Assessing the Learning of Folk Dance Movements Using Immersive Virtual Reality

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Fig. 1: Continuous phase for the first, second and third group

***Abstract*—Digital technologies can help with preservation of cultural heritage and virtual reality can be used for that purpose. In this paper, a virtual reality application that has the potential of assisting the learning process of folk dances is introduced. This application includes three different assisting approaches that are presented and evaluated with 30 healthy participants. An animated avatar of the professional dancer is shown in immersive virtual reality and participants were asked to imitate the movements in order to learn the dance. Movements were recorded using a passive optical motion capture system and afterwards compared to the recordings from the professional dancers. Questionnaire data were also collected and initial results indicate that participants that had feedback provided achieved better performance.**

***Index Terms*—virtual reality, folk dances, cultural heritage, motion capture, learning**

I. Introduction

Folk dances, as a part of intangible cultural heritage, have to be preserved and transmitted to the next, younger generations. Nowadays, along with the traditional methods of teaching dances, digital technologies can assist to teaching process and offer a new perspective. During the learning, participants are usually required to watch the demonstration of the dance and try to imitate and remember the movements. Video recordings are well-known way of presenting the dance, but they suffer from lack of interaction and feedback [13]. Virtual reality (VR) offers solutions for these limitations, incorporate more functionalities and it can improve interaction and user's immersion. Except standard functionalities like play/pause, forward/reward, can offer to the users to change the speed of the dance or to examine the dance from various viewpoints. Gender of the avatar in the application can be adjusted to the needs of the users. Also, in these applications feedback can be provided, which can be beneficial for learning process. VR applications can include more dances and offer the choice to the users which dance to learn or to watch.

The VR application, presented in this paper, provides different learning phases like watch phase, feet wait phase, body wait phase. Each of the phases enables different functionalities to the users, e.g. real-time feedback, footsteps. Two avatars of the professional dancer are available at the same time, and placed in a way that user can observe the movements even during the spinning. Male and female version of Czech folk dance, Horněmčanská sedlcká, are available. To be immersed in VR environment, users have to wear a head-mounted display (HMD) and the interaction is accomplished by using controllers. Functionalities available in the application for users are play/pause, change the learning phase, change the speed, switch between different steps of the dance and reset time to go back to the beginning of the dance. Our aim was to asses the learning process using the VR application and to compare different teaching approaches.

The application was experimentally tested with 30 healthy participants, that were divided into three groups. Each group had different learning phases available and they are described in the following sections. The first group was without any feedback, the second group had real-time feedback provided

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during the learning session, and the third group except real-time feedback during the learning session also had two additional phases with footsteps and whole body steps available. Our hypothesis was that the groups with feedback provided would achieve better scores for their dance performances. We also expected third group to perform better compared to the second one, since they had footsteps and body steps provided. Participants had 20 minutes to learn the dance, and after that they were asked to perform only with music playing. Users' movements were captured using passive optical motion capture system and compared to the professional's for the evaluation purposes. Analysis of the motion capture data was done offline, using Dynamic Time Warping (DTW) [14] and relevant scores were calculated. Experimental results show that participants form the groups that had feedback provided, had better results than participants from the first group. Also, the second group had the best results in total.

