Skye's Edge: Designing an Adaptive Virtual Coach for Skateboarding Mastery

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Abstract

This project develops Skye, a virtual skateboarding coach, to assist users in mastering skills through adaptive, engaging interactions. Skye uses real-time sensor data to provide tailored feedback, emotional expressions, and biomechanical overlays. By celebrating successes, offering empathetic support, and demonstrating techniques, Skye ensures an intuitive and motivating experience. Drawing on research in virtual coaching and emotional modeling, the system adapts to the dynamic nature of skateboarding, promoting skill improvement and sustained motivation.

CCS CONCEPTS • HCI • Virtual Human • Interaction Design • Emotional Modeling

1 Introduction

Virtual humans are digital representations of people that use artificial intelligence and animations to interact with users in ways that feel natural and human-like. They can communicate using both verbal and non-verbal methods, like speech, gestures, and facial expressions. One area where virtual humans are becoming increasingly popular is coaching, where they can help users learn new skills or achieve personal goals in a non-judgmental environment.

As coaches, virtual humans can offer personalized support, feedback, and encouragement. They are able to analyze a user's actions, adapt to their needs, and even simulate emotions to create a more engaging experience. Because they rely on data and algorithms, virtual human coaches can provide tailored advice, which makes them useful in various settings, from sports and fitness to helping people build healthier habits. Since they are available anytime and don't get tired or need breaks, they can fill in when human coaches aren't accessible.

In sports and fitness, virtual human coaches have shown promise in helping users improve their skills, stay active, and adopt healthier lifestyles. These systems can guide users through exercises, provide tips on technique, and keep them motivated. By creating a supportive and non-judgmental environment, virtual human coaches make it easier for people to stay committed to their fitness goals and enjoy being active, even without the need for in-person coaching.

2 Related Work

In developing a virtual human coach for skateboarding, we reviewed existing research on virtual coaching for physical activities to identify foundational approaches and insights. While no studies specifically addressed skateboarding, a variety of relevant works in lifestyle coaching and balance movement provided valuable perspectives.

For this project, we looked into research related to creating a virtual human coach for sports, specifically focusing on how we could apply these ideas to skateboarding. While we didn't find any studies directly about skateboarding, we came across some interesting research in coaching for promoting a more healthy lifestyle and encouraging activities, and other specific fields such as movement therapy.

Our investigation highlighted key approaches to fostering natural and intuitive interaction with users and the importance of designing a virtual human capable of expressing emotions. Emotional modeling was found to be critical for motivating users and enhancing engagement through communication that feels authentic and personalized.

We also examined the limitations encountered in existing systems. These are challenges we will need to keep in mind as we work on our skateboarding coach. Overall, the research helped us build ideas and gave us a better understanding of what works and what doesn't when it comes to virtual human coaching.

2.1 The Role of Emotions in User Engagement

In task-oriented scenarios, such as achieving a daily walking distance goal, emotional cues play a crucial role in aligning the coach's demeanor with the user's needs. For example, a happy and enthusiastic virtual coach can encourage persistence, while an emotionally intense coach expressing determination may inspire users to push harder toward performance goals.

Virtual humans that can mimic natural emotions are particularly impactful thanks to their ability to adapt their expressions to suit the context of the interaction. In fitness environments, where users may experience fatigue or frustration, the empathetic expressions of a virtual coach can act as a form of emotional support, helping users overcome barriers and maintain a positive outlook. These characters are not just facilitators of instruction but also partners in the user's journey, making them integral to the broader coaching experience. By mirroring the emotional tone of the interaction, virtual coaches create an environment of mutual understanding and collaboration, which can be especially motivating in scenarios where users might otherwise feel isolated or discouraged.

Moreover, emotionally intelligent responses have been shown to influence not only how users perceive their coaches but also how they view their own performance. Positive emotional expressions from a coach can reinforce a user's sense of accomplishment, boosting confidence and fostering a growth mindset. Beyond user motivation, the ability of emotional virtual characters to engage users has implications for broader applications in education, rehabilitation, and mental health. For instance, in learning environments, an emotionally intelligent virtual tutor can adapt to a student's frustration by offering encouragement, turning moments of difficulty into opportunities for growth.

