Interactive Dance Choreography Assistance

Victor de Boer[1], Josien Jansen[1], Ana-Liza Tjon-A-Pauw[1] and Frank Nack[2]

[1] Department of Computer Science, Vrije Universiteit Amsterdam, Amsterdam, the Netherlands
[2] Informatics Institute, Universiteit van Amsterdam, Amsterdam, the Netherlands
v.de.boer@vu.nl, josienjansen1@gmail.com,
analizatjon7@gmail.com, f.m.nack@uva.nl

Abstract. Creative support for the performing arts is prevalent in many fields, however, for the art of dance, automated tools supporting creativity have been scarce. In this research, we describe ongoing research into (semi)automatic automated creative choreography support. Based on state-of-the-art and a survey among 54 choreographers we establish functionalities and requirements for a choreography assistance tool, including the semantic levels at which it should operate and communicate with the end-users. We describe a user study with a prototype tool which presents choreography alternatives using various simple strategies in three dance styles. The results show that the needs for such a tool vary based on the dance discipline. In a second user study, we investigate various methods of presenting choreography variations. Here, we evaluate four presentation methods: textual descriptions, 2D animations, 3D animations and auditory instructions in two different dance styles. The outcome of the expert survey shows that the tool is effective in communicating the variations to the experts and that they express a preference for 3D animations. Based on these results, we propose a design for an interactive dance choreography assistant tool.

Keywords: Dance choreographies, Dance representation, Performing arts, Creativity support

1 Introduction

The arrival of digital media and computational tools have opened up new possibilities for digital creativity [1]. In the field of dance, digital technologies have been used for instructing, and assessing dance as well as opportunities to expand dance resources and redefine the learning process [2] [3]. However, tools supporting automatic dance creativity are scarce.

According to [4], making choreographies in the traditional way is very costly and time-consuming. The use of accurate computer software can be really helpful to make it less costly and time-consuming. Another difficulty dancers can come across, is lack of inspiration for making a new choreography [5]. Smart technology can provide suggestions for choreography elements or for more variety in steps, addressing this challenge.

When making choreographies, a choreographer typically starts from a particular stimulus such as a specific physical movement, a musical phrase, a visual image, or a state of mind [6]. It requires choreographers to engage with inner motivations to express feelings as well as to dialogue with the external environment, whether that be visual, aural, tactile or kinesthetic environmental stimulus [7]. Furthermore, the goal of a dance production, as with any other art, is the creative exploration of an idea. Within dance, this exploration takes place through the choices made regarding choreographic expression, musical accompaniment, costuming, lighting, scenic elements, and props [8]. Choreographers can build a piece on their own or with other dancers, either way, this is an iterative and interactive process where technology can play an assistive role. We include the external stimulus to discover what inspires a choreographer in a creative process.

In this paper we investigate to what extent choreographers can be supported by semi-automatic dance analysis and the generation of new creative elements. In Section 3, we outline specific needs and requirements for a new tool based on the state-of-the-art and through a survey. This includes the selection of appropriate semantic level at which should operate and communicate with the end-users. Based on the results we developed a simple prototype choreography assistant which uses various strategies for creative support. We evaluate this in three dance styles. In Section 4, we then focus on the presentation methods of these choreography variations. In a second user study, we investigate which methods of presenting choreography variations.

2 Related Work

2.1 Automatic Creativity and Dance

As technology continues to develop, the possibilities of integrating it in the process of creating dance increases as well. Stoppiello and Coniglio believed that linking the actions of a performer to the sound and imagery that accompanied them would lead to new modes of creation and performance [9]. Merce Cunningham's "Biped" choreography integrated computer-captured dance movements and interpreted it with hand-drawn graphics, so that animated and abstract dance characters projected on a screen moved along with and among the real dancers [10]. In the media video "Ghostcatching" Bill T. Jones's recorded actions, a portrait of Jones as performer, was used to animate abstract dancers in an 8,5 minute virtual dance [11]. What these dance productions all have in common is that they aim to discover new ways of creating dance and this study has the same goal, however, we are focused on the choreographers' needs in this process and not on the end product that the audience observes.

