Usability Evaluation of Kinect-Based System for Ballet Movements

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Abstract. Since the 1800s, ballet education is influenced by the use of mirrors. The aim of this study is to evaluate a Kinect-based system called Super Mirror, to discover if it has an impact on the usability in ballet instruction. Ballet students were evaluated on eight ballet movements (plié, élevé, grand plié, battement tendu (front, side and back), passé and développé) to measure the Super Mirror's impact. The results show a potential usage in ballet education but improvements of Super Mirror are needed to comply with the standardized subject-matter expert's criteria.

Keywords: Usability · Kinect · Ballet · User evaluation

1 Introduction

Gray, a pioneer for dance technology once said, "Dance, the oldest art, is today but a young science" [6]. Ballet instruction roots in the studio and is composed of three components: barre, specialized flooring and mirrors. Today, its traditional approach is still in use; the learning environment of mirror use in ballet likely began sometime in the eighteenth century, although historically the genesis is not clearly documented [5]. Mirrors thus become central to a dancer's ballet education. The psychology of a dancer is built around it as it is taught around it. The mirror becomes the source for a dancer on how others view them and the portrayal of success of their technique [11]. A dancer's perception of themselves is partially bound to the existence of mirrors in traditional dance environments. It contributes a physical self-evaluation, behavior regulation, and competition in dancers [7]. Its traditional approach has been the subject of a new methodology suggested by Marquardt et al. titled, Super Mirror [9]. It is a system developed through the use of Kinect-based technology that "combines the functionality of studio mirrors and prescriptive images to provide the user with instructional feedback in real-time" [9].

While the Super Mirror and the similar YouMove system by Anderson et al. develop a comprehensive evaluative methodology [2], the focus was not on benchmarking the systems to the expertise of ballet teachers. A need remains for a method to evaluate the quality of feedback received from the Super Mirror, a reference system, to the expertise of a subject matter, a ballet teacher, a control. Testing the quality of feedback will indicate a level of effectiveness of the system and ensure potential efficiency as a learning tool for ballet. The purpose of this study focuses on the

A. Marcus (Ed.): DUXU 2015, Part II, LNCS 9187, pp. 464–472, 2015.
DOI: 10.1007/978-3-319-20898-5_45

effectiveness and efficiency of the feedback received from the Super Mirror on pre-professional ballet dancers. Can a system prove to be as accurate as a ballet teacher in assessing the quality of dancers' movements?

2 Related Work

Studying the effects of mirrors in dancers' perceptions of themselves with regard to their performance and as a guide to self-correction is not new. Studies by Radell et al. [12] have suggested that the use of a mirror in a ballet classroom may negatively affect the skill acquisition of the dancer and ultimately impact their performance, which has contradicted the results from Dearborn et al. [3]. The first study [12] has concluded that while 85.7 % of dancers remarked that the use of mirrors has influenced their understanding of the concepts taught, satisfaction with overall appearance decreased for high performing dancers in a mirrored class [11]. Green has expressed, in a critique of traditional dance instruction, "the constant focus on an externalized view of the body, as reflected in the mirror, objectifies the dancer's body and requires students to strive to achieve a specific 'look' while being 'corrected' so the students perform 'proper' dance technique" [7]. While the mirror provides immediate visual feedback in real-time, it also may result in a false perception of a dancer's weaknesses. The consciousness of thoughts contributed by the mirror may welcome detrimental effects in the overall well-being of the dancer and hinder the development of their technique.

In order to combat the given negative effects of mirror in ballet instruction, researchers have turned to technology to help aide teachers and students alike as a guide to self-correction. This study [2] compared the YouMove system to traditional video-based instruction methods and has discovered that learning increased using the system. Another study [4] reported the effects of real-time virtual reality (VR) feedback on motor skills and explored the ability to focus the learner to key features of a to-be learned action. Similarly, [16] has identified that video analyses support a basis for rank-specific supplemental training in ballet companies. Video analyses help, "teachers…tailor their classes to the appropriate intensity and can create combinations…that can replicate the demands of specific roles" [16]. Further studies [8] have revealed that students considered streaming video as effective for carrying out self-evaluation. Other studies have suggested computer animations benefit dancers with experience and are at least as effective for learners without dance experience in contrast to video [13].

