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Presenting Movement in a Computer-Based Dance Tutor

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This article addresses how to present movement information to learners as part of a larger project on developing a nonconventional computational system that teaches ballet. The requirements of such a system are first described, and then discoveries regarding the first requirement, presenting movement to a user, are discussed. Background research regarding how people learn movement, hypotheses concerning presenting movement with computer animation versus videotape, and an experiment testing those hypotheses are presented. The experiment required individuals to perform movements after viewing them in one of the formats. Each participant viewed a movement sequence multiple times and then was evaluated on his or her performance of that movement by two expert judges. Animations resulted in higher performance ratings for individuals with some previous dance experience. Format did not affect performance for other learners. This result implies that domain knowledge interacts with presentation format in learning ballet. These results will influence the design and implementation of a computer-based dance tutor under development, and they point to several interesting research directions, including exploring the effects of multimodal sensory presentations and prior knowledge in learning movement.

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1. INTRODUCTION

The development of an interactive computer-based dance tutor presents several interesing research problems. The system is envisioned to be a virtual aid for teaching formal ballet and other dance techniques to users and, as such, needs to consider the best way to present movement, what type of interaction users need for optimal learning, and appropriate feedback from the system to the user regarding performance and errors. The domain of teaching dance was chosen for study particularly because it forces us to examine the interface issues of interactive systems that need to be "off the desktop." Because dance is a full-body, physical activity, a typical desktop computer is not going to provide the user with the appropriate environment for learning. In this article, the issues underlying the development of a nonconventional computer-based interaction system are discussed, as well as the requirements of such a system and the methodology undertaken to address one of the requirements in particular, presenting movement to the user.

Dance instruction provides an interesting challenge to the development of a computer-based system, especially because various aspects of it are well studied in the human-to-human instruction domain. Dance instruction occurs generally in classrooms or studios with a suggested student-to-teacher ratio of approximately 10:1. In practice, many classes have upwards of 30 students enrolled, and that reduces the personalized attention for the individual student from the instructor.

In the classroom, students receive limited individual attention and are encouraged to practice on their own to master the technique. However, strict alignment and corrections are necessary to properly learn ballet technique and to avoid creating misaligned "muscle memories," so practicing without a coach may not be the best approach (Lawson, 1983). Here may be an ideal situation for a computer-based system to aid in teaching.

An interactive computer-based dance tutor that uses nonconventional input and output methods may provide the individualized attention that some dance classes lack. Such a system will allow individuals to learn and master ballet technique through practice outside of formal classes. Such a system has four overall requirements:

First, the system must present movement to the user. In the classroom scenario, the instructor performs a movement, shows the students the various nuances within the movement, and further discusses the variabilities of each. The instructor also may show the students movements from different viewpoints. The student should be able to interact with the system, manipulate the viewpoints as desired, and query for further information as needed.

Second, the system must observe the students' *movement*. In the classroom, the instructor watches all the students as they mimic the movement previously presented. The computer-based system also has to track the user and determine how close his or her performance was to the one the system previously displayed.

Third, the system must provide feedback to the student. In the classroom, an instructor will provide direct feedback to the student and guide him or her interactively. The computer-based system also needs to provide feedback to the student on how he or she can improve various forms and movements.

Fourth, the system must allow for interaction and communication. A significant aspect of this teaching scenario is the interaction between the student and the teacher. A major requirement of a computer-based system is to allow a similar interaction; however, the dynamics of such an interaction are somewhat different. A computer-based system may be more one on one; hence, the student can ask more personalized questions and also get personalized guidance. The student can ask for repetition of movement, request presentation from a different visual perspective, ask specific questions, and practice at different speeds.

1.1. Interaction Design Issues

It is obvious that this type of system poses a variety of challenges in terms of how to design the interface and interaction elements. The task of determining what sort of interface would be best suited for dance instruction is rather daunting.

It should be no surprise that learning dance is a highly interactive process—to learn, you must do (Gray, 1989; Lawson, 1983; Schlaich & Dupont, 1993). This is a difficult interface issue, especially if one is bound to the desktop model of computing. How can learning dance fit into that type of setup? Would a dancer derive any benefit from a traditional computing environment? The desktop model is not an optimal design for an interactive computer-based dance tutor. It is quite cumbersome and unnatural. One could imagine a system that is nonconventional or one that does not conform to the idea of a contained box mounted on a desktop: a system with a large monitor to present information, a nonconventional method of inputting commands (i.e., not a keyboard or a mouse), a specialized camera to track movement, an audio system to allow for speech input, a special floor with sensors to measure footfalls, and a ballet bar with sensors to measure students' posture and weight. One can see how "doing" dance may be more optimized in this design. However, given that it is nonconventional, it does present challenges in how to best design the interface and interaction elements for usability.