II. Related work

Learning by observing teacher's movements has been previously documented [19], [20]. In [15] a VR study for folk dance and print art allows users to visualise 3D avatars. Li [16] presents a multimedia platform for teaching Chinese folk art performance that helps students to improve their theoretical knowledge and arouse their learning interest. In [17], an assessment of dancers' arm position movements in traditional dance is described. Chen et al. [18] proposed a VR training application using a 3D avatar. Users are recorded during the learning process and three types of feedback are provided. Also, they could change the speed and the point of view. Kanawong et al. [21] recorded teacher's performance and stored positions of key joints. Two ways of feedback are given, expert's evaluation and by the learning system. Training for folk dances where HMD was used to present the dance in VR is described in [22]. Again, user's movements were compared to the teacher's and real-time feedback was given. Performances evaluation is another task to be considered. In [23], two metrics were presented, using knee-distance and ankle-distance for each frame. Calculating maximum correlation coefficients between user's and teacher's normalized distances, two accuracy scores were introduced. A generic framework for assessing candidate similarity models is presented in [28]. DTW was used to evaluate suitability of various motion features. In [18], the distance between the teacher's and user's movements were calculated using DTW and the Euclidian distance between joint angles, positions and velocities. Another research that propose using DTW to find similarity between two segments is [27]. The pose distance is computed as the sum of Euclidean distances between the 3D coordinates of the corresponding joints. In [26], users can interact with the application using controllers, change the speed, play/pause. Also, additional comments are available in specific time moments, to help users to better understand the dance. Users can switch between different avatars and different environments. Similar to other applications, the application presented here enables users to interact with it using controllers and adjust the learning process to their pace and wishes. Users can switch between phases without need to fulfill any requirements in the previous one. Corresponding music for the dance is available so users can immediately try to learn to synchronize their movements according to it. Real-time feedback is also provided during the learning phase based on comparison of poses of a user and professional dancer's avatar.

III. VR application

The VR application is implemented using Unity3D [24] and the Virtual Reality Toolkit API (VRTK API) [25]. The VR scene is modeled to represent a real model of the room where the user testing was held and the timer was implemented to measure the time limit set for the experiment. The timer will start when the corresponding button on the controller is pressed. Participants used Oculus Quest HMD, and they used only one controller while the other one was used by the experimenter to setup the experiment. The right controller is rendered in user's right hand. The application provides three different teaching approaches with different phases available for three different groups of participants. Table I shows the implemented phases and their availability for the different experimental groups. Participants were split into the groups randomly. The application takes care of selecting the group and enables learning phases based on the selected group. Dances are available in the dance menu after the application starts and dance animations are loaded once the dance is selected by the user. The dance is associated with the corresponding music and detected steps. Also, professional dancer's and user's animations are attached to humanoid avatars. Avatars of the professional dancers are available in male and female version and shown to the user. Part of the dance that is presented to the user is based on the current time moment in the application. When the dance is loaded skeleton nodes are associated with avatar's transforms. Additionally, gender of the avatar is activated according to the user's gender.

A. Learning phases

In the 'Watch phase' opaque avatar of the professional dancer is shown to the user. This phase is common for all groups and its purpose is to give an idea about what will be the user's task. After watching the dance in this phase users move to the next phase using dedicated controls on the controller. The next phase is group dependent since each group has different teaching approach. Once the users leave the 'Watch phase', they cannot return back to it. Continuous phase enables user to try the dance in a compact form. Users can switch between different steps of the dance and change the speed. This phase is available for all three groups and it contains two opaque avatars of the professional dancer. Additionally, the second and the third group have one transparent avatar placed between two opaque avatars. The transparent one can be walked through and used for immediate feedback. 'Continuous phase' for the first, second and third group respectively is shown in Fig. 1. Participants that belong to the third group

TABLE I: Phases available for test groups

Test group	*Watch phase*	*Transparent avatar in Continuous phase*	*Opaque avatars in Continuous phase*	*Feet wait phase*	*Body wait phase*
First group	yes	no	yes	no	no
Second group	yes	yes	yes	no	no
Third group	yes	yes	yes	yes	yes

can return to the Feet wait phase, while other two groups stay in Continuous phase until the end. Feet wait phase is designed to teach the user footsteps of the dance. In this phase, footprints representing feet position are shown. After a user step onto the current footprints, the next footstep will be displayed. This phase is available only for the third group of participants. When they finish, they can move to the next phase named 'Body wait phase'. Body wait phase helps users to learn body movements. The application waits until the user poses inside the transparent avatar and then shows the next body step. Again, this phase is available for the third group of participants. From this phase participants can move to 'Continuous phase'. Feet wait phase and Body wait phase are shown in Fig. 2.

B. Feedback

Feedback provided in the application is based on pose comparison of the participant with the pose of the avatar of the professional dancer. All skeleton nodes are compared, and a line is rendered between nodes that are too distant from each other, showing to the participant which body part is in incorrect position. Participant has to correct the position of that body part in order to continue with learning session. Distances and angles thresholds were determined experimentally.

