatar [59]. Additionally, different skin colours were applied over the same 3D model which did not incorporate the nuances of racially diverse avatars [124].

It has been shown how immediate learning improvements as a result of increases in imagery are likely to lead also to improvements when learning sessions are prolonged and repeated [49, 50, 80], and while our work demonstrates how minimal avatar customisation can enhance immediate cognitive effects that are crucial for psychomotor learning, it is important to validate how these effects manifest over longer time lengths. It is also important to better understand whether the relationship between avatar similarity and performance is linear and what extent of customisation is optimal. Prior work has indicated that the role of avatar similarity is complex with a number of factors, e.g. individual differences, task and situation, impacting whether a digital-self should be used [3, 103]. Whilst our results support the use of matched feature avatars and show that perceived avatar similarity positively influences feedforward learning efficacy, further investigation is required to fully understand the relationship between avatar similarity and learning in virtual environments. In particular, it would be useful to confirm whether the effects observed in the present study get larger as avatar similarity increases or whether, and when, other factors such as the uncanny valley [112] are introduced, resulting in negative feelings towards the avatar and reducing its efficacy [65, 102, 159].

7 CONCLUSIONS

We demonstrated how minimal customisation of instructor avatars can enhance learning of a psychomotor task in a virtual environment. Using the example of dance, we compared instructor avatars with features matching the learner and avatars with dissimilar features, revealing that matched-feature avatars enhance learning with improved visual imagery. We conclude that:

(1) Minimal customisation of instructor avatars can enhance observational learning, while being easy to use and implement.
(2) Minimal customisation can be effective for learning in screen-based and immersive virtual environments, with potentially greater effects in VR.
(3) Minimal customisation works better for learners with lower perceived competence, higher perceived avatar similarity, and, when in VR, higher presence.

Observational learning with customised instructor avatars holds promise as a training technique, with potential for increased efficacy in immersive training environments. As a result, developers are well advised to consider customisation of instructor avatars.

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REFERENCES

[1] 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*. ACM, [Place of publication not identified], 311–320.

[2] Ramin Ashraf, Behrouz Abdoli, Reza Khosrowabadi, Alireza Farsi, and Jaime A Pineda. 2021. The Effect of Modeling Methods on Mirror Neurons Activity and a Motor Skill Acquisition and Retention. *Basic and Clinical Neuroscience* 0, 0 (2021), 0–0.

[3] Laura Aymerich-Franch and J Bailenson. 2014. The use of doppelgangers in virtual reality to treat public speaking anxiety: a gender comparison. In *Proceedings of the International Society for Presence Research Annual Conference*. Citeseer, Vienna, 173–186.

[4] Laura Aymerich-Franch, René F Kizilcec, and Jeremy N Bailenson. 2014. The relationship between virtual self similarity and social anxiety. *Frontiers in human neuroscience* 8 (2014), 944.

[5] Seongmin Baek, Seungyong Lee, and Gerard Jounghyun Kim. 2003. Motion retargeting and evaluation for VR-based training of free motions. *The Visual Computer* 19, 4 (2003), 222–242.

[6] Jeremy Bailenson, Kayur Patel, Alexia Nielsen, Ruzena Bajscy, Sang-Hack Jung, and Gregorij Kurillo. 2008. The Effect of Interactivity on Learning Physical Actions in Virtual Reality. *Media Psychology* 11, 3 (Sep 2008), 354–376. https://doi.org/10.1080/15213260802285214

[7] Jeremy N. Bailenson, Jim Blascovich, and Rosanna E. Guadagno. 2008. Self-Representations in Immersive Virtual Environments1. *Journal of Applied Social Psychology* 38, 11 (2008), 2673–2690. https://doi.org/10.1111/j.1559-1816.2008.00409.x _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1559-1816.2008.00409.x.

[8] Jeremy N Bailenson, Nick Yee, Dan Merget, and Ralph Schroeder. 2006. The Effect of Behavioral Realism and Form Realism of Real-Time Avatar Faces on Verbal Disclosure, Nonverbal Disclosure, Emotion Recognition, and Copresence in Dyadic Interaction. *Presence: Teleoperators and Virtual Environments* 15, 4 (Aug. 2006), 359–372. https://doi.org/10.1162/pres.15.4.359 Publisher: MIT Press.

[9] Albert Bandura. 1986. *Social foundations of thought and action*. Vol. 1. Prentice Hall, Englewood Cliffs, NJ.

[10] Albert Bandura, Dorothea Ross, and Sheila A Ross. 1961. Transmission of aggression through imitation of aggressive models. *The Journal of Abnormal and Social Psychology* 63, 3 (1961), 575.

[11] Albert Bandura, Dorothea Ross, and Sheila A. Ross. 1963. Imitation of film-mediated aggressive models. *The Journal of Abnormal and Social Psychology* 66, 1 (1963), 3–11. https://doi.org/10.1037/h0048687 Place: US Publisher: American Psychological Association.

[12] Albert Bandura and Richard H Walters. 1977. *Social learning theory*. Vol. 1. Prentice-hall, Englewood Cliffs, NJ.

[13] Soumya C. Barathi, Daniel J. Finnegan, Matthew Farrow, Alexander Whaley, Pippa Heath, Jude Buckley, Peter W. Dowrick, Burkhard C. Wuensche, James L. J. Bilzon, Eamonn O'Neill, and Christof Lutteroth. 2018. Interactive Feedforward for Improving Performance and Maintaining Intrinsic Motivation in VR Exergaming. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (CHI '18)*. Association for Computing Machinery, Montreal QC, Canada, 1–14. https://doi.org/10.1145/3173574.3173982

[14] Rachel Barlow. 2018. Proprioception in dance: a comparative review of understandings and approaches to research. *Research in Dance Education* 19, 1 (2018), 39–56.