Burton et al. [12] researched how Laban Movement Analysis (LMA) could be useful for more expressive human-machine interaction. Jadhav et al. describe similar research in the field of automated choreography, focusing on Indian Bharatanatyam Dance [13]. Their goal was a computer program that generate new experimental steps for them. Here they faced two main challenges: 1) to avoid impracticable (not doable) and impractical (not practiced) dance steps, and 2) to generate steps that had surprise value or novelty. In order to model the dance steps, a classification was needed whereby there is a clear representation of human movements, at a higher level than LMA notation. Following this, we use dance terms because of their usability.

Other studies have created systems where interactive environments are used to create, practice and perform choreographies including a virtual reality-based tele-immersive environment [14] or interactive augmented reality for live performances [15]. Sheppard et al. developed an application where multiple participants interact independent of physical distance, which resulted in tele-immersive dance (TED), a highly interactive collaborative environment [16]. Such tele-immersive environments have a similar framework as the choreography assistant tool. Except this tool would give suggested variations and generate it in real-time, that part is missing in the previous mentioned systems.

2.2 Dance Sensing

Several kinds of systems exist to capture movements of the human body. These include motion sensing systems such as markerless 3D camera clusters [17], cameras with reflective markers [18], wireless sensor modules worn at wrists and ankles [19], wearable wireless sensor nodes [20], pressure sensing floors [21] and a kinect-based human skeleton tracking system [22]. These studies demonstrate how well movements can be tracked and how motion detection can be used in various forms. This sensing –although non-trivial- is out of scope of this research.

2.3 Dance Representation

Most choreographies are never stored in retrievable forms. They either are retained in memory of the choreographer or are stored in video registrations. However, retrieving information from (large libraries of) is not easy as video is a “blind medium”, which is meaningless until one watches it [23].

Several representation languages for human movement have been developed. One study discusses the Labanotation system that is used for analyzing and recording movement. It comprises a symbolic notation, related to music notation, where symbols for body movements are written on a body parts [24]. One study developed a method to generate coded description from motion-captured data with the Labanotation Editor [25]. As a follow up, the researchers developed XML for Labanotation to represent text and interchange data via the Internet. With LabanXML specific motion patterns can be searched, dance movements analyzed and body motion archived [26]. Wilke et al. used Labanotation to develop a LabanDancer system and translate Labanotation scores into 3D human figure animations, because most dancers and choreographers cannot read or write the notation [27].

The Benesh Movement Notation is another well-known dance notation. Benesh is written like a music score: on a five line stave that is read from left to right and from the top of the page to the bottom. According to Bianchini et al., Labanotation and Benesh notation are not capable to be integrated into a software environment [28]. It is also hard to analyze dance movements within the existing dance notations. Both notations are quite comprehensive and therefore difficult to learn [29].

A more common way of communication among dancers are style-specific *dance terms*. For example in classical ballet, common terms like the third position, pas-de-deux and plié are terms most western-educated dancers understand. Recent work by El Raheb et al. has led to the development of a hierarchical vocabulary based on classical ballet syllabus terminology (Ballet.owl) implemented as an OWL-2 ontology [30]. Their BalOnSe tool provides a web interface for ballet that allows the user to annotate classical ballet videos with terms from this ontology. The ontology consists of steps in dance terms and indicates the corresponding type of step. We build on this ontology for our dance-terms based prototype. In Section 3 we investigate the appropriate representation level for communicating dance variations to users.

2.4 Dance Presentation

Most digital tools for dance contain UI presentation elements, mostly divided into visual and auditory presentations. Dancers are stimulated by visual presentations such as visual effects [15], lighting [31], and 3D virtual rooms [32]. Visual effects could be presented as 2D animations where abstract figures, circles and lines are used or written text is shown to an audience [33] [34] [35]. The effects can be presented as 3D animations as well. One example is texture-mapped drawings around a 3D character [10]. Another example is the study where 3D images are based on a motion-captured human body with kinematic models, hand-drawn lines modelled as mathematical curves and sampled charcoal strokes [11]. There are also studies that use animated human figures with models based on hierarchical skeletons [21] [25] [36].