Virtual coaches that have the ability to sustain emotionally intelligent dialogues bring an essential human element to digital coaching systems, enhancing both the effectiveness and the enjoyment of user interactions. Their ability to motivate, engage, and support users through emotionally intelligent responses positions them as vital components of next-generation virtual coaching technologies.

2.2 Behavioral Sciences in LLM-Based Coaching

Many virtual coaches are developed integrating behavioral science principles in large language models (LLM). These principles aim to create more human-like interactions by emphasizing key coaching attributes such as actionability, realism, motivation, and empathy. One study in particular demonstrates how these attributes can be incorporated into coaching systems through the use of coach phrase priming, a technique that uses linguistic prompts and enhances the motivational impact of coaching dialogues. "Manual review also judged coach phrase priming as providing significantly greater motivation and concrete coaching strategies versus the unprimed LM. This suggests that Coach phrase priming may be an effective and accessible strategy for customising LLMs for various coaching scenarios.'' (Hedge, 11) This approach follows well-established psychological theories that highlight the importance of language in shaping behavior and attitudes.

2.3 Limitations

Several limitations are evident across the reviewed studies, highlighting areas for further exploration and improvement. A common constraint lies in the evaluation methodologies, which often rely on simulations or short-term experiments. These approaches fail to capture the complexity of real-world scenarios or the long-term engagement patterns of users. Moreover, many studies are restricted to specific, structured activities such as golf swings or VR boxing, limiting their applicability to different sports like skateboarding.

The representation of emotions in virtual coaching systems is another area with significant limitations. Simplistic depictions of emotional states, such as happiness or anger, do not account for the subtleties and complexities of mixed emotions that may resonate more deeply with users. Similarly, feedback mechanisms in many systems are unidirectional or overly rigid, which can lead to disengagement over time. This lack of adaptability is particularly problematic in dynamic sports contexts, where real-time adjustments to coaching strategies are essential.

Finally, while nonverbal and verbal communication strategies have shown promise, their static nature restricts their potential for broader application. Few systems integrate real-time adaptation, which is crucial for maintaining relevance and engagement in activities where user performance evolves over time. Addressing these limitations could significantly enhance the effectiveness of virtual coaching systems.

2.4 Software architectures for virtual agents

Building software architectures for virtual agents is essential to making them interactive, engaging, and capable of meaningful communication. These architectures act as the backbone, ensuring that virtual agents can understand, respond, and interact with users in a way that feels natural and intuitive. Over the years, significant progress has been made in creating flexible systems that allow agents to integrate various behaviors and adapt to different interaction scenarios.

One of the most important aspects of modern architectures is modularity, which makes it easier to manage the many components that virtual agents rely on. For example, frameworks like the Behavior Markup Language (BML) and the SAIBA architecture divide the agent's tasks into stages: planning the agent's intent, deciding on appropriate behaviors, and then realizing these behaviors through speech, gestures, or facial expressions. This clear separation helps developers mix and match components, like facial expression generation or gesture synthesis, without worrying about breaking the system. These modular designs are also highly adaptable, which is crucial for applications ranging from education to healthcare.

Another important aspect in virtual agents architectures is enabling multimodal interaction, in order for them to combine different forms of communication, like speech, gestures, and facial expressions, enhancing a more natural dialog with the user. Being able "to include behaviors that are visible, communicative, and linked to the on-going speech" (Pelachaud, 263) is vital for assuring non-verbal communication, which has a deep meaning in the dialog, according to social science. For instance, when an agent speaks, it might also smile, nod, or use hand gestures to reinforce its message. Studies show that when these behaviors are synchronized properly, users perceive the agent as more natural and engaging.

Adaptability is another growing area of focus in virtual agent architectures. More advanced systems are being designed to learn from user interactions and adjust their behavior over time. For instance, an educational agent might adapt its teaching style based on how quickly a student is learning. This kind of responsiveness often involves integrating machine learning into the architecture, allowing the agent to make smarter decisions based on the user's feedback and performance. Such adaptability makes virtual agents more effective in long-term interactions, as they can evolve alongside the users they are supporting

3 Illustrative Scenario

This scenario illustrates a possible use case for such virtual coach, in this we also try to give a proper idea of what our focuses will be while we design our system. The scenario can be entitled "learning a kickflip with a virtual skate coach".