[15] G Batson. 2008. Proprioception. *International Association for Dance Medicine and Science* 0, 0 (2008), 1–7.

[16] Amy L Baylor. 2011. The design of motivational agents and avatars. *Educational Technology Research and Development* 59, 2 (2011), 291–300.

[17] Rena Bayramova, Irene Valori, Phoebe E McKenna-Plumley, Claudio Zandonella Callegher, and Teresa Farroni. 2021. The role of vision and proprioception in self-motion encoding: An immersive virtual reality study. *Attention, Perception, & Psychophysics* 83, 7 (2021), 1–14.

[18] Gigi Berardi. 2004. Teaching Dance Skills: A Motor Learning and Development Approach. *Journal of Dance Medicine & Science* 8, 4 (2004), 125–125.

[19] Max V. Birk, Cheralyn Atkins, Jason T. Bowey, and Regan L. Mandryk. 2016. Fostering Intrinsic Motivation through Avatar Identification in Digital Games. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (San Jose, California, USA) *(CHI '16)*. Association for Computing Machinery, New York, NY, USA, 2982–2995. https://doi.org/10.1145/2858036.2858062

[20] Andri S Bjornsson, Elizabeth R Didie, and Katharine A Phillips. 2022. Body dysmorphic disorder. *Dialogues in clinical neuroscience* 12, 2 (2022), 221–232.

[21] Bettina Bläsing, Beatriz Calvo-Merino, Emily S Cross, Corinne Jola, Juliane Honisch, and Catherine J Stevens. 2012. Neurocognitive control in dance perception and performance. *Acta psychologica* 139, 2 (2012), 300–308.

[22] B Bläsing, G Tenenbaum, and T Schack. 2009. Cognitive structures of complex movements in dance. *Psychology of Sport and Exercise* 10 (2009), 350–360.

[23] Felix Born, Sophie Abramowski, and Maic Masuch. 2019. Exergaming in VR: The Impact of Immersive Embodiment on Motivation, Performance, and Perceived Exertion. In *2019 11th International Conference on Virtual Worlds and Games for Serious Applications (VS-Games)*. IEEE, Vienna, 1–8. https://doi.org/10.1109/VS-Games.2019.8864579

[24] Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative research in psychology* 3, 2 (2006), 77–101.

[25] Anne-Marie Burns, Richard Kulpa, Annick Durny, Bernhard Spanlang, Mel Slater, and Franck Multon. 2011. Using virtual humans and computer animations to learn complex motor skills: a case study in karate. In *BIO Web of Conferences*,

Vol. 1. EDP Sciences, Montpellier, France, 00012.

[26] Daniel W Carruth. 2017. Virtual reality for education and workforce training. In *2017 15th International Conference on Emerging eLearning Technologies and Applications (ICETA)*. IEEE, Stary Smokovec, Slovakia, 1–6.

[27] Jacky CP Chan, Howard Leung, Jeff KT Tang, and Taku Komura. 2010. A virtual reality dance training system using motion capture technology. *IEEE transactions on learning technologies* 4, 2 (2010), 187–195.

[28] Philo Tan Chua, Rebecca Crivella, Bo Daly, Ning Hu, Russ Schaaf, David Ventura, Todd Camill, Jessica Hodgins, and Randy Pausch. 2003. Training for physical tasks in virtual environments: Tai Chi. In *IEEE Virtual Reality, 2003. Proceedings.* IEEE, Los Angeles, CA, USA, 87–94.

[29] Alexandra Covaci, Anne-Hélène Olivier, and Franck Multon. 2014. Third Person View and Guidance for More Natural Motor Behaviour in Immersive Basketball Playing. In *Proceedings of the 20th ACM Symposium on Virtual Reality Software and Technology* (Edinburgh, Scotland) *(VRST '14)*. Association for Computing Machinery, New York, NY, USA, 55–64. https://doi.org/10.1145/2671015.2671023

[30] Emily S Cross, B Bläsing, M Puttke, and T Schack. 2010. Building a dance in the human brain: Insights from expert and novice dancers,. *The Neurocognition of Dance: Mind, Movement and Motor Skills* 1, 1 (2010), 177–202.

[31] Jeremy Dalton. 2021. *Reality check: how immersive technologies can transform your business: how immersive technologies can transform your business* (1 ed.). Kogan Page, New York.

[32] HSC Dance. 2022. HSC Dance - Kinaesthetic awareness. https://sites.google.com/education.nsw.gov.au/hscdance/core-performance/alignment-principles/kinaesthetic-awareness

[33] Marie-Christine Désy and Hugo Théoret. 2007. Modulation of motor cortex excitability by physical similarity with an observed hand action. *PLoS One* 2, 10 (2007), e971.

[34] Edward Downs, Nicholas D. Bowman, and Jaime Banks. 2019. A polythetic model of player-avatar identification: Synthesizing multiple mechanisms. *Psychology of Popular Media Culture* 8, 3 (2019), 269–279. https://doi.org/10.1037/ppm0000170 Place: US Publisher: Educational Publishing Foundation.

[35] Peter W. Dowrick. 1991. *Practical guide to using video in the behavioral sciences.* John Wiley & Sons, Oxford, England. Pages: xii, 335.

[36] Peter W. Dowrick. 1999. A review of self modeling and related interventions. *Applied and Preventive Psychology* 8, 1 (Dec. 1999), 23–39. https://doi.org/10.1016/S0962-1849(99)80009-2

[37] Peter W. Dowrick. 2012. Self model theory: learning from the future. *WIREs Cognitive Science* 3, 2 (2012), 215–230. https://doi.org/10.1002/wcs.1156 _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1002/wcs.1156.

[38] Peter W. Dowrick. 2012. Self modeling: Expanding the theories of learning. *Psychology in the Schools* 49, 1 (2012), 30–41. https://doi.org/10.1002/pits.20613 _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1002/pits.20613.