IV. Methodology

A. Participants

A total of 31 participants took part in the experiment, but one participant was excluded due to inability to recall the dance they had to learn. At the end 30 participants, 15 male and 15 female, between 18 and 33 years old and without previous experience in dances joined the experiment. Participants were split into 3 equal groups. The order of participants and their assignment to groups were randomized. Before the experiment started, they all filled the consent form and they were informed that they can drop out anytime and withdraw their data from the experiment. Also, they were told to inform the experimenter immediately in case of any difficulties, e.g. motion sickness. The study was approved by the research ethics committee of Masaryk University with a reference number EKV-2019-067.

B. Experiment

Participants had to learn the dance called Horněmčanská sedlcká, which is approximately 60 seconds long and that is why it was chosen for the experiment. For male participants, male version and male avatar of the dance was presented, while for female participants, female version and female avatar was shown. The experiment was 90-120 minutes long and at the beginning they watched a tutorial which should help them learn controls. Participants had up to 10 minutes to see and try the functionalities and to learn how to interact with the application. Tutorial text was placed on the virtual blackboard, so the application can be used as a standalone, without experimenter present. After the participants were familiar with the interaction they proceeded with the learning phase. They had 20 minutes for learning. The time limit was determined after the pilot testing. Once the learning phase was done, participants were asked to perform the dance three times only with music playing. Final performances with only music playing were recorded using motion capture system with passive markers, OptiTrack [9], and motion data were used for analysis together with the data from the questionnaires.

C. Questionnaires

The questionnaires used in this study include the pre-exposure and post-exposure simulator sickness questionnaire (SSQ), the presence questionnaire (PQ) and the NASA task load index (NASA-TLX). Participants had to fill Pre-SSQ before the experiment started, while the rest of the questionnaires was filled at the end. SSQ is commonly used to report measures of cybersickness symptoms which can be experienced in VR environments [7]. This is a four-point scale questionnaire with symptoms rated from 0 = 'None' to 3 = 'Severe'. Four subscores, nausea (N), oculomotor (O), disorientation (D) and total score (TS) were calculated according to [7]. For assessing user experience in the immersive VR environment, the PQ was used [8]. This questionnaire included 22 questions with seven point scale, 1 = 'Not at all' to 7 = 'Completely'. Again, related sub-scores were calculated as suggested in the literature [8]. NASA-TLX [10] was used for cognitive workload measurements. It includes six questions with 21-point scale ranging from 1 = 'low' to 21 = 'high', and for performance 1 = 'perfect' to 21 = 'failure'. A debriefing session was performed in written form and participants were able to express their impressions, comments and suggestions. Participants were filling electronic questionnaires prepared on a computer at the laboratory.

V. Results

A. Motion Capture Data Analysis

Motion capture data were filtered using cubic interpolation and exported to CSV files. Further analysis was done using Dynamic Time Warping algorithm (DTW) [11]. DTW is a popular technique for finding an optimal alignment between two sequences. The outcome is the distance between two vectors and smaller distance means higher similarity between signals. To assess how well participants performed the dance,

Fig. 2: Feet wait phase (left) and Body wait phase (right)

normalized quaternions from their motion capture data were compared to normalized quaternions from motion capture data from the professional dancers. Scores were found as mean value of distances calculated for each body joint [12]. Since the participants in the second and third group could use the transparent avatar for immediate feedback our hypothesis was that these participants would learn and perform better. Each participant was recorded three times, three scores were calculated and the best one was chosen for the analysis. First, Shapiro-Wilk test was applied for checking the distribution. According to this test, our data have normal distribution ($p=0.091$, $p = 0.161$, $p = 0.659$, for the first, second and third group). Further, since we had three groups to compare one-way ANOVA was performed. Table II shows mean scores and standard deviation (SD) for all three groups of participants. Table II illustrates that the second group has the lowest mean

TABLE II: Comparison between three groups of participants

Test group	***Mean scores***	***SD***
First group	5942.2126	1960.91295
Second group	5005.3674	1181.95137
Third group	5317.2176	1117.16352

score, which means participants from this group had better performance compared to the other two. However, there is no significant difference between groups, $F(2,27) = 1.052$, $p = 0.363$. According to Tukey post hoc test there is no significant difference between scores for each group ($p = 0.343$, between first and second group, $p = 0.614$, between first and third group and $p = 0.884$, between second and third group).