In addition to the visual presentations, there is the notion of aural stimuli that may be used in the choreography process. These stimuli usually come from music, but from auditory pitches or noises that movements produce as well [37] [38] [39]. The previously mentioned presentations are used as a basis for the development of our presentation methods.

One of the most influential and significant works that used animated figures for choreography is the work of Merce Cunningham. He used a computer system called Life Forms, which is an interface that supports choreography and where the tool becomes a “visual idea generator” [2] [6]. Another paper presents the evolution of Life Forms, DanceForms, which lets choreographers try out ideas and animations before ever meeting with live dancers [4]. These studies show how people interact with computer systems in their creative process. However, this is a static way where people sit behind a computer and create pieces with clicks of a mouse. In Section 4, we discuss how to presents the interaction in a more dynamic way in the dance studio.

3 Dance representation

In this section, we describe an investigation into how choreographers make choreographies and what their general attitude towards technological help in this area is. This gives us the opportunity to identify requirements for an assistant in dance analysis to generate new creative elements in choreographies. To this extent we first describe the setup and results of a survey, followed by a design of a prototype and a user study.

3.1 Survey setup

To get insight in the attitude of dancers towards the use of technology within the process of creating choreographies, we conducted an online survey. This survey included questions on how choreographers develop choreographies. We included questions about awareness and use of various dance notations and to what extent users are willing to use digital technologies to support them in their creative process. The survey and its results is described in detail in [40]. Here we reproduce the most important findings. The questionnaire was distributed among Dutch choreographers through within Dutch dance communities through social media. 54 choreographers (9 male, 45 female) responded. Almost 75% of the participants followed a certified dance education.

3.2 Survey results

With respect to dance notations, the survey results confirmed earlier findings from [23] that most choreographers store choreographies through written notation, in memory, or video registration. 61% of the respondents use the aforementioned dance terms for making and remembering their choreographies. Almost 80% of the respondents report not being able to work with dance notations as Laban and Benesh.

To determine the acceptance of digital tools for creative support, participants were asked about willingness to adopt a tool that, for example, gives new variations based on an existing choreography. A significant sub-group (55%) of the respondents does have a positive attitude towards such tools. However, the dancers with a negative attitude are often very negative, where they give arguments such as loss of human aspects of dance, loss of ownership of a choreography or possible difficulty to work with such tools. We also asked participants to rate the importance of various features of choreographies on a 1 (very important) to 5 (not important) Likert scale. As the results in Table 1 show, musicality, creativity and emotion turned out to be the most important aspects in choreographies.

Table 1. Avg. importance ratings of choreography aspects on a Likert scale 1 (high) to 5 (low)

Aspect	Avg. rating
Originality	2.15
Musicality	1.57
Creativity	1.78
Technique	2.30
Symmetry	2.41

To end the questionnaire, an open question was asked about potential features for a potential choreography assistant tool. Using a MoSCoW method, a list of requirements for a choreography assistant tool was developed. Participants indicate that:

- The tool must work with different dance styles
- A dancer must be able to add their existing choreography to the tool
- The tool is able to give new suggestions for choreography variations
- The suggestions must be based on different, rule-based strategies
- The dancer must be able to see the choreography at any moment (written)
- The dance notation used is dance terms
- The tool must be “easy to use”, and have fast variation generation time (seconds) The tool is able to explain complex movements in have simplified body movements (legs, arms, belly, knees, hips and head)

3.3 Prototype

Based on the requirements from the previous section, we developed a prototype choreography assistant tool. This prototype is a mobile application (to facilitate use at any time and any place) for dancers where users can enter a choreography consisting of different subsequent steps and the prototype generates variations based on different strategies. When opening the application, the user chooses a dance style. The prototype supports classical ballet, modern dance and street dance. The user continues in a new screen where they can enter their choreography in ten steps, using dance terms (see Figure 1)[1].

Dance ontologies. For classical ballet, these dance terms are based on the BalOnSe ontology from [30], as introduced in section 2.3. In the prototype, 78 ballet steps from BalOnSe were implemented. For modern dance, an ontology from Phyllis Eckler was used to implement steps for this dance style. This ontology exists of 57 modern dance steps[2]. For street dance, this was more difficult. There were no existing ontologies for street dance steps found, so a partial ontology for this dance style consisting of 31 steps was made based on experience of one of the authors of this paper.