1.2. Presenting Movement to the User

The first hurdle to cross in the development of this system, and the focus of this article, is the proper presentation of movement sequences to the user. Because a computer-based system is proposed, it might seem obvious to use computer animation as a way of initially presenting movement sequences. However, one does not want to be limited by technology or, by the same token, assume that one must use the latest in technology just because it is available. Video presentation may be a better format. The choice in presentation format is crucial because the users of this system need a good presentation of an initial movement so they can recognize that movement and then recreate it physically.

1.3. Learning From Visual Displays

Scaife and Rogers (1996) argued that researchers need to look at the following three factors when evaluating the efficacy of graphic external representations in learning: computational offloading, re-representation, and graphical constraining. Computational offloading is the idea that a good graphic will reduce the effort of the individual learning new information or solving a particular problem (Larkin & Simon, 1987). For example, a simple map often can reduce the effort of reaching a destination by providing a spatial guide to a series of right and left turns. Re-representation refers to the fact that graphic presentations can facilitate learning only when they share the same abstract structure as the real-world learning experience. Using the example of a map again, a map that depicts roads traveling in different paths than in the real world, a strange and unrepresentative abstract structure, probably would hinder a user from finding a desired place. Finally, graphical constraining is the idea that individuals will learn better when a visual display closely resembles the internal representation of the learner, guiding the learner to make the appropriate inferences and to avoid errors. A map that appropriately delineates cities from one another can graphically constrain a user from wasting his or her time by looking for a common street name in the incorrect city.

Hegarty and Just (1993) researched the ability of individuals to construct mental models, or representations, of how different mechanical pulley systems worked. Although this may seem unrelated to a dance tutor, these pulley systems require what Hegarty and Just termed a *kinematic mental model*, or an internal representation of movement. Ballet students also need such an internal representation of movement to learn new dance steps. Hegarty and Just compared participants' understanding of the mechanics of a pulley system developed by reading about that system, examining diagrams characterizing that system, and combining both readings and diagrams. They found that participants best understood the mechanics of the pulley system by studying both the text and diagrams of the system. Drawing on these results, they argued that individuals incorporate information from the text and diagrams to create a kinematic mental model and can then properly visualize how the system works. Or, to put it another way, when an individual forms a mental model of a kinematic system, the individual then can examine his or her representation to answer questions about that model. This is in contrast to the individual who does not create this model and therefore, needs to make a chain of inferences from a series of static images to answer those same questions. This latter approach is presumably more error prone.

It may be the case, then, that an animation provides information in a way that helps learners to create representations of dance without the need of many inferences—inferences that could result in errors. Fewer inferences also may be required during subsequent practice and performance, again reducing the potential for mistakes. Scaife and Rogers's (1996) idea of graphical constraining is also relevant here. If a poor model and display style are chosen for a movement presentation, the inferences that learners can make may be constrained, but constrained in such a way as to lead to more errors.

In a similar vein, Gray, Neisser, Shapiro, and Kouns (1991) compared observational learning of ballet sequences by using static and dynamic images from videotape. Consistent with Scaife and Rogers's (1996) claims, Gray et al. found that dynamic, or kinematic, presentation better afforded the learning of movement over static images. This may be because learners, in a dynamic learning situation, do not have to make inferences about the speed or trajectory of a movement.

Pane, Corbett, and John (1996) argued that there is a definite value to animations in learning procedures because such sequences provide trajectory and motion information concerning steps within the procedure that static images cannot, minimizing the need for a learner to make (incorrect) inferences. In ballet, motion and trajectory information is crucial to a learner; thus, it would seem that a dynamic presentation is optimal. However, neither Gray et al.'s (1991) nor Pane et al. 's (1996) research discriminates between videos or computer-generated animations for learning efficacy.

Rieber (1990) argued that dynamic displays are needed when data visualization and conceptualization, motion, and trajectory information are necessary for learning. Rieber suggested it is then, and only then, that dynamic displays offer an advantage to learners over static pictures. Rieber (1990) further argued that although a dynamic presentation of information can be more helpful in learning when these three types of information need to be conveyed, one needs to make sure that some of the same principles that one uses to construct good static pictures are also applied. Two of these guidelines are that the static pictures—and presumably, with the extension of the argument, dynamic displays—must be highly related to any accompanying text or language and that designers must limit the pictures or displays to little detail when learning is externally paced in order not to overwhelm the learner (Rieber, 1990).

A dance movement sequence does need to portray visualization, motion, and trajectory information, so it would make sense that dynamic displays could be of greater value than static images. Thus, it is not surprising that Gray et al. (1991) found that novice dancers performed better when given kinematic representations of dance than static ones. This suggests that individuals could extract more information from the kinematic representations. Nevertheless, too often dynamic displays are used because they are impressive and flashy and not because they will aid the user in learning. Therefore, the choice of a dynamic presentation format is very important.