3 Research Methodology

A controlled study was conducted using pre-professional ballet dancers to compare the Super Mirror's assessment of movements, an embedded reference system, to the evaluation of a ballet teacher, the control. A total of 5 ballet students from the State Ballet School, Ilija-Nikolovski Luj from Skopje, Macedonia were tested. The pre-professional students were between the ages of 16 to 18 with an average of 8.8 years of ballet education. Each student has class 5 times a week with each class lasting for an hour and 30 min, excluding rehearsals for performances. Eight movements

provided by the Super Mirror: plié, élevé, grand plié, battement tendu (front, side and back), passé and développé were assessed. Each movement has an embedded reference model, a predefined movement template that measured the correct matches or "hits" as referred by the terminology reported in [9] by comparing the set of thresholds of the x, y and z rotational values of the left upper leg, right upper leg, left lower leg and right lower leg. The only interaction the Super Mirror had was motion-capture. This was "performed by joint skeleton tracking through a Kinect camera, and the transfer of input from the camera to the processor [was] mediated by the Synapse application [14]. The specific interfaces developed for [the] system use the Tryplex toolkit [15], a set of open source macro patches for Quartz Composer" [9].

Intentionally, each dancer began with alteration, either with or without the Super Mirror to nullify any possible effects of the dancer to accustom to the system. This will avoid the ability to receive a higher number of "hits" without achieving higher performance techniques. Additionally, to remove any influence caused by the Super Mirror, the teacher was positioned where she was unable to view the screen where the Super Mirror was projected. Differentiated from the YouMove design, the experiment added a control, a ballet teacher, for the purposed of testing the reference system, the Super Mirror.

3.1 Procedure

Testing the dancers involved setting up the Super Mirror and having the system displayed on a 37" LCD screen in a wide room to most closely resemble a ballet studio. A pre-test questionnaire was first distributed to all of the participants to capture certain demographics such as age, how long they have been dancing ballet for, how many hours per week do they dance, etc. The dancers were tested in an ascending order by grade in order to keep a clear and logical flow. One by one, the dancers were tested on the eight movements. Each movement was performed enface (to the front) according to a number of times predetermined from the ballet teacher. This number was due to the artistic nature of ballet. It was necessary and essential to mimic the number of times each movement was performed as in a typical ballet class to evoke as closely as possible its natural environment. All the movements, plié, grand plié, battement tendu (front, side and back), passé and développé except for élevé, were performed 4 times. Élevé was performed 8 times. Figure 1 explains the procedure of testing one participant.

Each test comprised of eight movements. Each movement was conducted in two sequences (S1 and S2). Each sequence comprised of two parts, P1 and P2 that included with and without (W/O) the Super Mirror. Between each sequence, a one-minute break was given to allow for rest. The teacher evaluated each part and assessed the student's performance on a scale of one to ten based on a set of criteria specific to each movement. During the test, when the part with the Super Mirror was included, the dancer's accuracy of performed movement was measured against the embedded reference model in the system. The dancers' successful performance was registered by the system as a number of matches or "hits" as offered by the terminology used in [9]. The roles of Kinect and the teacher were complementary. The teacher assessed the technique elements that were not tested by the system to determine its effectiveness. After all the students were tested, a System Usability Scale (SUS) was administered to both

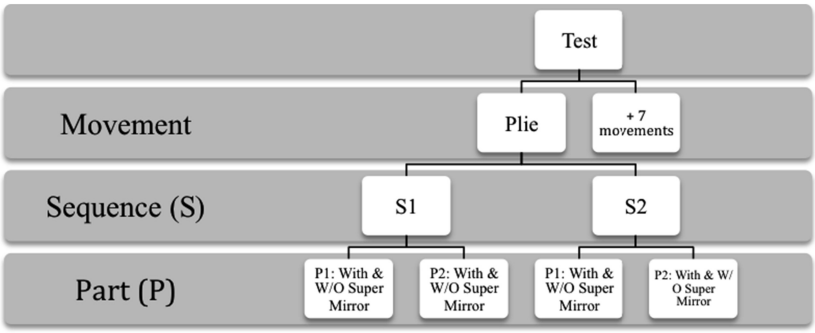

Fig. 1. Experiment procedure for a single participant

Fig. 2. Dancers performing a plié (left) and passé (right) using the Super Mirror

the students and the teacher, which also included open-ended questions. A short discussion was held to gather feedback about the system. Figure 2 shows the dancers using the Super Mirror during the experiment.

4 Results and Discussion

Data from previous studies involving the testing of the YouMove system [2] reveal the effectiveness of using such systems when compared to traditional video-based instruction methods. In our study, the focus was the comparison of such a system to the knowledge of a domain specific expert. The results concentrated on three specific