3.1 Context

Alexandre, a 16-year-old aspiring skateboarder, straps on their helmet and launches the "Skate Coach" app on their phone. The app connects wirelessly to sensors embedded in Alex's skateboard and shoes, providing real-time data to a virtual human coach named Skye. Skye appears on Alex's phone as an animated, energetic skateboarder with a friendly demeanor, wearing a backward cap and oversized hoodie.

3.2 Interaction begins: greeting & motivation

The app opens with Skye waving and smiling broadly. "Hey Alex! Ready to shred today? I thought we could tackle that kickflip you've been working on. You're so close—I can feel it!"
Alex nods and taps the "Start Session" button. Skye gives a thumbs-up animation and says, "Let's warm up first. Give me three solid ollies!"

3.3 Real-time feedback & encouragement

Alex performs an ollie, and Skye's virtual character mimics the movement, showing the proper form alongside Alex's performance data on the screen. "Nice pop!" Skye says, leaning forward with a smile. "But see how your front foot isn't sliding up the board smoothly? Try again, but think about dragging your foot all the way to the edge."

Alex tries again. The sensors track the board's motion and Alex's movements. A diagram appears on the side of the screen, overlaying Alex's performance with an ideal kickflip motion. "That's it! Your foot placement is much better now," Skye says, with an encouraging fist pump.

3.4 Addressing frustration: Adaptive emotion

After a few failed attempts, Alex sighs and looks down at the phone. Skye's expression softens, tilting their head slightly. "I get it—this trick can be a real beast. But hey, every skater wipes out before they land it. Let's break it down together, okay?"

Skye then shifts into a focused expression and demonstrates the kickflip in slow motion with exaggerated movements. "Watch this—see how my front foot flicks off the edge of the board? You've got this!"

3.5 Positive Reinforcement & Celebration

Finally, after a few more tries, Alex lands a shaky but complete kickflip. Skye throws their arms in the air, spinning their virtual board in excitement. "YES, Alex! That was killer! Did you feel that sweet flick? Let's do it again to lock it in!"

Alex laughs and sets up for another attempt, feeling motivated. Skye's energy and celebratory animations make the success feel shared and rewarding.

3.6 Wrapping up: Progress reflection

After the session, Skye sits down cross-legged in the app, smiling warmly. "That was rad! You nailed the kickflip twice today, and your ollies are getting so consistent. I've logged your progress, so next time we'll work on landing it cleaner. Until then, keep practicing and keep being awesome!"

The app logs Alex's session, showing stats like trick success rate and areas to improve. Skye waves goodbye and fades out with a cheerful, "Catch you later, skater!"

4 Social behaviors

Here we'll describe how our coach shall behave in specific scenes & context. Highlighting the interactions & intents we have while designing such a coach.

4.1 Empathy & adaptability

Skye should dynamically respond to Alex's emotions, such as showing understanding and offering encouragement when Alex feels frustrated (as seen in 3.4 of the scenario and supported by findings about emotion contagion from the first paper).

4.2 Interactive feedback

Provide detailed, real-time analysis of performance, blending visual aids (e.g., overlaid diagrams) with verbal feedback to guide learning effectively. The use of tailored feedback mirrors findings that personalized coaching increases both intrinsic and extrinsic motivation.

4.3 Celebratory responses

Skye should visibly and energetically celebrate successes with Alex, fostering a sense of accomplishment and motivation. Research shows that reinforcing achievements with positive gestures and words enhances enjoyment and competence perception.

4.4 Coaching styles through movement

Skye's animations and gestures should convey confidence and positivity, using expansive, fluid, and coordinated movements (as suggested by full-body kinematic studies). For instance, subtle adjustments like smoother animations during encouragement or sharper movements during corrections can enhance the perception of supportiveness and reliability.

4.5 Persistent goal-oriented support

Maintain a consistent focus on long-term progress while adjusting the intensity of interactions based on Alex's immediate needs and performance. This aligns with how adaptive and persuasive feedback sustains motivation.

4.6 Design

To have an idea of Skye's behavior, here is some draft of facial emotions made on MARC(Simon's model), one that is an approval face (figure 1) and the other is an emotion representing disappointment(figure 2). For a coach teaching a sport, one of the most important aspects (in sports in general) is the preparation, thus an animation of head-stretching has been created. The idea later on, will be to create a complete session of preparation between Alex and Skye. The two emotions modeled below should be used to give a proper answer to Alex's dedication to the preparation, if Alex is doing good then Skye responds with an approval face otherwise it's the angry/disappointed face awaiting Alex.