This research focuses on the distinction between animations and video. The visual display literature does not discriminate between the two. As long as the display is representative and dynamic, in theory, it should then be effective for learners. But is this truly the case? Video, the recording of a human performing dance, intuitively seems to be a better choice. After all, videotape is the epitome of re-representation. However, there are problems inherent in videotape that computer animations can control, such as distortion, lighting, and human error; in addition, there are other factors, such as animations providing an easier way to present multiple perspectives of the same movement. Thus, the domain of learning ballet may provide an opportunity to explore whether there are differences in learning due to the type of dynamic presentation formation—animation or video.

1.4. How Does the User Learn a Movement?

Generally, dance is taught in a communal classroom setting, where one teacher is responsible for teaching at least 10 students. This scenario seems to be an ideal situation for a supplemental computational dance system to aid in teaching. But what do ballet students need to effectively learn a movement? Do they undertake a particular method or procedure that needs to be considered in our design? Is there something special involving what they need to see to mimic a movement? To answer these questions, a task analysis of learning a basic ballet movement was conducted. It may seem that it would be more prudent to ask dance teachers about how students best learn dance, but it might be even more appropriate for interface development to uncover the preferences, needs, and workflow of the ballet student.

The task analysis was based on results from a survey given to novice movement students about how they go about learning a movement as well as observational data collected by the first author. The detailed task analysis can be found in Appendix A.

In terms of presentation, the majority of novices stated that repetition of movement was important as well as the breakdown of a movement. Most novices stated that they preferred breakdown to be by body part (e.g., independent focus on legs, then arms, etc.) rather than by basic ballet movements (plié, tendu, etc.).

The task analysis yielded two key observations about how users think about learning a movement sequence. The first is that learners will look at gross motion first and then refine it later. The second is that learners will look at motion by breaking down the movement by body areas, focusing on the legs first, then the arms, and then peripheral areas like the head, hands, and feet. This is not to say that the peripheral body information is not needed. To master a movement, more and more detail is necessary, but it would appear that gross motion information builds an important foundation for subsequent learning.

1.5. Role of Background Knowledge

Another issue addressed in this research is the effects of background knowledge on learning from dynamic displays. What kind of representational differences are there between more and less experienced dancers? In general, people with greater domain knowledge of a topic are better at encoding a new representation and applying their prior knowledge to novel situations (Ericsson & Lehmann, 1996; Hayes, 1989). Furthermore, expertise is maintained through extensive practice and preparation (Ericsson & Lehmann, 1996).

Two talent factors suggested as crucial to acquiring dance skill are spatial and imagery ability. When empirically testing these factors, however, both Corsi-Cabrera and Gutierrez (1991) and Priddle (1974) failed to find correlations between expertise and spatial ability. However, differences in imagery ability between expert and novice dancers have been found. Overby (1990) found that experienced dancers' dance imagery had strong visual and verbal components, whereas novice dancers' imagery was mostly visual. That is, expert dancers encoded not only the movement itself as novices did but also verbal cues that went with the movement, such as the name or the appropriate counts that described the movement.

Because of the ill-defined differences between expert and novice dancers, this study tested only individuals with no or limited prior dance experience. However, because it would make sense that those with previous dance ability may have some advantage over those with no dance experience in terms of performance, it is also important to look at any differences between those two groups. Spatial and imagery ability also were examined for participants of varying experience to make sure any possible effects were not due solely to those factors.

1.6. Video Versus Animation

As outlined in the task analysis, the presentation format of the proposed system needs to adequately present gross movement so that learners can focus attention on specific body parts and then pay attention to increasing detail as the basic foundation of their internal representation of the movement sequence is built. This basic foundation needs to include gross motion and trajectory information, as suggested by Rieber (1990), for the development of an appropriate kinematic mental model. Users who participated in a pilot questionnaire study stated that good joint segmentation and body part delineation are important to properly perceive the motion and trajectory information from a presentation. Intuitively, it would seem that either videotape or computer animation would be effective for the presentation of movement in the proposed system. Both certainly fulfill Scaife and Rogers's (1996) requirement of re-representation by presenting a human (or in the case of the animation, humanlike) model. But a video presentation has its problems. In videotape, variables such as camera angle and lighting need to be controlled. Individuals may not be able to extract the right level of detail from a videotaped movement to perform it or be able to distinguish joint information adequately. Put another way, the limitations in even the best quality video might inappropriately graphically constrain the way that users make inferences about the movement, thereby leading to poor representations and, thus, poor performance of the movement.

Background research of movement presentation indicates that a computer animation might be more beneficial to novice dance students in their formation of a movement presentation for at least three reasons. First, Johansson (1975) argued that clear joint information is crucial to understanding motion and trajectory information. He examined point-light displays of humans moving and found that people need only the information from the joints in the body to perceive a movement. He argued that people use a perceptual vector analysis to extrapolate trajectory and further motion information. A rendered computer animation can be made to shade joints very well to differentiate them. Joints may not be as distinct in a videotape, due to distortion and the body type of the dancer performing the movement.

Second, individuals need an appropriate level of quality and precision for presentations to be effective. Videotape makes it difficult for dancers to extract specific and detailed body information (Benesh & Benesh, 1977; Hutchinson-Guest, 1993), and, due to this, videotape is not often used in ballet instruction or for chronicling choreography. In fact, the dance community uses a very complex static notation for chronicling movement to avoid the problems inherent in videotape.