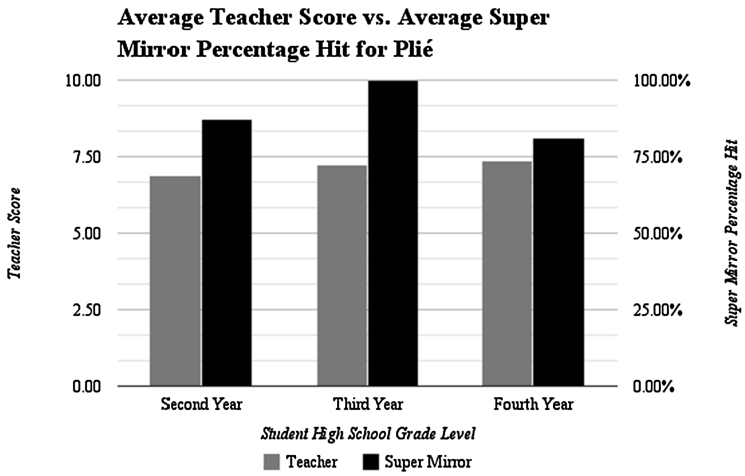

Fig. 3. Plié score

movements, plié, élevé and tendu front. The other five movements, grand plié, tendu side, tendu back, passé and développé to the side, were not included because the Super Mirror results were non-conclusive. This was most likely due to the inability to adapt the reference model of the movements to the height of the dancers.

Further investigation is needed to accurately calibrate the reference template to the specificity of each dancer. Adequately, the possibility for comparison between the Super Mirror and the teacher was impossible. The following figures represent aggregate results of the three movements. The aggregation of the scores of each movement was based on the grade level of the student (x-axis), the average teacher score (left y-axis) and the average Super Mirror hit (right y-axis). The teacher score was graded on a scale of 1-10, while the Super Mirror score was a ratio given as a percentage of the successful "hits" vs. the predetermined number of times a movement was performed. Figure 3 represents the assessment of the teacher score vs. the Super Mirror score in the movement of a plié. A plié is the bending of the knee or knees [1].

The teacher's score indicated a gradual level of increase with the experience level of the student. According to the subject-matter expert, the teacher scored the dancers on the following set of criteria for a plié: do heels lift from the floor, is weight distributed equally between both feet, are legs turned out from the hips, are shoulders back, is stomach in, is back straight, is torso strong, are ribs in, are hands soft, are arms synchronized with legs, and is bottom tucked in. As students move from year to year, their technique improves. Therefore the teacher's score was greater. However, the same trend is not seen with the Super Mirror. The results from the Super Mirror showed higher results compared to the teacher score. The Super Mirror "hits" compared only the angles of knee and hip joints with prerecorded angle widths [9]. This indicated that the Super Mirror score complexity is much lower than the teacher's. The Super Mirror did not carry the ability to view the dancer's technique as a whole therefore accounting for inaccurate results. Figure 4 represents the assessment of an élevé, a rise on demi-pointe [1]. According to the subject-matter expert, an élevé has the same complexity as a plié.

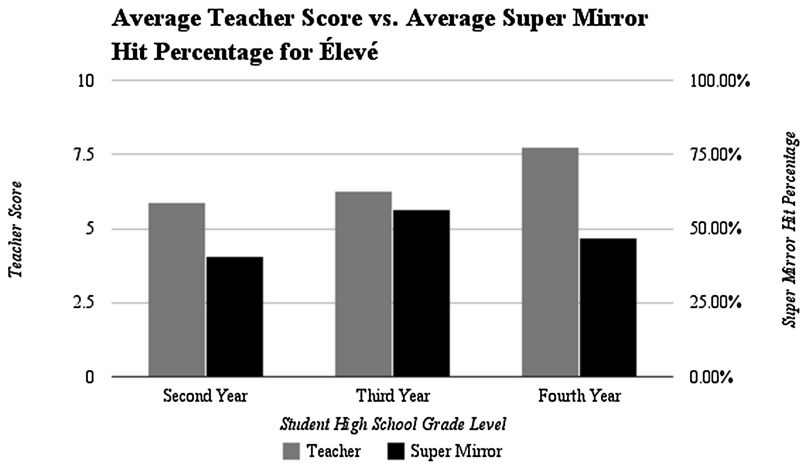

Fig. 4. Élevé score

The teacher assessed the dancers on the following set of criteria for an élevé: are legs turned out, is weight distributed between both feet, are knees straight, are shoulders back, is stomach in, is back straight, is torso aligned, are ribs in, and are heels turned out. The teacher's score also increased with the student's experience. The same explanation determined the score as a plié. As the students' advance, their technique improves; therefore the teacher's score increases. Contrary to a plié, the Super Mirror score is lower than the teacher's score. Our explanation was that the Super Mirror system does not detect the angles as well as the plié. Figure 5 represents the assessment of a tendu front. A battement tendu is an extension of the leg [1].