Figure 1: approval face

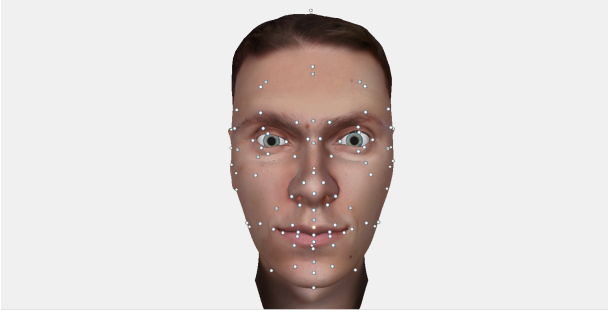
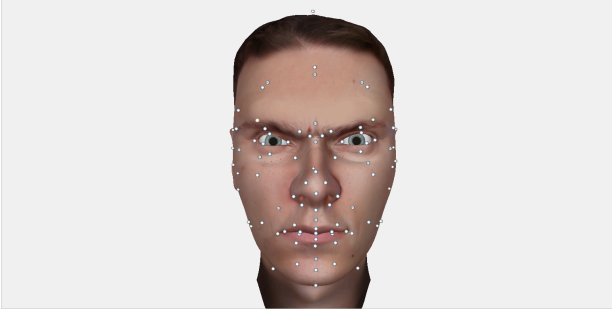


Figure 2: disappointment face



4 Emotions to express

By integrating these behaviors and emotional expressions, the virtual skate coach can create an engaging, motivating, and empathetic coaching experience tailored to Alex's journey. This design also incorporates research findings on how emotional engagement and adaptive feedback enhance user performance and satisfaction.

Table 1: Emotions of the virtual coach for global situations

Emotions	User Situation	Description
Encouragement	Attempting difficult or new tricks.	Positivity through facial expressions (smiles, raised brows) & vocal tones to express support
Empathy	Struggling to do a trick	Mix of concern & encouragement, using slower tones & gestures (leaning forward or tilting head) to display understanding.
Excitement & Joy	Achievements & triumphs	Exaggerated animations (jumping, spinning, …) to emotionally share the wins and create a sense of shared success.

Emotions	User Situation	Description
Determination	Skill demonstration	Serious yet encouraging demeanor, precise and deliberate movements. Emphasizing the importance of mastering the technique.
Resilience	Need for improvements	Expressing confidence and using motivational language, blending warmth with constructive criticism. Making user feel capable of improvement

7 System Implementation

7.1 State Machine

The implemented state machine offers a structured overview of how the virtual coach would behave in an actual use case. Thus detailing the sequential process through which the system interacts with the user. Such design ensures a comprehensive experience overview, for Skye it’s done through warm-up exercises, balance activities, and specific skateboard moves [Fig. 3].

The initial interaction begins with a welcoming gesture, followed by a choice between either preparatory activities —focused on balance & stretching— or a demonstration and explanation of specific skateboarding moves followed by an assessment phase leading then to a success or fail reaction from the coach.

The virtual coach’s primary objective is to facilitate either warm-up routines through balance exercises & stretches or learning skateboarding techniques, through accurate and well-explained demonstrations coupled with tailored reactions

7.2 Architecture

The architectural scheme [Fig. 4] inspires the logic of the state machine, providing detailed insights into the coach's physical behaviors and responses. The design incorporates tailored gestures and postures that reflect various relevant emotions throughout the session’s steps.

The virtual coach initiates interactions by waving during greetings, reinforcing user engagement through non-verbal communication. Later on, disapproval is expressed through subtle nods, while successful actions are acknowledged with applause.

This integration of physical gestures ensures that the virtual coach's interactions remain dynamic and contextually appropriate, fostering a sense of connection and motivation throughout the user's progression.