Finally, as a dancer gains experience, he or she will need a presentation format that can provide increasing detail so that the learner can refine his or her representation of a movement. Because more experienced dancers might well-understand the gross motion and trajectory information of a movement, they need to then focus on more detailed information including peripheral body parts. Animation may have the plasticity to allow the best of both worlds: gross presentation that allows easy extraction for early novice dancers as well as presentation with more detail for dancers with more experience. This is a matter regarding what each user is ready for individually. Even if the quality of the videotape allows the user to perceive basic movement information, it still may not be good enough for more advanced students to get the more detailed, more peripheral movement information that they need to form a representation and recreate that movement. One could create multiple videotapes of the same movement from different perspectives and at different levels of detail. However, this would be much more labor intensive than developing one animation and potentially more error prone.

Given these considerations, a computer animation should give users an advantage in learning movement over videotape. The animation does not have distortion or error effects that a video may have, and joint segmentation can be made clear and distinct for users of varying abilities. Additionally, in one animation, several views and levels of detail can be programmed into one file, which can help users to master movements as they practice.

2. METHODS

The experiment presented here was designed to begin an examination of the best way to present dance to help individuals represent and learn movement. As stated previously, it was expected that animations would produce better learning of simple movement sequences than videos because of the clarity of joint information for perceptual vector analysis.

2.1. Participants and Design

Thirty-two novice ballet students with a mean age of 21.5 years (*SD* = 2.55 years) and 2 years or less of dance training were tested in this study. Although 2 years may seem like a fair amount of dance training, the mean length of training for participants was 0.50 years (*SD* = 0.74 years) with a mean of 2.92 years (*SD* = 4.78) since they had last taken a dance class. Additionally, all classes that participants reported having taken were beginning level classes.

Participants were randomly placed into either the video (mean age = 21.6 years, *SD* = 2.56 years) or the animation (mean age = 21.4 years, *SD* = 2.63 years) condition. There were equal numbers of both sexes and previous dance classifications (no dance, dance but no ballet, ballet) in each group. Table 1 shows the design of the

Table 1: Number of Participants in Each Cell of Experiment

	Previous Dance Experience		
	Ballet	*No Ballet*	*No Dance Experience*
Animation	4	4	8
Video	4	4	8

study. Table 2 provides ability measures. Participants in the animation group had a nonsignificant difference of twice as much dance experience as those in the videotape group. However, dance experience included all types of dancing, including cotillion and swing dance, and on further breakdown, the groups were roughly equal in terms of previous ballet experience, with the videotape group being slightly higher (animation = 0.42 years, videotape = 0.46 years). Of the 32 participants, 16 had previous dance experience and of these 16, 8 had previous ballet experience. None were current dance students.

Participants were recruited by flier from the Georgia Institute of Technology's subject sign-up board maintained by the School of Psychology. Participants were compensated with either extra credit in their introductory psychology courses or $5. All participants had normal or corrected-to-normal vision.

2.2. Materials and Apparatus

Movements were presented on a Dell Precision 610 personal computer. Three distinct movement patterns were presented either by video or by computer animation. Each movement was similar in length and composed of the same basic ballet components in different combinations. The movements varied slightly in difficulty and were based on standard, rudimentary ballet bar exercises used in beginning ballet classes. The movements were plié, ron de jambe, and tendu passé. Each

Table 2: Ability Measures for Participants Across Presentation Conditions and *F* and *p* Values for Between-Condition Comparisons

	Animation ($n = 16$)		*Video* ($n = 16$)			
	M	*SD*	*M*	*SD*	F^a	*p*
Ability rating	5.72	1.86	5.25	1.69	0.56	.46
Written test	0.25	0.45	0.50	0.63	1.67	.21
Movement pretest	3.12	0.90	2.99	0.63	0.22	.64
VVIQ	60.44	5.87	63.38	9.87	1.04	.31
Surface development	23.50	9.07	26.00	4.62	0.96	.33
Cube comparison	35.57	5.53	36.19	3.94	0.14	.72
Years of dance	0.32	0.62	0.66	0.85	0.86	.36
Years since last dance class	2.71	4.73	3.13	4.96	0.06	.81

Note. VVIQ = Vivid Visual Imagery Questions. [a] $df = (2, 29)$ for all comparisons.

movement took approximately the same amount of time as the others, approximately 30 counts in 4/4 time, or 15 s. All movement sequences both began and ended with the same preparation and finish.