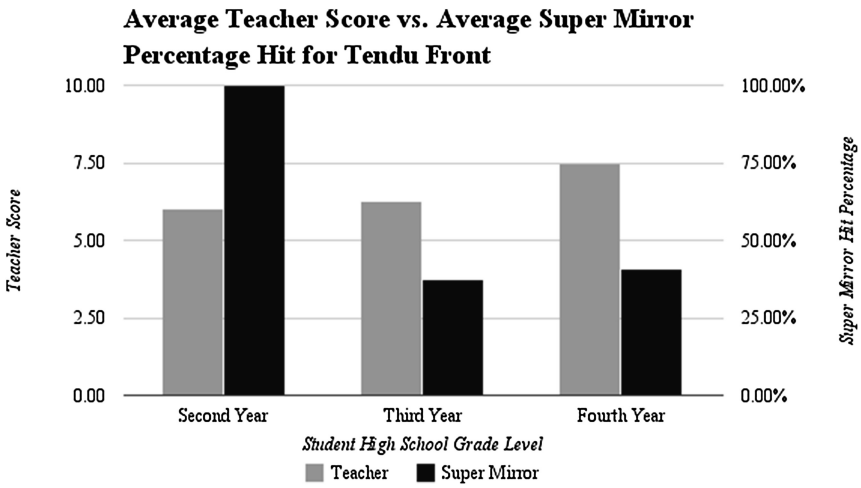

Fig. 5. Tendu front score

According to the subject-matter expert, a tendu is the most complex out of the three movements. The teacher assessed the dancers on the following set of criteria similar to the other two movements: are legs turned out, is weight of the body on the left foot, is tendu begun with a turned-out heel, are shoulders back, is stomach in, and is back straight. The teacher's scores follow the same pattern as the previous two movements i.e., increases with the level of complexity. We found a similar reaction where the Super Mirror system was not able to successfully detect the angles. The system scores show certain anomalies in the second year students. Our explanation was that the second year students were capable to negatively accustom to the faults of the system, although the teacher's scores were the lowest as expected. Most of the students recognized the system's inability to recognize a correct battement tendu. One student said, "I observed that I got a "hit" if I did some of the movements [battement tendu front] in a specific way that was inconsistent to ballet principles".

SUS presented a mean score of 57 for the students and a score of 42.5 for the teacher which indicated a below average result. A score above 68 would be considered as above average as presented by Usability.gov [17].

5 Conclusion

The Super Mirror is only capable to assess the partial complexity of the movements' i.e., the angle of joints to be within certain limits. The teacher score shows a pattern that is proportional to the level of the student's experience, while the Super Mirror shows opposite scoring compared to the teacher when the complexity of movement increases. Nevertheless, the Super Mirror shows a consistency of scores among the students for the same movement regardless of the opposition of the teacher that gives an opportunity to calibrate the system to match the teacher's scores.

With the know-how of our previous experience in the world of ballet and the teacher's input, the following improvements on the Super Mirror are envisioned. First, the Super Mirror reference model needs to have a fast tuning capability. In other words, there is a need for an easier capability to calibrate the system for each individual dancer through a simple user interface. Further, the measured parameters (the angles of the joints and hips) should be expanded in the direction of the assessment criteria of the subject-matter expert. Examples of the criteria include detecting if the weight is distributed equally between both feet or one, if the legs are turned out, and if the arms are synchronized to the legs. The ballet professor indicated that, "[The Super Mirror] may be useful if perfected and simplified for use in class. It cannot evaluate physical predispositions for a classical ballet dancer and other important factors, such as musicality and dance ability." At the end of this stage of development, a user interface designed based on Nielsen's 10 Usability Heuristics would be beneficial to improve the interaction between the dancer and the system. This would allow users to be able to manipulate the system's parameters and consequently increase their learning. The system should always present a visibility of its status by giving familiar terminology to the user rather than using system terms. Moreover, the system should provide more user control, consistency, error prevention, recognition rather than recall, flexibility, adequate error messages, and finally help and documentation [10].

Although initial testing of Super Mirror was not highly conclusive to test the effectiveness and efficiency of the feedback, these types of tools open the door to integrate a Kinect technology to ballet. Even more, it shows promise. With an adequate improvement of the system and a user-controlled capability to calibrate the parameters, a Kinect-based system has the potential to become a useful tool to students, teachers, and professionals. In a more advanced stage of development, the level of usability of the Super Mirror will further increase, if there is a measurement of the speed of movements, a correlation between the speed of movements and music, a correlation between the movement of head, arms, and feet, and the measurement of posture and balance. The most exciting part is the possibility of making a technical and even artistic assessment of the whole performance that could potentially benefit ballet competitions, and remove the bias of subject matter experts. The integration of video streaming, multiple networked Kinect sensors and cloud technology as a one system would move ballet from "Dance, the oldest art, is today but a young science" to the needs of 21st century ballet.

Acknowledgements. Authors would like to thank Joao Beira and Sebastian Kox for offering the Super Mirror system for testing and providing technical help. We thank Prof. Snezana Filipovska, Ph.D. and Prof. Slagjana Spasenovska, M.A. for the insightful input regarding the fundamentals of ballet, through which many of the ideas in this paper were developed and shaped. We would also like to acknowledge the students from the State Ballet School, Ilija-Nikolovski Luj from Skopje, Macedonia who participated in the study.

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