Figure 3: state machine (within MARC)

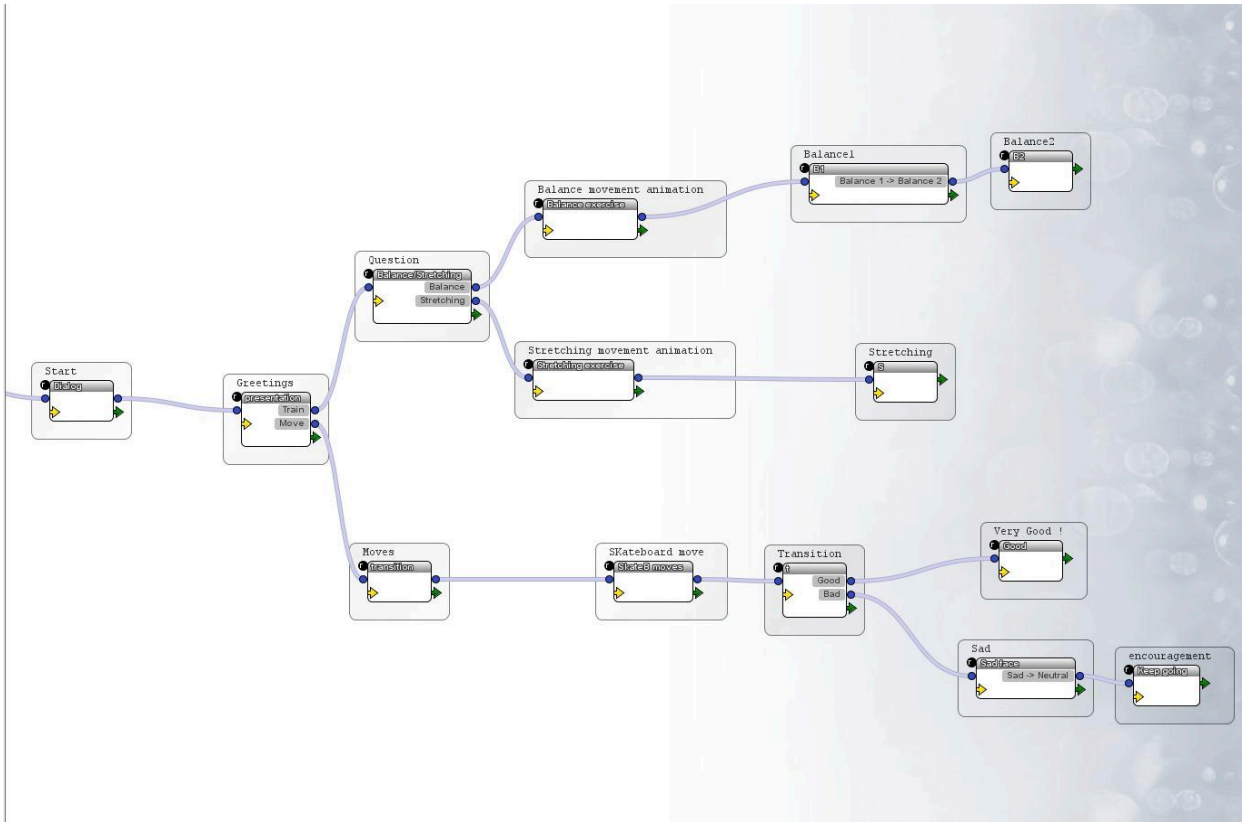
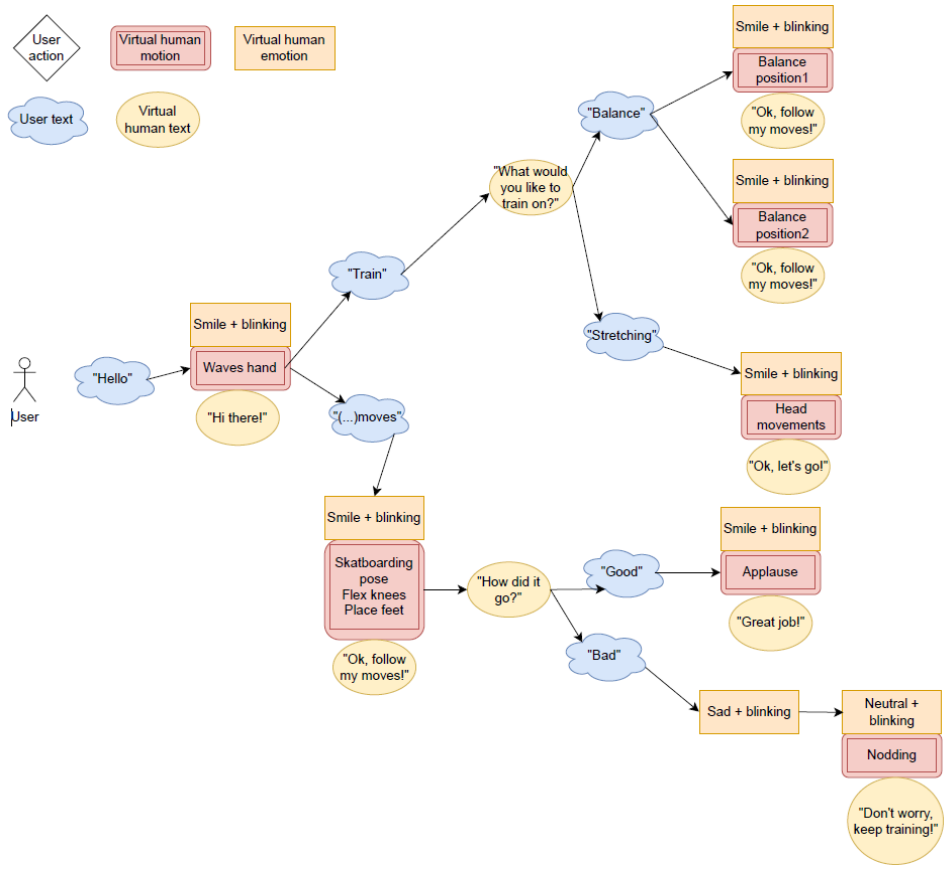