Generating variations. To generate new variations based on the entered choreographies, we implemented two main strategies. The first strategy replaces one random step by another random new step from the same dance style. The second strategy takes the ontology hierarchy into account and replaces a random step in the choreography by one that shares a ‘parent’ step in the ontology hierarchy. For example, a specific type of jump is replaced by a different type of jump. The expectation is that

[1] The prototype is developed as a simple Android application which can be used with a minimum SDK version of 17. The application and source code are available at https://github.com/biktorrr/Dancepiration

[2] These steps were retrieved from the web document at http://faculty.lacitycollege.edu/ecklerp/modern_dance_terminology.htm

the variations based on the ontologies will be more appreciated by the dancers than the completely random option. A third strategy randomly selects either one of the other two strategies or changes more than one step. We however did not evaluate this third variation. The variations are triggered by the user pressing one of three buttons. In the screenshot shown in Figure 1, these are the buttons labeled 1-3.

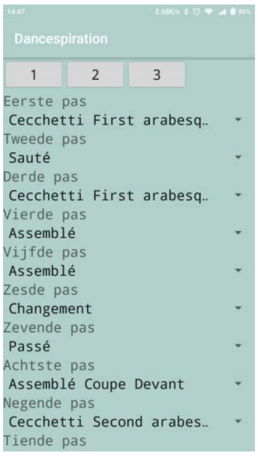

Fig. 1: Screenshot of the mobile choreography assistant prototype

3.4 User study

Setup. We evaluated the prototype in a user study done with six Dutch students from the dance academy Codarts. The participants were asked to 1) choose at least one dance style and make a simple choreography and enter it in the prototype. They were asked to rate this choreography on a 10-point scale. Next, the participant was asked to generate variations using both the random and the ontology-based strategy, each three times. The strategies were not explained to the participants and the buttons were numbered not named

For each variant, participants were asked to rate the new choreography on a 10-point scale again.. Participants were also asked to indicate the executability of the variation and to indicate how correct, creative, helpful and meaningful the variation was on a Likert scale from 1 (very bad) to 5 (very good). Finally, participants were asked what their opinion about the application in general was and what variant they prefer the most.

Results. The random-based variations are compared to ontology-based ones in Table 2 based on different aspects. This shows that in every single aspect the ontology-based variant is outperforming the random variations. For the average choreography score and correctness this difference is statistically significant.

Table 2. Average ratings of two variants (grade on a 1-10 scale) and differences in assessment of different elements (on 1-5 scale). *, ** indicates statistical significance at α=0.10 and α=0.05 respectively (t-test/anova.

Score	Original	Random	Ontology-Based	Difference	
Average grade	*6.17*	*5.50*	*6.35*	***+0.85***	**
Correctness		2.89	3.37	**+0.48**	*
Creativity		3.19	3.37	+0.18	
Helpfulness		2.59	3.00	+0.41	
Meaningfulness		2.70	2.96	+0.26	

In Table 3, the four aspects per dance style are shown including the differences between the two variants. When looking at the results from dance style perspective, it seems that ballet is the worst performing dance style. The correctness of ballet is the lowest in comparison to the other dance styles. It is also the only dance style whereby the random variant performs better than the ontology-based variant. Interesting is the rating of creativity, whereby ballet is the best performing. One participant indicated in the user study for ballet variations: "These variations are not logic and fitting, however they are very creative."

Table 3. Average ratings per aspect based on dance styles *, ** indicates statistical significance at α=0.10 and α=0.05 respectively (t-test/anova.