B. Questionnaires evaluation

PQ was used to examine how much immersed participants were while using the application. In Fig. 3 can be seen that participants from the second group had the lowest mean scores for each category, but without significant difference. Results from the NASA-TLX questionnaire are shown in Fig. 4. Participants in the first group experienced the task less mental, physical and temporal demanding and they needed less effort to accomplish the task. Also, they marked themselves to be more successful in Performance compared to the participants from the other two groups. The only significant difference was for Mental demand ($p = 0.05$, between the first and the second group and $p = 0.005$, between the first and the third group). Pre and Post SSQ results are presented in Fig. 5. Participants from the third group experienced the symptoms of cybersickness stronger than the other participants. Also, mean values for all scores for each group were higher after the experiment, what is expected when participants are immersed in VR environment.

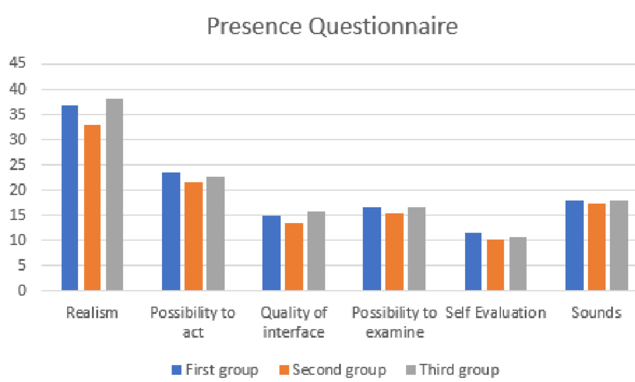

Fig. 3: Mean scores of subscores from PQ

Regarding the qualitative feedback, participants rated this experiment as positive and interesting experience. Four participants think that the application has a potential to be used for teaching people how to dance. Three participants wrote that they enjoyed the VR environment and it was immersive and one found presence of two avatars very useful during the spinning part of the dance. Three participants reported it was difficult for them to learn the dance without a partner present. Some of them also liked the possibility to slow down the dance and examine the dance from different viewpoints. One participant suggested use of virtual mirror, where user can