Figure 4: architecture scheme



8 Facial Gestures & Body Animations

8.1 Facial Gestures

The virtual coach employs a series of facial expressions to enhance the realism and effectiveness of the coaching experience. Three primary facial expressions are utilized to convey emotional feedback during sessions.

1) A subtle blinking motion paired with a mildly sad expression communicates gentle disapproval, providing constructive feedback without inducing discouragement.
2) Conversely, positive reinforcement is expressed through happy blinking, characterized by a broad smile that conveys satisfaction and joy following successful attempts.
3) Neutral nodding serves as a transitional expression, filling moments of silence or neutral interaction to maintain a consistent and engaging presence.

In addition to these core expressions, an unused but potentially valuable expression of anger has been conceptualized to address significant user errors or unsafe behavior. This expression aims to underscore the severity of the situation without evoking frustration.

8.2 Postures

Five postural animations yet comes in addition to facial gestures, contributing to the overall embodiment of the virtual coach.

1) The applause animation involves subtle hand movements that convey approval and celebration.
2) Two distinct balance postures are employed to guide users through balance exercises. The first posture involves standing on one foot with arms extended and the torso inclined forward [Fig. 5a], promoting physical stability. The second posture features the user balancing on one foot while the other foot rests against the opposite knee, with hands joined at the chest and the back maintained in an upright position [Fig. 5b].
3) Stretching animations consist of deliberate head movements in both vertical and horizontal directions, encouraging users to engage in comprehensive warm-up routines.
4) The skateboarding demonstration posture, though relatively simple, serves as a foundational representation of various skate moves, with future iterations anticipated to incorporate more intricate maneuvers.
5) A basic wave animation is also integrated, enhancing the coach's friendly and approachable demeanor during greetings and farewells.

8.3 Combination

The integration of facial expressions and body animations allows for the creation of cohesive and contextually appropriate combinations that enhance user engagement.

Balancing exercises and stretching routines would be often accompanied by a smiling expression, fostering a sense of enjoyment and ease during preparatory activities.

Applause and waving gestures are consistently paired with smiling to reinforce positive emotions and build rapport with the user.

In situations where the user's performance requires acknowledgment without explicit celebration, nodding during applause serves to convey moderate approval, encouraging continued effort while maintaining a balanced and supportive atmosphere.

Figure 5a: “plane” balance pose

Figure 5b: “meditate” balance pose

9 Testing

9.1 Method

The virtual coach and the overarching system were subjected to qualitative testing to gather comprehensive insights and feedback. One of the authors, leveraging experience as a former professional skateboarder, conducted an initial review to assess the system's alignment with real-world skateboarding practices.

Additionally, a professional skate coach, Kenny Perelli, aged 29, provided external evaluation. Perelli, who also specializes in mental training, engaged with the virtual coach through a demonstration presented by one of the authors. This collaborative evaluation encompassed an in-depth analysis of the state machine workflow, providing valuable perspectives on the coach's efficacy in fostering skill development and psychological engagement.