Element	Style	Random	Ontology-Based	Difference	
Correctness	Ballet	2.89	2.56	-0.33	
	Streetdance	2.78	3.56	**+0.78**	*
	Modern	3.00	4.00	**+1.00**	**
Creativity	Ballet	3.44	3.56	+0.12	
	Streetdance	2.78	3.11	+0.33	
Helpfulness	Ballet	2.67	2.67	0.00	
	Streetdance	2.44	2.89	+0.45	
	Modern	2.89	3.44	+0.55	
Meaningfulness	Ballet	2.89	2.78	-0.11	
	Streetdance	2.33	2.67	+0.34	
	Modern	2.89	3.44	+0.55	

For the question which variants they preferred, 90% expressed preference for the ontology-based variation instead of the random option.

Discussion. In general, the variations based on the ontologies are considered better than the original choreography. The participants indicated they would like to work with a complete application for preparing dance choreographies and lessons.

The ontology-based variation results in the highest-rated choreographies for most aspects and styles. For classical ballet, the tool performed the worst in general among while classical ballet is the most researched dance style with the most extended ontology. A possible reason for this is that classical ballet is the most strict dance style in terms of existing dance terms. The other dance styles are very flexible in their steps and there are a lot more possibilities for follow-up steps. The aspect correctness can be seen as one of the most important aspects of this application. When a suggestion is not executable, the whole choreography will be considered to be bad. This confirms findings from [13], which also concludes that this is especially difficult to achieve.

4 Dance presentation

In the previous section, we have shown the potential of a choreography assistance tool based on dance term representation. We did not discuss the influence of presentation method of choreography variations. The prototype described in Section 3 has a very basic text-based User Interface. In this section, we investigate which presentation methods are considered most effective by end-users for an interactive dance choreography assistant tool. To this end, we developed a second prototype, where choreography variations can be presented in four different methods. In this experiment, we focus on two new dance styles: Hip-hop and Dancehall[3].

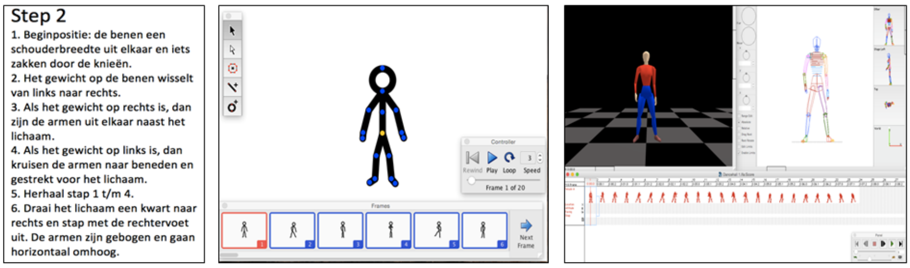

Fig. 2. Three of the four presentation methods (auditory is omitted). From left to right: textual, 2D animation (Styx tool) and 3D animation (DanceForms)

4.1 Four presentation methods

We here first describe the four presentation methods, which include both visual and auditory modalities. The visual methods (shown in Figure 2) consisted of textual descriptions, 2D animations and 3D animations and the auditory method consisted of voice-overs. The reason for choosing these four presentation methods is that they differ from each other in the sense that they each present a different approach but propose the same variation.

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[3] More information about the dance styles can be found at https://en.wikipedia.org/wiki/Hip-hop_dance and http://www.gangalee.net/dancehall_info.php respectively

- **Textual descriptions**. The textual descriptions were based on Laban and Benesh movements. However, as Section 3 shows, most dancers are not familiar with these notations, we used (Dutch) written descriptions of individual poses and movements. Rather than using dance terms, here we use detailed descriptions of these poses ("start with legs apart at a shoulders' length, bend knees slightly"). This was done to ensure that the presentation methods could be used for a range of dance styles, including less formal ones for which appropriate training is needed.
- **2D animations**. The 2D animations were created with Stykz (https://www.stykz.net/) which is a multi-platform animation program to develop stick figures. The software is frame-based, so every frame can be customised individually. Therefore, every movement can be animated and modified as desired. The body parts were created with added lines and adjusted by clicking on the points and dragging them in the wanted direction. The timeline and speed could be adjusted with the controller panel and the play button generated the end product in another window without the dots.
- **3D animations**. The 3D animations were created with the choreography software DanceForms 2 (http://charactermotion.com/products/danceforms/), which is designed to visualize dance steps or entire routines in an easy-to-use 3D environment. The 3D animations for this study consisted of one character and were made from scratch, however, large groups of characters or existing sequences from the DanceForms database could be used as well.
- **Auditory descriptions**. The textual instructions were converted to audio versions using Google Translate text-to-speech. This resulted in audio versions of the same instructions.