Movements were displayed as similarly as possible in the two different formats. For instance, both size and image integrity (focus, lighting, etc.) were matched as closely as possible. The first format, videotape, was recorded by using a digital camcorder. Some keyframes from the videotape can be seen in Figure 1. The figure used in the videotape is a former professional dancer, dressed in a red leotard and blue tights, performing each exercise. The movement sequences were recorded in a controlled environment, where both background and foreground were the same

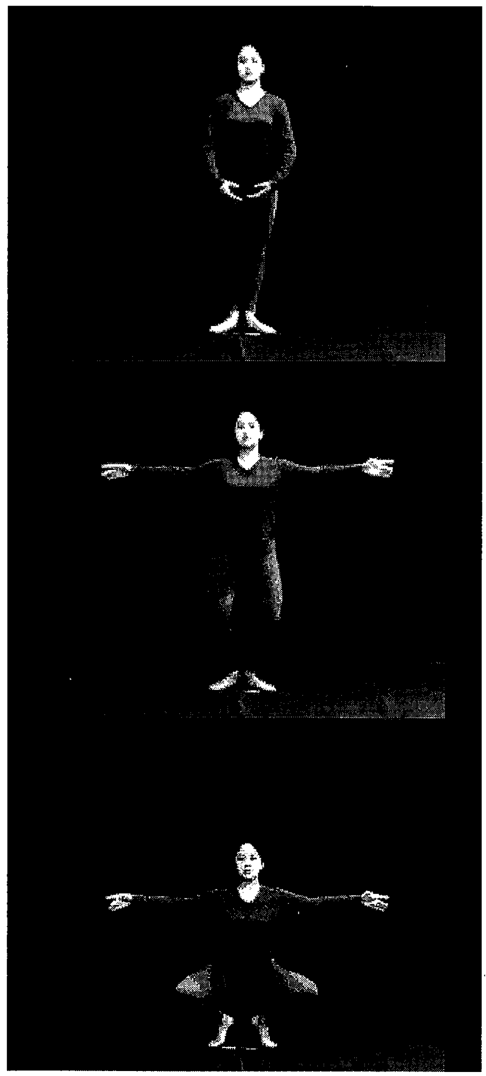

FIGURE 1 Keyframe examples of human figure used in videotape presentations.

color. Each digital sequence then was downloaded to the testing computer and made into an .avi movie file with Macromedia Director software.

The second format, computer animation of movement, was created using Lifeforms, a three-dimensional modeling and rendering program created for choreography and dance instruction. Each animation was "built" from templates of ballet building blocks included in the program. These simple movements in the templates were generated from motion capture data of professional dancers. To record these data, sensors were placed on the joints of a professional dancer by the creators of the program and then uploaded into Lifeforms. These animations were then exported to a Quicktime movie format and then altered into .avi movie files by using Macromedia Director. Keyframes of the animation can be found in Figure 2.

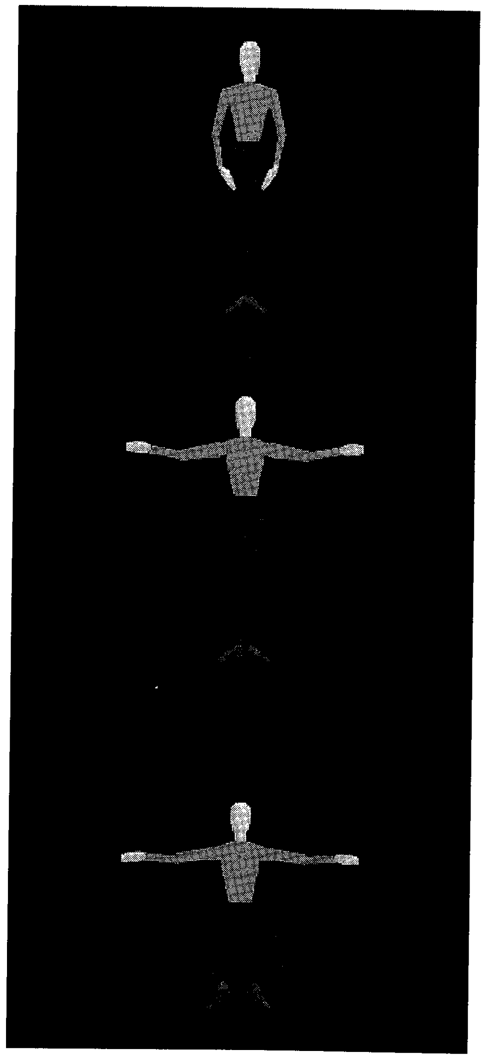

FIGURE 2 Keyframe examples of humanoid figure used in animations.

All movement sequences were evaluated before use in the experiment by an advanced ballet student as being representative of the appropriate movement. She was able to name each movement as well as recreate it when asked.

It is difficult to equate ability, even at the novice stage of learning. To help ensure that participants were roughly similar, a two-part ballet test was given to each participant. This test was created with the help of a ballet instructor from the Atlanta Ballet who was not involved in other aspects of the experiment. The written test included five questions regarding vocabulary and concepts generally taught in the first year of ballet training (see Appendix B). The movement pretest involved participants' performing a simple tendu coupe exercise after a live demonstration by one of the evaluators. Two ballet instructors acted as evaluators of the participants' performance. Both instructors were former professional ballet dancers who had ample experience teaching novice students. Both were blind to the nature of the experiment and the presentation type each participant viewed. A copy of the evaluation sheet for the movement pretest can be found in Appendix C.