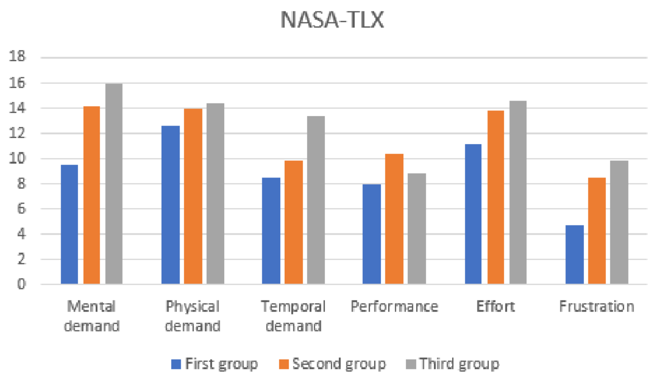

Fig. 4: Mean scores for questions from NASA-TLX

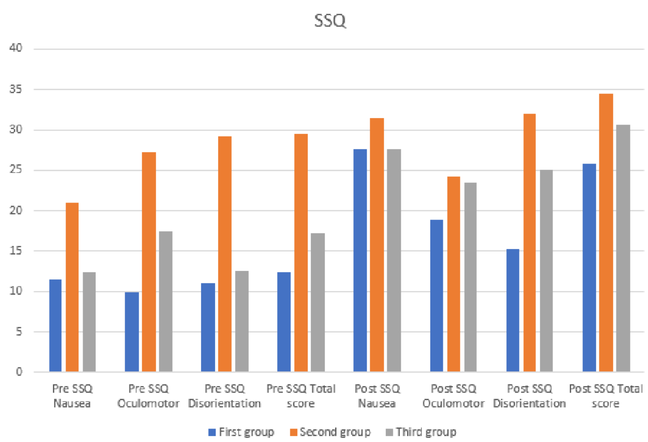

Fig. 5: Mean scores of subscores from Pre and Post SSQ

see his/her and virtual teacher's avatar. Several participants proposed to split the dance so it is possible to learn it step by step. A bar was displayed for a limb that was not placed in a correct position. This way immediate feedback was provided to the users and they liked having this option. Few participants that did not have feedback provided (the first group) suggested implementation of it. The transparent avatar did not scale according to the user, so it was useless for tall participants. The fact that it was not possible to go to the end of one section and switch to another one was frustrating for one participant. The other participant found this experience interesting and stressful at the same time, saying that more time for practicing was needed, even though the time for the experiment was determined after the pilot study. One participant found the application and especially Continuous phase to be very helpful and also suggests to enable watching the dance between attempts in final performance. The other phases like Feet wait phase and Body wait phase were not significantly useful according to another participants. For two participants using VR was completely new experience but they enjoyed and it was very interesting.

VI. Discussion

Participants from third group reported the highest average scores for mental demand, physical demand, but also for effort and frustration. This can be caused with two additional phases during the learning session that they had to go through. Even though, the second group had the best average score, they found the application less realistic, with lower possibility to act and examine the environment, according to PQ. Also, they estimated themselves to be less successful in final performance. This is supported by both, PQ and NASA-TLX questionnaire. Some participants explored the dance from the different angles and at a different speed. However, even though only one controller was used some participants found it to be clumsy and needed more time to learn how to use the controller. This could be because more time to practice the interaction was required. The dances added to the application includes spinning. A wireless HMD was used to ensure health and safety conditions. Furthermore, participants were not able to see movements of their fingers during the interaction with the controller. According to feedback, this seemed artificial. This is technology limitation of our system, since there is no finger tracking provided. Gloves with markers on each finger could overcome this problem. Motion sickness is still a common side-effect of VR environments [1] and it had effects in this work. Our results show that users experienced symptoms, such as disorientation, dizziness, nausea, vomiting, stronger after the experiment. This is in line with [2], [3], [4]. Physical movement with HMD on can induce sickness symptoms [6]. This is commonly reported side-effect of HMDs. The problem may be solved if participants use the VR only to observe the dance and dance movements and remove the headset during the tryouts. In this experiment we managed to solve a problem from the previous experiment, where participants could not see the avatar while spinning [4], [5]. Only one participant in this experiment mentioned to have a problem to decide which avatar to look at, during the spinning.

VII. Conclusion

This paper examined three different immersive VR approaches for learning folk dances. Participants were recorded after learning session and their motion data were compared to the data from the professional dancers. For motion data recording, optical motion capture system with frame rate 120 Hz was used. Optical motion capture systems are usually considered to be good enough to be used for providing ground truth data. Even though the experiment did not yield any significant results, it showed that participants with feedback provided during the learning session achieved better scores. Having additional phases with footsteps and body steps available were not beneficial for the third group, since the second group had the best results. Probably these two phases were overwhelming for them since they found the task very mental and physical demanding. However, the third group performed better than the first one, which supports the idea of feedback to be beneficial for the learning process. All participants managed to remember the dance and perform it only with music playing together with their comments in debriefing session show the potential of application to be used for teaching purposes in general. From questionnaires analysis, after the experiment participants experienced stronger symptoms related to motion sickness. This is common for VR environments, especially when users move inside these environments, which was the case in our experiment. Also, participants found the environment immersive and think the application has potential to be further used for teaching and preservation of folk dances.

In the future, step detection should be improved and step pattern should be added for each dance step. Instead of requiring participants to take a pose inside the transparent avatar to get a feedback, automatic comparison should be implemented. This way users can move more naturally and get real-time feedback. Also, it would be interesting to offer all available phases to users so they can choose the most suitable way for learning. Giving better feedback from a professional dancer at the end of the final performance could be beneficial for the users to know how well they performed.

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