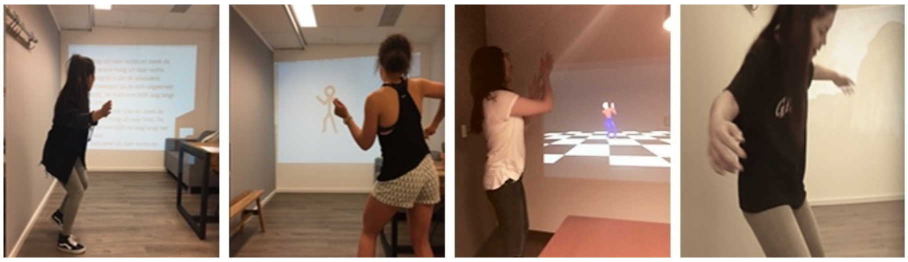

Fig. 3: Four participants during the 2nd user experiment. From left to right this shows variations presented through textual, 2D animation, 3D animation, and auditory instructions.

4.2 Setup

Seven experts participated in the experiment. These participants were gathered from Beatz dance studio in the Netherlands. All participants were trained in two dance styles for this experiment. Before the user study started the participants were asked to sign an informed consent letter and fill out a pre-experiment survey on background information of the participant.

Next, the participants were taught a simple choreography. As the variations were generated before the experiment and to ensure that each participant started with the same choreography, they were shown choreographies for each of the two styles, consisting of 16 counts of steps. After this, three pre-programmed variations were shown using one of the four presentation methods. To increase immersion, the visual methods were presented using a large projection screen. Each participant was asked to execute the movements to demonstrate that they understood the presented variations before moving to the next variation. After three variations for one method, the next method was presented. This resulted in 12 variations per dance style per participant. Figure 3 shows participants for each of the four styles.

The participants were then asked to give their assessment on the presentation methods in a post-experiment survey. Here participants were asked to for each of the presentation methods 1) give an overall assessment; 2) indicate how creatively stimulating these are; 3) how understandable the method is; and 4) whether the method disrupts the creative process. Scores were given on a 1-10 scale. The entire survey can be found in [41]

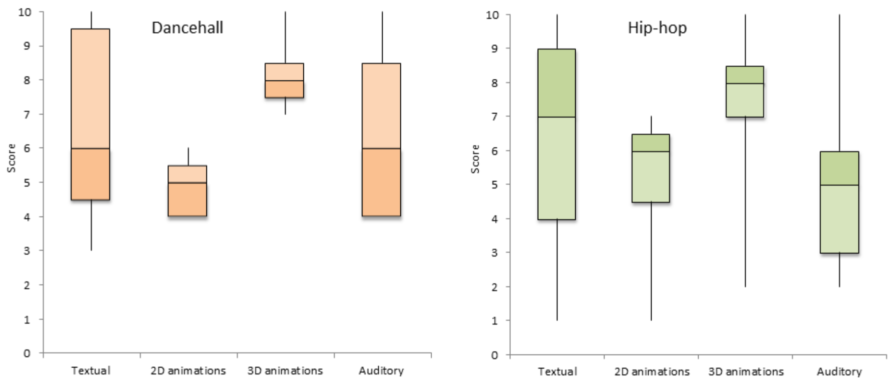

Fig. 4. Boxplot showing medians, variation and extremes of overall assessment of four presentation methods for Dancehall (left) and Hip-hop (right)

4.3 Results

Figure 4 shows the results for the overall assessment for the four presentation methods for the two dance styles in two boxplots. These show mean values, variance and range of values. Even though variance is quite substantial (especially for the Textual method), the patterns are very similar between the two styles. This indicates that there is little difference between the styles in how the methods are perceived. Both plots show that the 3D animation is consistently rated highest (with one notable negative outlier in the hip-hop), followed by textual descriptions.