Participants also were given a small cognitive battery consisting of the Vivid Visual Imagery Questionnaire (VVIQ; Marks, 1973), a questionnaire asking about imagery generation, the Cube Comparisons test, a mental rotation and spatial ability measure (Ekstrom, French, Harman, & Dermen, 1976), and the Surface Development test, which is a further visualization test (Ekstrom et al., 1976).

2.3. Procedure

Participants were run individually. Once participants arrived, they were immediately introduced to the first ballet instructor–evaluator. The second evaluator was seated in a second room, watching through a two-way mirror, in order to keep the testing room free of clutter, discourage discussion between the two evaluators about their ratings, and make participants as comfortable as possible.

Next, participants were given the movement pretest. The first evaluator demonstrated the exercise one to three times (at the participant's discretion) and encouraged questions and practice from the participant. The participant then was asked to perform the movement on his or her own and was evaluated by both instructors using the evaluation sheet in Appendix C.

Immediately following the pretest, the learning portion of the experiment started. This part of the experiment consisted of the participant viewing the three movement sequences one at a time. Individuals were shown a movement in one of the two presentation styles (a between-subject manipulation). They were instructed that they could view the movement on the computer up to five times, and they were permitted to use any practice or strategy during or in between viewings to aid in their performance. After these viewings, individuals were given one try to perform the movement, and this attempt was evaluated. The individual would then view the next movement.

Both instructors evaluated each participant on his or her performance of the movement, making notes about the participant's practice style as well. The expert evaluators judged the movement based on four criteria: timing, upper body, lower body, and whether they could tell what movement was being performed (see Appendix C). All participants performed the same three movements in the same order (plié, ron de jambe, and tendu passé). This order was suggested by one of the domain experts (who did not participate in the evaluation) as a rank of difficulty. It was her opinion that if movements were presented in this order, it would minimize confusion and fatigue.

Once participants performed all three movements, they filled out a demographic sheet, the VVIQ, the Cube Comparisons test, the Surface Development test, and a debriefing form.

3. RESULTS

There were no significant differences between groups in the number of viewings, with participants in the animation presentation viewing the movements a mean of 4.63 times ($SD = 0.50$) and the participants in the video presentation condition viewing the movements a mean of 4.75 times ($SD = 0.58$), $F(1, 30) = .43$, $MSE = 1.72$, $p = .70$. Although the amount and type of practice participants did was not coded, it was observed that if participants practiced at all, they always faced the computer monitor and followed along while the presentation played.

The two expert evaluators had reasonably high correlations on their various movement ratings of individuals. These correlations are presented in Table 3. It was expected that participants with some dance experience would learn more effectively—and thus receive higher ratings—from animations than from videos, whereas the presentation format would not matter for those with no dance experience. Mean performance ratings are shown in Table 4. A two-way analysis of variance of performance ratings was conducted with presentation condition and previous dance ability as the independent variables. A significant main effect was found for dance experience, $F(2, 26) = 3.63$, $MSE = .225$, $p = .04$, but not for presentation condition, $F(1, 26) = .43$, $MSE = .23$, $p = .52$. A trend was found in the interaction of dance ability and presentation, $F(2, 26) = 3.06$, $MSE = .23$, $p = .06$.

To further explore the effect of presentation style on performance, dance and ballet groups were analyzed separately. Participants with previous dance (i.e., ballet, swing, modern, etc.) experience ($n = 16$) showed a significant effect of presentation type, where the eight individuals in the animation condition were rated higher across the three movements than the eight individuals in the video condition, $F(1, 14) = 6.86$, $MSE = .11$, $p = .02$.

Table 3: Pearson Correlations of Movement Ratings Between Two Expert Evaluators

	Pearson's r
Preability score	.66
Movement score	.84
Plié score	.69
Ron de jambe score	.74
Tendu passé score	.60

Table 4: Ratings of Participants' Performance

	Plié		*Ron de jambe*		*Tendu passé*		*Average*	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
All individuals ($n = 32$)								
Animation	3.91	0.54	3.67	0.69	3.68	0.89	3.75	0.59
Video	3.78	0.64	3.66	0.55	3.84	0.59	3.76	0.49
Individuals with prior dance experience ($n = 16$)								
Animation	4.13	0.38	4.13	0.38	4.32	0.44	4.18	0.25
Video	3.75	0.53	3.63	0.54	3.83	0.54	3.74	0.39
Individuals without prior dance experience ($n = 16$)								
Animation	3.75	0.60	3.32	0.68	3.19	0.84	3.42	0.57
Video	3.82	0.81	3.72	0.61	3.86	0.69	3.80	0.63
Individuals with prior ballet experience ($n = 8$)								
Animation	4.09	0.50	4.09	0.36	4.22	0.60	4.14	0.30
Video	3.44	0.58	3.53	0.46	3.67	0.75	3.55	0.31
Individuals without prior ballet experience ($n = 24$)								
Animation	3.85	0.55	3.53	0.72	3.50	0.92	3.60	0.61
Video	4.00	0.64	3.71	0.59	3.90	0.55	3.80	0.53

When only participants with prior ballet experience were analyzed ($n = 8$), again the mean movement rating showed a significant difference, with the four individuals in the animation group being rated higher than the four in the video group, $F(1, 6) = 7.28$, $MSE = .10$, $p = .04$.