The qualitative approach was adopted due to the contextual nature of the feedback sought, focusing on experiential insights rather than quantitative metrics.

9.2 Results

The results of the testing phase were broadly encouraging, affirming the relevance and potential of the implemented concepts.

Both evaluators recognized the efficacy of the emotional expressions and gestural feedback in promoting user engagement and motivation. While the need for greater precision and an expanded repertoire of skateboarding exercises was identified as a limitation, the foundational framework was deemed sufficiently robust to support further development.

The absence of advanced skateboarding moves was acknowledged as a drawback, yet the fluidity and coherence of the existing gestures and emotional responses were highlighted as key strengths.

A critical issue raised during testing pertained to the practicality of the hardware setup. Given that skateboarding is predominantly an outdoor activity, reliance on laptops or stationary devices was deemed impractical. The consensus suggested that mobile phone compatibility would offer a more feasible solution, accommodating the mobile and dynamic nature of skateboarding environments. The potential integration of augmented reality (AR) technology was dismissed due to the associated visibility challenges and the necessity for unobstructed spatial awareness during skateboarding.

Overall, the feedback underscored the virtual coach's strong potential as a foundational prototype, with the evaluators expressing confidence in its capacity for future refinement and expansion.

10 Authors

4.1 About

Ilinca Murărescu holds a Bachelor's degree in Computer Science and is currently pursuing a Master's degree in Computer Science with a specialization in Software Systems Engineering. As an exchange student, her interest in Human-Computer Interaction (HCI) stems from a passion for psychology and the intersection of technology with human behavior. Her primary contributions to the project involved designing the facial expressions and movement patterns of the virtual human model, which she found particularly enriching.

Baptiste Samoyault completed his undergraduate studies at Université Paris-Saclay, starting in 2018. Despite facing challenges during his third year of Computer Science, he found his passion within the Master's program in HCI. His background in physical training and personal fitness underscored the importance of incorporating preparatory exercises, such as stretching, into the project.

Abel Henry-Lapassat holds a dual Bachelor's degree in Computer Science and Mathematics, as well as a diploma in Marketing and Entrepreneurship. Currently enrolled in the second year of the HCI Master's program, he brings valuable experience as a former professional skateboarder, having competed for two years. His extensive involvement in skateboarding events over the past five years has greatly informed and shaped the project's focus, ensuring practical relevance to the skateboarding community.

4.2 Contributions

Ilinca - Correcting introduction, Correcting Related Work, Software Architecture for virtual agents.
Abel - Report Rewrite (whole part3 + latest corrections), Testing as “skate expert”, Adding more references.
Baptiste - Writing References and Design Part, Modelling MARC emotions, Making MARC animations

11 Discussion & Future Work

Despite its promising foundation, the virtual coach presents certain limitations that need to be addressed in future iterations. One significant limitation lies in the requirement for appropriate hardware, such as mobile phones, to ensure usability in outdoor environments. Additionally, the precision and accuracy of skateboard movements require further refinement to meet the demands of this highly specific and intricate sport.

The METUX model offers a valuable framework for addressing these limitations by ensuring the virtual coach fosters engagement and psychological well-being at multiple levels, from interface interaction to overall life experience【28†source】. By applying METUX, the coach’s design can enhance user autonomy, competence, and relatedness throughout the training process.

Future work will focus on developing more advanced features, including endowing the virtual coach with a distinct personality and individualized style, enhancing user engagement and creating a more immersive experience. These improvements aim to personalize the virtual coach to reflect varying user preferences and needs.

A multimodal corpus approach will be utilized to expand the range of behaviors and gestures exhibited by the coach. By analyzing diverse human movements and expressions, more sophisticated and natural interactions can be modeled, thereby increasing the coach’s realism and responsiveness.

For future evaluations, a more robust protocol will be implemented, involving participants with varying levels of skateboarding expertise. Tasks will include replicating complex tricks demonstrated by the coach, with performance measures focusing on accuracy, engagement, and psychological need satisfaction, aligning with guidelines from the SIA handbook. This approach will ensure a comprehensive assessment of the coach’s effectiveness.

Ultimately, this project contributes to the broader field of virtual human research, exemplifying how technology can be harnessed to enhance sports training, mental engagement, and overall well-being, bridging the gap between physical activity and digital interaction.

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