Table 4 shows the mean scores for the four criteria (including overall assessment) aggregated over the two dance styles. This shows that for each of scores, the 3D-animations outperform the other presentation methods. When asked directly which method they preferred, five out of seven participants indicated a preference for the 3D-animations.

Table 4: Mean scores and variance for the four assessment criteria for the two dance styles combined. The highest means are underlined.

	Overall assessment		Stimulation of creativity		Understanda-bility		(Un-) dis-ruptiveness	
	μ	σ	μ	σ	μ	σ	μ	σ
Textual	6.5	3.1	5.4	2.6	6.7	3.3	6.1	3.1
2D animations	5.4	1.9	5.8	2.3	5.5	2.2	6	3
3D animations	**7.7**	2	**7.1**	2.2	**7.7**	2.1	**7.7**	2.5
Auditory	5.6	2.8	4.7	2.6	6.3	2.6	5.6	2.9

Discussion. The overall assessment of the presentation methods of the two dance styles shows that both datasets are balanced around the same scores. The medians in all cases differ at most with 1. Overall, the results show that the participants have a neutral or positive attitude towards the four presentation methods. However, the scores of the 3D animations were significantly higher than the other presentation methods. Thus, the participants prefer the 3D animations as a method to stimulate their creativity, because it is clear to understand and does not interrupt the creative process. This presentation method is considered to be the most effective and accepted for the interactive dance choreography assistant tool.

The participants were neutral towards the 2D animations and the auditory instructions. Regarding the 2D animations they were less positive about the clear understanding of the variations and more positive about the level of interruption in the creative process. This suggests that the animations were not clear enough to understand and requires further development. Moreover, this means that the animations were not interrupting the process. Regarding the auditory descriptions the participants were less positive about the stimulation of creativity and more positive about the clear understanding of the variations.

5 Discussion and Future work

In this paper, we presented investigations into support for choreography. In both applications, we identify that there is interest in such a tool at least with a significant subset of participants. We have also seen that background knowledge in the form of a dance representation (ontology) can be used to generate variations on choreographies. We acknowledge that our rules for generating such variations are quite basic and more elaborate variation rules can be constructed. Where for now we only use hierarchical relations, other relations between steps can be exploited. For example, the steps could be annotated with information about difficulty, ‘level of energy’, emotional valence or other features, which can be incorporated in the rules. Eventually, we could use Machine Learning to identify ‘good’ choreography fragments and base variations on such learned material.

Another limitation of the studies is that we investigated short choreographies. With more elaborate choreographies, successful variation strategies are likely to differ from shorter ones. This would require further investigation. Similarly, the user studies described here are performed with limited numbers of participants. To more robustly affirm the findings, larger and more longitudinal studies will be insightful.

Here, we also looked at dance as a standalone art form, whereas in practice music plays a big role in developing and performing choreographies. Combining dance representations and rules with representations for music can result in new possibilities for generating choreography variations [42].

Finally, the results of these investigations provide input for the representation, variation generation and presentation parts of a choreography assistance tool. The method of user input is out of scope for this research, but should be investigated in detail. Such an input method can consist of an extended version of the input method described in Section 3, can consist of speech recognition, or ideally be interpreted from motion-captured dance movements [16] [17].

6 Conclusion

In this paper, we presented an investigation into the requirements and possibilities of automated choreography assistant tool. Results show that indeed choreographers can be assisted by semi-automatic analysis of choreographies and the creative generation of new choreography elements. However, from the questionnaire we identify two sub groups of choreographers, one of which has a very positive and one a negative view on such a tool. The survey corroborates existing research in the conclusion that such a tool should be based around dance terms as a representation language. Dance ontologies can be developed or reused to represent choreographies and to base variations on. For some dance styles, this approach is more successful than for others but that hierarchies in these ontologies can be exploited to design executable variations.

We furthermore explored which presentation methods of choreography variations are considered to be effective in the UI of an interactive dance choreography assistant tool. A user study with manually created variations showed that 3D animations received the most positive assessment and are therefore preferred by the experts.

The research presented in this paper shows the potential value of semi-automatic analysis of dance and creative generation of new elements in the choreography as well as presentation during the choreography process.

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