When individuals without previous dance experience were analyzed ($n = 16$), no significant differences were found in performance ratings as a function of learning from video or animation presentation, $F(1, 15) = 1.62$, $MSE = .36$, $p = .22$.

Thus, it seems that learners with some previous experience were better able to take advantage of animations compared with videos, whereas for those with no experience the format did not matter.

4. DISCUSSION

Presentation format presumably is an important factor in the implementation of a computer-based dance tutor. Given previous research, there was no particular reason to expect computer animations and videotape of movement sequences to be differentially effective presentation formats for the proposed system. However, a task analysis indicated that a learner first needs to ascertain joint segmentation as well as gross motion and trajectory information. A computer animation was expected to be more effective than a video in providing information for learners to form useful representations that aid performance due to its feature of distinct joint segmentation. The hypothesis of this study was that computer animations would help people learn dance because of the joint segmentation. Additionally, it was thought that learners with previous dance experience would learn faster and perform better overall than those without any previous dance experience.

Individuals in the animation condition were rated higher on their dance performance if they had some prior dance experience. For the 16 individuals who had prior dance experience, which ranged from ballet to cotillion dance, those who viewed animations were rated higher on their performance than those who viewed the videotape. No significant differences as a function of presentation format were found for individuals without prior dance experience. Thus, it would seem that learners with some previous dance experience were better able to take advantage of animations compared with videos, whereas for those with no experience the format did not matter.

Scaife and Rogers (1996), in their discussion of graphical constraining, placed great importance on the "right" multimedia presentation, because the presentation constrains the inferences that a user can make about the situation. Perhaps video graphically constrains individuals with previous ballet experience in such a way as to create performance detriments. Individuals without prior ballet experience may not have experienced this difference in difficulty because they were less likely to have an existing representational schema of dance to guide the encoding process. Instead, they extracted basic movement information that was supported equally well by animation or video presentation.

The results of this study imply that computer animations are appropriate for presentation in the proposed dance tutor. They benefit learners with dance experience and are at least as effective as videos for learners without dance experience. The results also raise some interesting directions for future research.

5. CONCLUSIONS AND FUTURE RESEARCH

Two clear extensions might be pursued following this work. First, training in this experiment involved only one sensory modality, vision. In dance classes, visual, verbal, and kinesthetic factors all play a part in learning movement, as found in the questionnaire surveying students about their movement training. Further research should involve an examination of all of these factors as well as their interactions in learning. Until these issues are examined, it is difficult to fully determine how the proposed tutor should present movement and feedback to the user.

Second, only novice dancers—those with 2 years or less of experience—were tested in this experiment. It may be that dance students with more experience, especially ballet experience, might need to extract different information from a presentation of movement, and such differences need to be taken into account. Therefore, the effects of domain knowledge should be investigated more thoroughly. Perhaps the advantages of animation relative to video will be more pronounced as more experienced dancers are tested and as dancers are taught more complex movements or more fine-grained aspects of basic movements.

The development of a computer-based dance tutor is a daunting task. It involves the complex interaction of presentation, tracking, and feedback systems. To best implement this tutor, further research must be done to better characterize the effects of domain knowledge and multimodal sensory input. In addition, once the presentation issues for this tutor have been more thoroughly investigated, we must then examine the remaining pieces of this system: student observation, student feedback, and interaction and communication. Thorough inquiry into these areas, and into the way that ballet students currently manage these issues within the classroom, is necessary to develop the best interface possible for a successful ballet tutoring system.

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APPENDIX A

Task Analysis of Learning a Ballet Movement

- Step 1: Listen to name of movement
  - Actively encode name of movement
- Step 2: Examine first demonstration of movement
  - Note starting position
    - Retrieve from memory possible starting positions
  - Listen for verbal cues
    - Is instructor counting aloud?
    - Is instructor describing the movement?
    - Is instructor verbally breaking down the movement into basic movements?
    - Does the movement itself create a verbal cue (like the brush of the foot)?
  - Determine timing
  - Attend to motion and trajectory of legs
    - Do the feet leave the floor?
    - Which direction do the feet go?
    - Do the knees bend?
    - Do both legs perform the same motion and trajectory?
    - What is the distribution of weight?
- Step 3: Examine second demonstration of movement
  - Attend to motion and trajectory of arms
    - Note arm position
      - Retrieve from memory knowledge of possible arm positions
    - Where are the arms in contrast to the head?
    - Do the elbows bend?
    - Do both arms perform the same motion and trajectory?
    - What is the distribution of weight?
  - Simulate leg motion in time
    - Does leg motion fit timing?
    - Is torso strong?
    - Apply verbal cues
    - Notice breakdown of movements into basic movements
      - Retrieve from memory knowledge of basic movements
- Step 4: Examine third demonstration of movement
  - Simulate leg and arm motion in time
    - Are arms and legs fitting in time?
    - Is torso strong?
    - Is weight distributed properly?
    - Incorporate internal shifts of body weight
  - Attend to peripheral body motion
    - Does the head move?
    - Are feet pointed or flexed?
    - Are hands properly aligned?
- Step 5: Perform movement