[39] Peter W. Dowrick, Weol Soon Kim-Rupnow, and Thomas J. Power. 2006. Video Feedforward for Reading. *J Spec Educ* 39, 4 (Feb. 2006), 194–207. https://doi.org/10.1177/00224669060390040101 Publisher: SAGE Publications Inc.

[40] Peter W. Dowrick and John M. Raeburn. 1995. Self-modeling: Rapid skill training for children with physical disabilities. *J Dev Phys Disabil* 7, 1 (March 1995), 25–37. https://doi.org/10.1007/BF02578712

[41] James E Driskell, Carolyn Copper, and Aidan Moran. 1994. Does mental practice enhance performance? *Journal of applied psychology* 79, 4 (1994), 481.

[42] Nicolas Ducheneaut, Ming-Hui Wen, Nicholas Yee, and Greg Wadley. 2009. Body and Mind: A Study of Avatar Personalization in Three Virtual Worlds. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Boston, MA, USA) *(CHI '09)*. Association for Computing Machinery, New York, NY, USA, 1151–1160. https://doi.org/10.1145/1518701.1518877

[43] Robert Andrew Dunn and Rosanna E Guadagno. 2012. My avatar and me–Gender and personality predictors of avatar-self discrepancy. *Computers in Human Behavior* 28, 1 (2012), 97–106.

[44] Daniel L Eaves, Gavin Breslin, Paul Van Schaik, Emma Robinson, and Iain R Spears. 2011. The short-term effects of real-time virtual reality feedback on motor learning in dance. *Presence: Teleoperators and Virtual Environments* 20, 1 (2011), 62–77.

[45] Kynan Eng, Ewa Siekierka, Pawel Pyk, Edith Chevrier, Yves Hauser, Monica Cameirao, Lisa Holper, Karin Hägni, Lukas Zimmerli, Armin Duff, et al. 2007. Interactive visuo-motor therapy system for stroke rehabilitation. *Medical & biological engineering & computing* 45, 9 (2007), 901–907.

[46] Andrew Feng, Evan Suma Rosenberg, and Ari Shapiro. 2017. Just-in-time, viable, 3-D avatars from scans. *Computer Animation and Virtual Worlds* 28, 3-4 (2017), e1769.

[47] Ronald A Finke. 1979. The functional equivalence of mental images and errors of movement. *Cognitive psychology* 11, 2 (1979), 235–264.

[48] Isabel Sophie Fitton, Jeremy Dalton, Michael J Proulx, and Christof Lutteroth. 2022. Dancing with the Avatars: Feedforward Learning from Self-Avatars. In *CHI Conference on Human Factors in Computing Systems Extended Abstracts* (New Orleans, LA, USA) *(CHI EA '22)*. Association for Computing Machinery, New York, NY, USA, Article 458, 8 pages. https://doi.org/10.1145/3491101.3519732

[49] A Floyer-Lea and PM Matthews. 2004. Changing brain networks for visuomotor control with increased movement automaticity. *Journal of neurophysiology* 92, 4 (2004), 2405–2412.

[50] Anna Floyer-Lea and Paul M Matthews. 2005. Distinguishable brain activation networks for short-and long-term motor skill learning. *Journal of neurophysiology* 94, 1 (2005), 512–518.

[51] Gerard G Fluet and Judith E Deutsch. 2013. Virtual reality for sensorimotor rehabilitation post-stroke: the promise and current state of the field. *Current physical medicine and rehabilitation reports* 1, 1 (2013), 9–20.

[52] Murray Forman and Mark Anthony Neal. 2004. *That's the joint!: the hip-hop studies reader.* Routledge, New York.

[53] Leonardo S Fortes, Sebastião S Almeida, Gibson M Praça, José RA Nascimento-Júnior, Dalton Lima-Junior, Bruno Teixeira Barbosa, and Maria EC Ferreira. 2021. Virtual reality promotes greater improvements than video-stimulation screen on perceptual-cognitive skills in young soccer athletes. *Human Movement Science* 79 (2021), 102856.

[54] Jesse Fox, Jeremy Bailenson, and Joseph Binney. 2009. Virtual experiences, physical behaviors: The effect of presence on imitation of an eating avatar. *Presence: Teleoperators and Virtual Environments* 18, 4 (2009), 294–303.

[55] Jesse Fox, Jeremy N Bailenson, and Tony Ricciardi. 2012. Physiological responses to virtual selves and virtual others. *Journal of CyberTherapy & Rehabilitation* 5, 1 (2012), 69–72.

[56] Cornelia Frank, Katharina Bekemeier, and Andrea Menze-Sonneck. 2021. Imagery training in school-based physical education improves the performance and the mental representation of a complex action in comprehensive school students. *Psychology of Sport and Exercise* 56 (2021), 101972.

[57] Cornelia Frank, Felix Hülsmann, Thomas Waltemate, David J Wright, Daniel L Eaves, Adam Bruton, Mario Botsch, and Thomas Schack. 2022. Motor imagery during action observation in virtual reality: the impact of watching myself performing at a level I have not yet achieved. *International Journal of Sport and Exercise Psychology* 0, 0 (2022), 1–27.

[58] Joakim Grant Frederiksen, Stine Maya Dreier Sørensen, Lars Konge, Morten Bo Søndergaard Svendsen, Morten Nobel-Jørgensen, Flemming Bjerrum, and Steven Arild Wuyts Andersen. 2019. Cognitive load and performance in immersive virtual reality versus conventional virtual reality simulation training of laparoscopic surgery: a randomized trial. *Surgical Endoscopy* 34, 3 (Jun 2019), 1244–1252. https://doi.org/10.1007/s00464-019-06887-8

[59] Guo Freeman, Divine Maloney, Dane Acena, and Catherine Barwulor. 2022. (Re)Discovering the Physical Body Online: Strategies and Challenges to Approach Non-Cisgender Identity in Social Virtual Reality. In *CHI Conference on Human Factors in Computing Systems* (New Orleans, LA, USA) *(CHI '22)*. Association for Computing Machinery, New York, NY, USA, Article 118, 15 pages. https://doi.org/10.1145/3491102.3502082

[60] Mar Gonzalez-Franco, Anna I Bellido, Kristopher J Blom, Mel Slater, and Antoni Rodriguez-Fornells. 2016. The neurological traces of look-alike avatars. *Frontiers in human neuroscience* 10 (2016), 392.

[61] Scott W Greenwald, Alexander Kulik, André Kunert, Stephan Beck, Bernd Fröhlich, Sue Cobb, Sarah Parsons, Nigel Newbutt, Christine Gouveia, Claire Cook, et al. 2017. Technology and applications for collaborative learning in virtual reality. In *Making a Difference: Prioritizing Equity and Access in CSCL.* International Society of the Learning Sciences., Philadelphia, PA.

[62] Julie Grezes and Jean Decety. 2001. Functional anatomy of execution, mental simulation, observation, and verb generation of actions: A meta-analysis. *Human brain mapping* 12, 1 (2001), 1–19.

[63] Shlomi Haar, Guhan Sundar, and A Aldo Faisal. 2021. Embodied virtual reality for the study of real-world motor learning. *Plos one* 16, 1 (2021), e0245717.

[64] Craig R Hall, Diane E Mack, Allan Paivio, and Heather A Hausenblas. 1998. Imagery use by athletes: development of the sport imagery questionnaire. *International Journal of Sport Psychology* 29, 1 (1998), 73–89.

[65] Yuji Hatada, Shigeo Yoshida, Takuji Narumi, and Michitaka Hirose. 2019. Double Shellf: What Psychological Effects can be Caused through Interaction with a Doppelganger?. In *Proceedings of the 10th Augmented Human International Conference 2019* (2019-03-11) *(AH2019)*. Association for Computing Machinery, New York, NY, USA, 1–8. https://doi.org/10.1145/3311823.3311862

[66] Andrew F. Hayes and Jacob J. Coutts. 2020. Use Omega Rather than Cronbach's Alpha for Estimating Reliability. But…. *Communication Methods and Measures* 14, 1 (2020), 1–24. https://doi.org/10.1080/19312458.2020.1718629 arXiv:https://doi.org/10.1080/19312458.2020.1718629

[67] CM Heyes and CL Foster. 2002. Motor learning by observation: evidence from a serial reaction time task. *The Quarterly Journal of Experimental Psychology Section A* 55, 2 (2002), 593–607.

[68] Caryl H. Hitchcock, Mary Anne Prater, and Peter W. Dowrick. 2004. Reading Comprehension and Fluency: Examining the Effects of Tutoring and Video Self-Modeling on First-Grade Students with Reading Difficulties. *Learning Disability Quarterly* 27, 2 (May 2004), 89–103. https://doi.org/10.2307/1593644 Publisher: SAGE Publications Inc.

[69] Yan Yin Ho, Eun-Young Yeo, and Dhaniah Suhana Binte Mohammad Wijaya. 2022. Turning Coffee Time into Teaching Moments Through Bite-Sized Learning

for Adult Learners. *The Journal of Continuing Higher Education* 0, 0 (2022), 1–16.

[70] Thuong N. Hoang, Martin Reinoso, Frank Vetere, and Egemen Tanin. 2016. Onebody: Remote Posture Guidance System Using First Person View in Virtual Environment. In *Proceedings of the 9th Nordic Conference on Human-Computer Interaction* (Gothenburg, Sweden) *(NordiCHI '16)*. Association for Computing Machinery, New York, NY, USA, Article 25, 10 pages. https://doi.org/10.1145/2971485.2971521

[71] Tobias Huber, Markus Paschold, Christian Hansen, Tom Wunderling, Hauke Lang, and Werner Kneist. 2017. New dimensions in surgical training: immersive virtual reality laparoscopic simulation exhilarates surgical staff. *Surg Endosc* 31, 11 (Nov. 2017), 4472–4477. https://doi.org/10.1007/s00464-017-5500-6

[72] Felix Hülsmann, Cornelia Frank, Irene Senna, Marc O Ernst, Thomas Schack, and Mario Botsch. 2019. Superimposed skilled performance in a virtual mirror improves motor performance and cognitive representation of a full body motor action. *Frontiers in Robotics and AI* 6 (2019), 43.

[73] Atsuki Ikeda, Yuka Tanaka, Dong-Hyun Hwang, Homare Kon, and Hideki Koike. 2019. Golf Training System Using Sonification and Virtual Shadow. In *ACM SIGGRAPH 2019 Emerging Technologies* (Los Angeles, California) *(SIGGRAPH '19)*. Association for Computing Machinery, New York, NY, USA, Article 14, 2 pages. https://doi.org/10.1145/3305367.3327993

[74] Anne R Isaac and David F Marks. 1994. Individual differences in mental imagery experience: developmental changes and specialization. *British Journal of Psychology* 85, 4 (1994), 479–500.

[75] Dewi Jaimangal-Jones, Annette Pritchard, and Nigel Morgan. 2015. Exploring dress, identity and performance in contemporary dance music culture. *Leisure Studies* 34, 5 (2015), 603–620.

[76] Jeffrey J Janssen and Anees A Sheikh. 1994. *Enhancing athletic performance through imagery: an overview.* Baywood Publishing Company, Amityville, New York, 1–22.

[77] Marc Jeannerod. 1994. The representing brain: Neural correlates of motor intention and imagery. *Behavioral and Brain sciences* 17, 2 (1994), 187–202.

[78] Marc Jeannerod. 2001. Neural simulation of action: a unifying mechanism for motor cognition. *Neuroimage* 14, 1 (2001), S103–S109.

[79] Lasse Jensen and Flemming Konradsen. 2018. A review of the use of virtual reality head-mounted displays in education and training. *Educ Inf Technol* 23, 4 (July 2018), 1515–1529. https://doi.org/10.1007/s10639-017-9676-0

[80] Wilsaan M Joiner and Maurice A Smith. 2008. Long-term retention explained by a model of short-term learning in the adaptive control of reaching. *Journal of neurophysiology* 100, 5 (2008), 2948–2955.

[81] Julia M Juliano and Sook-Lei Liew. 2020. Transfer of motor skill between virtual reality viewed using a head-mounted display and conventional screen environments. *Journal of neuroengineering and rehabilitation* 17, 1 (2020), 1–13.

[82] Yasmin B Kafai, Deborah A Fields, and Melissa S Cook. 2010. Your second selves: Player-designed avatars. *Games and culture* 5, 1 (2010), 23–42.

[83] Ni Kang, Ding Ding, M Birna Van Riemsdijk, Nexhmedin Morina, Mark A Neerincx, and Willem-Paul Brinkman. 2021. Self-identification with a Virtual Experience and Its Moderating Effect on Self-efficacy and Presence. *International Journal of Human–Computer Interaction* 37, 2 (2021), 181–196.

[84] Robert S Kennedy, Norman E Lane, Kevin S Berbaum, and Michael G Lilienthal. 1993. Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. *The international journal of aviation psychology* 3, 3 (1993), 203–220.

[85] James M Kilner and Roger N Lemon. 2013. What we know currently about mirror neurons. *Current biology* 23, 23 (2013), R1057–R1062.

[86] Hyun K Kim, Jaehyun Park, Yeongcheol Choi, and Mungyeong Choe. 2018. Virtual reality sickness questionnaire (VRSQ): Motion sickness measurement index in a virtual reality environment. *Applied ergonomics* 69 (2018), 66–73.

[87] Taeho Kim, Cornelia Frank, and Thomas Schack. 2017. A systematic investigation of the effect of action observation training and motor imagery training on the development of mental representation structure and skill performance. *Frontiers in human neuroscience* 11 (2017), 499.

[88] Marliese Kimmerle and Paulette Côté-Laurence. 2003. *Teaching dance skills: A motor learning and development approach.* Michael J Ryan, Andover, NJ: J.

[89] Emmanuelle P Kleinlogel, Marion Curdy, João Rodrigues, Carmen Sandi, and Marianne Schmid Mast. 2021. Doppelganger-based training: Imitating our virtual self to accelerate interpersonal skills learning. *PloS one* 16, 2 (2021), e0245960.

[90] Martin Kocur, Melanie Kloss, Valentin Schwind, Christian Wolff, and Niels Henze. 2020. Flexing Muscles in Virtual Reality: Effects of Avatars' Muscular Appearance on Physical Performance. In *Proceedings of the Annual Symposium on Computer-Human Interaction in Play* (Virtual Event, Canada) *(CHI PLAY '20)*. Association for Computing Machinery, New York, NY, USA, 193–205. https://doi.org/10.1145/3410404.3414261

[91] Ryota Kondo, Maki Sugimoto, Kouta Minamizawa, Takayuki Hoshi, Masahiko Inami, and Michiteru Kitazaki. 2018. Illusory body ownership of an invisible body interpolated between virtual hands and feet via visual-motor synchronicity. *Scientific Reports* 8, 1 (2018), 7541.

[92] Jordan Koulouris, Zoe Jeffery, James Best, Eamonn O'Neill, and Christof Lutteroth. 2020. Me vs. Super(Wo)Man: Effects of Customization and Identification in a VR Exergame. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI '20)*. Association for Computing Machinery, New York, NY, USA, 1–17. https://doi.org/10.1145/3313831.3376661

[93] John W Krakauer, Alkis M Hadjiosif, Jing Xu, Aaron L Wong, and Adrian M Haith. 2019. Motor learning. *Compr Physiol* 9, 2 (2019), 613–663.

[94] Peter J Lang. 1979. A bio-informational theory of emotional imagery. *Psychophysiology* 16, 6 (1979), 495–512.

[95] Gavin Lawrence, Nichola Callow, and Ross Roberts. 2013. Watch me if you can: imagery ability moderates observational learning effectiveness. *Frontiers in human neuroscience* 7 (2013), 522.

[96] Serena Lee-Cultura, Kshitij Sharma, Sofia Papavlasopoulou, Symeon Retalis, and Michail Giannakos. 2020. Using Sensing Technologies to Explain Children's Self-Representation in Motion-Based Educational Games. In *Proceedings of the Interaction Design and Children Conference* (London, United Kingdom) *(IDC '20)*. Association for Computing Machinery, New York, NY, USA, 541–555. https://doi.org/10.1145/3392063.3394419

[97] Natasha Lelievre, Laura St Germain, and Diane M Ste-Marie. 2021. Varied speeds of video demonstration do not influence the learning of a dance skill. *Human Movement Science* 75 (2021), 102749.

[98] Kelvin Leong, Anna Sung, David Au, and Claire Blanchard. 2020. A review of the trend of microlearning. *Journal of Work-Applied Management* 13, 1 (2020), 88–102.

[99] Danielle E Levac and Bojan B Jovanovic. 2017. Is children's motor learning of a postural reaching task enhanced by practice in a virtual environment?. In *2017 International Conference on Virtual Rehabilitation (ICVR)*. IEEE, Montreal, QC, Canada, 1–7.

[100] Sook-Lei Liew, Shihui Han, and Lisa Aziz-Zadeh. 2011. Familiarity modulates mirror neuron and mentalizing regions during intention understanding. *Human brain mapping* 32, 11 (2011), 1986–1997.

[101] Yen-Nan Lin, Lu-Ho Hsia, Meng-Yuan Sung, and Gwo-Haur Hwang. 2019. Effects of integrating mobile technology-assisted peer assessment into flipped learning on students' dance skills and self-efficacy. *Interactive Learning Environments* 27, 8 (2019), 995–1010.

[102] J.-L. Lugrin, J. Latt, and M. E. Latoschik. 2015. Anthropomorphism and Illusion of Virtual Body Ownership. In *Proceedings of the 25th International Conference on Artificial Reality and Telexistence and 20th Eurographics Symposium on Virtual Environments* (Kyoto, Japan) *(ICAT - EGVE '15)*. Eurographics Association, Goslar, DEU, 1–8.

[103] Erin MacAfee and Gilles Comeau. 2020. Exploring music performance anxiety, self-efficacy, performance quality, and behavioural anxiety within a self-modelling intervention for young musicians. *Music Education Research* 22, 4 (2020), 1–21.

[104] Heidy Maldonado and Clifford Nass. 2007. Emotive characters can make learning more productive and enjoyable: it takes two to learn to tango. *Educational Technology* 47, 1 (2007), 33–38.

[105] Manon Marinussen and Alwin de Rooij. 2019. Being Yourself to Be Creative: How Self-Similar Avatars Can Support the Generation of Original Ideas in Virtual Environments. In *Proceedings of the 2019 on Creativity and Cognition* (San Diego, CA, USA). Association for Computing Machinery, New York, NY, USA, 285–293. https://doi.org/10.1145/3325480.3325482

[106] Ben Marshall and David J Wright. 2016. Layered stimulus response training versus combined action observation and imagery: Effects on golf putting performance and imagery ability characteristics. *Journal of Imagery Research in Sport and Physical Activity* 11, 1 (2016), 35–46.

[107] Andrew AG Mattar and Paul L Gribble. 2005. Motor learning by observing. *Neuron* 46, 1 (2005), 153–160.

[108] Edward McAuley, Terry Duncan, and Vance V. Tammen. 1989. Psychometric Properties of the Intrinsic Motivation Inventory in a Competitive Sport Setting: A Confirmatory Factor Analysis. *Research Quarterly for Exercise and Sport* 60, 1 (1989), 48–58. https://doi.org/10.1080/02701367.1989.10607413 PMID: 2489825.

[109] Penny McCullagh, Barbi Law, and Diane Ste-Marie. 2012. 250 Modeling and Performance. In *The Oxford Handbook of Sport and Performance Psychology*. Oxford University Press, Oxford. https://doi.org/10.1093/oxfordhb/9780199731763.013.0013

[110] Eoghan McNeill, Adam J Toth, Niall Ramsbottom, and Mark J Campbell. 2021. Self-modelled versus skilled-peer modelled AO+ MI effects on skilled sensorimotor performance: A stage 2 registered report. *Psychology of Sport and Exercise* 54 (2021), 101910.

[111] Aidan P Moran, Mark Campbell, Paul Holmes, and Tadhg MacIntyre. 2012. Mental imagery, action observation and skill learning. In *NJ Hodges, and AM Williams (eds.). Skill Acquisition in Sport: Research, Theory and Practice (2nd edition)*. Routledge (Taylor and Francis), New York, NY, 94–111.

[112] Masahiro Mori. 2012. The uncanny valley: the original essay by Masahiro Mori. https://spectrum.ieee.org/the-uncanny-valley

[113] Brendan Mouatt, Ashleigh E Smith, Maddison L Mellow, Gaynor Parfitt, Ross T Smith, and Tasha R Stanton. 2020. The use of virtual reality to influence motivation, affect, enjoyment, and engagement during exercise: A scoping review. *Frontiers in Virtual Reality* 1 (2020), 564664.

[114] Jessica Navarro, Jorge Peña, Ausias Cebolla, and Rosa Baños. 2020. Can Avatar Appearance Influence Physical Activity? User-Avatar Similarity and Proteus Effects on Cardiac Frequency and Step Counts. *Health Communication* 37, 2 (2020), 1–8.

[115] Behnaz Nojavanasghari, Charles E. Hughes, and Louis-Philippe Morency. 2017. Exceptionally Social: Design of an Avatar-Mediated Interactive System for Promoting Social Skills in Children with Autism. In *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems* (Denver, Colorado, USA) *(CHI EA '17)*. Association for Computing Machinery, New York, NY, USA, 1932–1939. https://doi.org/10.1145/3027063.3053112

[116] Sanna M Nordin and Jennifer Cumming. 2005. Professional dancers describe their imagery: where, when, what, why, and how. *Sport Psychologist* 19, 4 (2005), 395–417.

[117] Sanna M Nordin and Jennifer Cumming. 2007. Where, when, and how: A quantitative account of dance imagery. *Research Quarterly for Exercise and Sport* 78, 4 (2007), 390–395.

[118] Takayuki Nozawa, Erwin Wu, and Hideki Koike. 2019. Vr ski coach: Indoor ski training system visualizing difference from leading skier. In *2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*. IEEE, Osaka, Japan, 1341–1342.

[119] Yoonsin Oh and Stephen Yang. 2010. Defining exergames & exergaming. *Proceedings of meaningful play* 2010 (2010), 21–23.

[120] Néstor Ordaz, David Romero, Dominic Gorecky, and Héctor R. Siller. 2015. Serious Games and Virtual Simulator for Automotive Manufacturing Education & Training. *Procedia Computer Science* 75 (Jan. 2015), 267–274. https://doi.org/10.1016/j.procs.2015.12.247

[121] Allan Paivio. 1985. Cognitive and motivational functions of imagery in human performance. *Canadian journal of applied sport sciences. Journal canadien des sciences appliquées au sport* 10, 4 (1985), 22S–28S.

[122] John K Parker, Geoff P Lovell, and Martin I Jones. 2021. An examination of imagery ability and imagery use in skilled golfers. *Journal of Imagery Research in Sport and Physical Activity* 16, 1 (2021), 20210006.

[123] Jocelyn Parong, Kimberly A Pollard, Benjamin T Files, Ashley H Oiknine, Anne M Sinatra, Jason D Moss, Antony Passaro, and Peter Khooshabeh. 2020. The mediating role of presence differs across types of spatial learning in immersive technologies. *Computers in human behavior* 107 (2020), 106290.

[124] Cale J. Passmore, Max V. Birk, and Regan L. Mandryk. 2018. The Privilege of Immersion: Racial and Ethnic Experiences, Perceptions, and Beliefs in Digital Gaming. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI '18)*. Association for Computing Machinery, New York, NY, USA, 1–19. https://doi.org/10.1145/3173574.3173957

[125] Jorge Peña, Subuhi Khan, and Cassandra Alexopoulos. 2016. I am what I see: How avatar and opponent agent body size affects physical activity among men playing exergames. *Journal of Computer-Mediated Communication* 21, 3 (2016), 195–209.

[126] Laura Petrosini, Alessandro Graziano, Laura Mandolesi, Paola Neri, Marco Molinari, and Maria G Leggio. 2003. Watch how to do it! New advances in learning by observation. *Brain research reviews* 42, 3 (2003), 252–264.

[127] Jorge Peña and Eunice Kim. 2014. Increasing exergame physical activity through self and opponent avatar appearance. *Computers in Human Behavior* 41 (2014), 262–267. https://doi.org/10.1016/j.chb.2014.09.038

[128] Sally Anne Radell, Margaret Lynn Keneman, Daniel D Adame, and Steven P Cole. 2014. My body and its reflection: a case study of eight dance students and the mirror in the ballet classroom. *Research in Dance Education* 15, 2 (2014), 161–178.

[129] Katherine M. Rahill and Marc M. Sebrechts. 2021. Effects of Avatar player-similarity and player-construction on gaming performance. *Computers in Human Behavior Reports* 4 (2021), 100131. https://doi.org/10.1016/j.chbr.2021.100131

[130] Rabindra Ratan, David Beyea, Benjamin J Li, and Luis Graciano. 2020. Avatar characteristics induce users' behavioral conformity with small-to-medium effect sizes: A meta-analysis of the proteus effect. *Media Psychology* 23, 5 (2020), 651–675.

[131] Rabindra Ratan, Matthew S Klein, Chimobi R Ucha, and Leticia L Cherchiglia. 2022. Avatar customization orientation and undergraduate-course outcomes: Actual-self avatars are better than ideal-self and future-self avatars. *Computers & Education* 191 (2022), 104643.

[132] Rabindra Ratan, RV Rikard, Celina Wanek, Madison McKinley, Lee Johnson, and Young June Sah. 2016. Introducing avatarification: An experimental examination of how avatars influence student motivation. In *2016 49th Hawaii International Conference on System Sciences (HICSS)*. IEEE, Koloa, HI, USA, 51–59.

[133] Rabindra A Ratan and Michael Dawson. 2016. When Mii is me: A psychophysiological examination of avatar self-relevance. *Communication Research* 43, 8 (2016), 1065–1093.

[134] Ross Roberts, Nichola Callow, Lew Hardy, David Markland, and Joy Bringer. 2008. Movement imagery ability: development and assessment of a revised version of the vividness of movement imagery questionnaire. *Journal of Sport and Exercise Psychology* 30, 2 (2008), 200–221.

[135] Nicolas Robin, Laurent Dominique, Lucette Toussaint, Yannick Blandin, Aymeric Guillot, and Michel Le Her. 2007. Effects of motor imagery training on service return accuracy in tennis: The role of imagery ability. *International Journal of Sport and Exercise Psychology* 5, 2 (2007), 175–186.

[136] Sue Rourke. 2020. How does virtual reality simulation compare to simulated practice in the acquisition of clinical psychomotor skills for pre-registration student nurses? A systematic review. *International journal of nursing studies* 102 (2020), 103466.

[137] Thomas Schubert, Frank Friedmann, and Holger Regenbrecht. 2001. The experience of presence: Factor analytic insights. *Presence: Teleoperators & Virtual Environments* 10, 3 (2001), 266–281.

[138] Dale H Schunk. 1987. Peer models and children's behavioral change. *Review of educational research* 57, 2 (1987), 149–174.

[139] Dale H Schunk and Antoinette R Hanson. 1989. Influence of peer-model attributes on children's beliefs and learning. *Journal of Educational Psychology* 81, 3 (1989), 431.

[140] Dale H Schunk, Antoinette R Hanson, and Paula D Cox. 1987. Peer-model attributes and children's achievement behaviors. *Journal of educational psychology* 79, 1 (1987), 54.

[141] Valentin Schwind, Pascal Knierim, Cagri Tasci, Patrick Franczak, Nico Haas, and Niels Henze. 2017. *"These Are Not My Hands!": Effect of Gender on the Perception of Avatar Hands in Virtual Reality*. Association for Computing Machinery, New York, NY, USA, 1577–1582. https://doi.org/10.1145/3025453.3025602

[142] Deirdre Scully and Evelyn Carnegie. 1998. Observational learning in motor skill acquisition: A look at demonstrations. *The Irish Journal of Psychology* 19, 4 (1998), 472–485.

[143] Matias N Selzer, Nicolas F Gazcon, and Martin L Larrea. 2019. Effects of virtual presence and learning outcome using low-end virtual reality systems. *Displays* 59 (2019), 9–15.

[144] Roland Sigrist, Georg Rauter, Laura Marchal-Crespo, Robert Riener, and Peter Wolf. 2015. Sonification and haptic feedback in addition to visual feedback enhances complex motor task learning. *Experimental brain research* 233, 3 (2015), 909–925.

[145] 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, 1 (2013), 21–53.

[146] Mary Sirridge and Adina Armelagos. 1977. The In's and Out's of Dance: Expression as an Aspect of Style. *The Journal of Aesthetics and Art Criticism* 36, 1 (1977), 15–24.

[147] Mel Slater, Bernhard Spanlang, Maria V Sanchez-Vives, and Olaf Blanke. 2010. First person experience of body transfer in virtual reality. *PLOS One* 5, 5 (2010), e10564.

[148] Diane M Ste-Marie, Natasha Lelievre, and Laura St. Germain. 2020. Revisiting the applied model for the use of observation: A review of articles spanning 2011–2018. *Research quarterly for exercise and sport* 91, 4 (2020), 594–617.

[149] Kylie A Steel, Roger D Adams, Susan E Coulson, Colleen G Canning, and Holly J Hawtin. 2013. Video Self-model Training of Punt Kicking. *Int. J. Sport Health Sci.* 11, 0 (2013), 49–53. https://doi.org/10.5432/ijshs.201233

[150] Katherine E Sukel, Richard Catrambone, Irfan Essa, and Gabriel Brostow. 2003. Presenting movement in a computer-based dance tutor. *International Journal of Human-Computer Interaction* 15, 3 (2003), 433–452.

[151] Mohsen Tavakol and Reg Dennick. 2011. Making sense of Cronbach's alpha. *International journal of medical education* 2 (2011), 53.

[152] Yin-Leng Theng and Paye Aung. 2012. Investigating effects of avatars on primary school children's affective responses to learning. *Journal on Multimodal user interfaces* 5, 1 (2012), 45–52.

[153] Emanuel Todorov, Reza Shadmehr, and Emilio Bizzi. 1997. Augmented feedback presented in a virtual environment accelerates learning of a difficult motor task. *Journal of motor behavior* 29, 2 (1997), 147–158.

[154] Milka Trajkova, A'aeshah Alhakamy, Francesco Cafaro, Rashmi Mallappa, and Sreekanth R. Kankara. 2020. Move Your Body: Engaging Museum Visitors with Human-Data Interaction. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI '20)*. Association for Computing Machinery, New York, NY, USA, 1–13. https://doi.org/10.1145/3313831.3376186

[155] Selen Turkay and Charles Kinzer. 2014. The effects of avatar-based customization on player identification. *International Journal of Gaming and Computer-Mediated Simulations* 6, 1 (2014), Article–number.

[156] Nikolaos Vernadakis, Asimenia Gioftsidou, Panagiotis Antoniou, Dionysis Ioannidis, and Maria Giannousi. 2012. The impact of Nintendo Wii to physical education students' balance compared to the traditional approaches. *Computers & Education* 59, 2 (2012), 196–205.

[157] Thomas Waltemate, Dominik Gall, Daniel Roth, Mario Botsch, and Marc Erich Latoschik. 2018. The Impact of Avatar Personalization and Immersion on

Virtual Body Ownership, Presence, and Emotional Response. *IEEE Transactions on Visualization and Computer Graphics* 24, 4 (2018), 1643–1652. https://doi.org/10.1109/TVCG.2018.2794629

[158] Laurel Wamsley. 2021. A Guide To Gender Identity Terms. https://www.npr.org/2021/06/02/996319297/gender-identity-pronouns-expression-guide-lgbtq

[159] Ning Wang, Ari Shapiro, Andrew Feng, Cindy Zhuang, Chirag Merchant, David Schwartz, and Stephen L Goldberg. 2018. Learning by explaining to a digital doppelganger. In *International Conference on Intelligent Tutoring Systems*. Springer, Cham, 256–264.

[160] Paul Watson and Dan Livingstone. 2018. Using mixed reality displays for observational learning of motor skills: A design research approach enhancing memory recall and usability. *Research in Learning Technology* 26 (2018), 2129.

[161] Maureen R Weiss, Penny McCullagh, Alan L Smith, and Anthony R Berlant. 1998. Observational learning and the fearful child: Influence of peer models on swimming skill performance and psychological responses. *Research quarterly for exercise and sport* 69, 4 (1998), 380–394.

[162] Sarah E Williams. 2019. Comparing movement imagery and action observation as techniques to increase imagery ability. *Psychology of Sport and Exercise* 44 (2019), 99–106.

[163] Jeremy D Wong, Dinant A Kistemaker, Alvin Chin, and Paul L Gribble. 2012. Can proprioceptive training improve motor learning? *Journal of neurophysiology* 108, 12 (2012), 3313–3321.

[164] Erwin Wu, Florian Perteneder, Hideki Koike, and Takayuki Nozawa. 2019. How to VizSki: Visualizing Captured Skier Motion in a VR Ski Training Simulator. In *Proceedings of the 17th International Conference on Virtual-Reality Continuum and Its Applications in Industry* (Brisbane, QLD, Australia) *(VRCAI '19)*. Association for Computing Machinery, New York, NY, USA, Article 5, 9 pages. https://doi.org/10.1145/3359997.3365698

[165] Shengjie Yao and Gyoung Kim. 2019. The effects of immersion in a virtual reality game: Presence and physical activity. In *International Conference on Human-Computer Interaction*. Springer, Cham, 234–242.

[166] Nick Yee and Jeremy Bailenson. 2007. The Proteus effect: The effect of transformed self-representation on behavior. *Human communication research* 33, 3 (2007), 271–290.