Take preparation stance
Take appropriate starting position
Are shoulders back?
Are legs turned out?
Is stomach in?
Are gluteus muscles tight?
Is back straight?
Is supporting arm relaxed?
Is head looking to working arm?
Inhale
Perform movement
Attend to balance and gross motion in time
Are arms and legs working together?
Is stomach in?
Are gluteus muscles tight?
Is back straight?
Is supporting arm relaxed?
Breathe
Step 6: Receive feedback
Attend to given verbal feedback
If necessary, repeat any or all of Steps 1 through 5
Feel kinesthetic feedback
Encode "muscle memory" for movement
Ask questions
Step 7: Perform movement with feedback
Take preparation stance
Take appropriate starting position
Are shoulders back?
Are legs turned out?
Is stomach in?
Are gluteus muscles tight?
Is back straight?
Is supporting arm relaxed?
Is head looking to working arm?
Inhale
Perform movement
Integrate demonstration, cue, and feedback into performance
Concentrate on the "feeling" of the movement
Attend to balance and gross motion in time
Have corrections been adequately made?
Are arms and legs working together?
Is stomach in?
Are gluteus muscles tight?
Is back straight?
Is supporting arm relaxed?
Breathe
If necessary, repeat either or both of Steps 6 and 7

APPENDIX B

Knowledge and Movement Pretests

Written Ballet Test:

Are you a current ballet student? Yes No
If yes, how long have you been taking ballet?______________________
If no, when and for what duration did you last take ballet?______________
How many times per week do/did you take ballet?__________________

Please answer the following questions to the best of your ability:

The height of a degage should be approximately how many inches?________
What is the difference between a glissade and an *assemble*?____________
Define *a terre*.______________________________________
In first position, where should the arms be placed?_________________
Does *en dedans* mean "back to front" (outside) or "front to back" (inside)?______
____

Movement Pretest:

Evaluator: Please rank the student on a simple tendu coupe exercise, where 5 is *strongly agree*, 4 is *agree*, 3 is *neither agree nor disagree*, 2 is *disagree*, and 1 is *strongly disagree*.

EXERCISE: From first position. Arms first to second in 4 counts. Tendu, coupe, tendu, close. One count each. Front, side, back, side. Arms back to first for close in 4.

The student performed the exercise with little difficulty.	1	2	3	4	5
The student understood the vocabulary used.	1	2	3	4	5
The student seemed to understand my demonstration of the exercise.	1	2	3	4	5
The student asked pertinent questions during my demonstration that led to increased understanding of the exercise.	1	2	3	4	5
Overall, I would rate this student's ability as high.	1	2	3	4	5
Did the student recognize the name of the exercise?			Yes		No

How many times did you have to demonstrate the exercise?______________
How did you break down the exercise (e.g., name of basic components of body part)?______________________________________

Additional notes:

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APPENDIX C

Evaluation Sheet

Instructions to the evaluator: Please base your evaluation of the following participant on her or his performance of the given movement. Do not compare his or her performance to any other individual's performance or compare it to any past performance the individual gave. In rating the different scales, please define "poor" as not performing anything remotely like the movement, "adequate" as having the bare basics, and "perfect" as performing the movement as it should be performed. In the comment section underneath the rating, please identify why you scored the participant the way you did.

Participant no.________ Name of movement__________ Sequence no.________

Please describe the type of practice the individual performed in between viewings.

Did the individual keep consistent timing? Yes No

How would you rate the individual's overall timing of the movement?

1	2	3	4	5
Poor		Adequate		Perfect

Comment:

Did the individual perform the upper body (arms, torso, head) part of the sequence correctly? Yes No

How would you rate the individual's overall upper body performance of the movement?

1	2	3	4	5
Poor		Adequate		Perfect

Comment:

Did the individual perform the lower body (legs, feet) part of the sequence correctly? Yes No

How would you rate the individual's overall lower body performance of the movement?

1	2	3	4	5
Poor		Adequate		Perfect

Comment:

Did the individual integrate the upper and lower body portions of the movement? Yes No

How would you rate the individual's integration of the lower and upper body?

1	2	3	4	5
Poor		Adequate		Perfect

Comment:

Would you recognize what kind of movement sequence this is just based on the participant's performance? Yes No

Why or why not?

Additional comments: