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ABSTRACT

The focus of this paper is to investigate how the design of visual feedback on full body movement affects the quality of the movements. Informed by the theory of embodiment in interaction design and media technology, as well as by the Laban theory of effort, a computer application was implemented in which users are able to project their movements onto two visuals ('Particle' and 'Metal'). We investigated whether the visual designs influenced movers through an experiment where participants were randomly assigned to one of the visuals while performing a set of simple tasks. Qualitative analysis of participants' verbal movement descriptions as well as analysis of quantitative movement features combine several perspectives with respect to describing the differences and the change in the movement qualities. The qualitative data shows clear differences between the groups. The quantitative data indicates that all groups move differently when visual feedback is provided. Our results contribute to the design effort of visual modality in movement-focused design of extended realities.

CCS CONCEPTS

• **Human-centered computing** → **Visualization design and evaluation methods**; *Interaction design process and methods*; • **Computing methodologies** → Motion capture;

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Embodied interaction, Motion capture, Visualization models

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1 INTRODUCTION

As the field of technology is evolving new platforms are being developed. The growth of new platforms also yield new ways of interaction and the possibility of including the body as the primary mean of interaction. An emerging volume of research is investigating how to use the entire body as an input device for interfaces, substituting the mouse-and-keyboard ways of interaction [8]. However, these novel input devices tend to be limited in terms of actual embodiment as they are engaged with the practical and technical development [15].

As the movement itself, rather than its interaction with an object, becomes the focus, the design techniques also diverge radically from earlier traditions [10]. Recently several researchers have highlighted the need for new approaches for interaction design [9, 10, 13, 20], and most of these approaches are put in context in Höök's seminal work on somaesthetic interaction design [12]. In the book, soma design is contrasted to visual-symbolic design and several exemplars of slow and contemplative design artifacts are provided. Many contemplative exercises are carried out with eyes closed, perhaps because the visual feedback is considered as a distraction. For example, Ståhl et al [22] reported that when an affective diary extracted the bodily state of its user from mobile data and visualized it as a "blobby" character on the screen, the image distanced users from their subjective experience of their own bodies. The body portrayed on the screen sometimes had a life of its own – "a strange organism with its own emotional and social processes" [12].

On the other hand, other properties of visualizations have been successfully utilized within the MOCO community [1, 3, 19]. Alaoui and colleagues used interactive visuals as metaphors of movement qualities [1], Bisig and Palacio explored the interactive visualisation and sonification of virtual body extensions for dancers in order to enlarge their bodily presence and movement possibilities [1, 3], and finally Larboulette and Gibet investigated the qualities of the expression of motion and how these qualities influence a 3D non-human simulation of a tree-like structure [19]. These examples indicate that the design of the visual feedback of the movement should be an articulated design effort, which will in turn change the behaviour of user. A design responding in one way may promote users to move with specific qualities, compared to others. But how can we test this assumption?

In this exploratory paper, we present an empirical investigation on whether visuals used result in users changing their movement behavior with respect to movement quality. That is, rather than targeting a specific movement for reproduction, we investigate qualities that can be applied to a variety of movements. Using a mixed-methods approach we outline how designs for movement qualities can be systematically investigated using first-person experiences as well as motion analysis. In the following sections we briefly go through some related research in Section 2 and provide an account for our first-person informed design and implementation in Section 3. We then describe the design, analysis and results of an experiment (Sections 4-5) and discuss the results (Section 6).

2 RELATED RESEARCH

Hornbæk and Oulasvirta define a concept of bodily interaction as *embodied action* [14]. While many concepts of interaction focus on how users move a cursor to the target object, embodied action highlights the *intentions* of the user (e.g. why they move their cursor) and the *context* in which they do it (due to work, being tired etc) [14]. It is hereby concentrated on the *lived experiences* and how our bodies shape everything we think and do [14]. Accounts of lived experiences during movement-based interaction are hard to spot in scientific literature. Two examples from movement and computing literature are summarized below.

Bisig and Palacio explored the interactive visualisation and sonification of virtual body extensions for dancers in order to enlarge their bodily presence and movement possibilities [3]. Using input of dancers' movements from a Kinect, a neural network produced spontaneous behaviour of the outer parts of the virtual extension. These extensions were closely related to the dancers, morphing and behaving based on the movements of the dancer's bodies and actions. The behaviour of the virtual extensions were a combination of reactive and pro-active – the motions of the dancers were mapped to the screen in front of them, though spontaneous behaviour was intertwined in the visual presentation. The reactive behaviour was implemented using a simulated mass-spring system, where the spontaneous behaviour was created using an artificial neural network [3].

Larboulette and Gibet investigated qualities of the expression of motion and how these qualities influence a 3D simulated system [19]. In this case, the embodiment was expressed through a non-human entity, a tree with three branches, expressing human like emotional content through motions that do not resemble human postures or movements [19]. The movements of the tree were portrayed using three branches which changed curvature, expanded or shrank in volume to e.g. simulate breathing. Furthermore, the hues and brightness of the leaves were utilized to convey the emotions, as well as their movements since the leaves could fall to the ground [19].

Not surprisingly, these examples touch upon Laban Movement Analysis (LMA). Laban's theory of effort [16] has been rigorously used for many years to describe and analyse movement (see e.g. [7, 20, 21]) and also inspired computational descriptors (see the review in [18]). LMA is a comprehensive system dealing with concepts of Body, Space, Shape and Effort [17], forming a symbolic notation to describe movement. Most of the previous research in interaction concentrate on the concept of *Effort* which concerns how the body distributes its economy of effort during movements. Laban and Lawrence [16] outlined how Effort as consist of four motion factors being Space, Weight, Time and Flow:

- Space, (Direct – Flexible), spans from direct like pointing to something, or indirect which is concerned with flexible wandering movements like waving [7].
- Weight (Light – Strong), where light, delicate movements such as e.g. the movement of a feather falling and in the other end with strong powerful, harsh movements like e.g. describing the movement of someone punching a punching bag [7].
- The time continuum (Sustained – Quick), is described to be concerned with the absence or awareness of urgency. Here in one end you can have sustained movement, which are lingering in time such as a yawn or you can, in the other end of the continuum, have sudden movements [7].
- Flow (Free – Bound), describes bodily tension and control. Where you in one end have uncontrolled movements, the other end has bound, controlled movements that can be stopped mid-action [7].

Laban Theory of Effort provides a framework and terminology to describe the felt sensation of movement qualities and has been used in many different fields. However, for every day users without training in LMA or phenomenological approaches for bodily awareness (some outlined in [12]) descriptions such as the effort dimensions above do not come intuitively to mind (see e.g. [21]). If we want to design movement based interactions with a certain movement quality in mind, we also need to evaluate whether users are affected by these designs. In the following we present the design of two visuals inspired by Laban Theory of Effort and an experiment to test whether the design of these affected users' behavior.

3 DESIGN AND IMPLEMENTATION

In the ideation phase preceding the design, all authors engaged in a series of movement exercises (partly adopted from Loke's movement exercises in [20]). Through these movement exercises we had first-person experiences of movement while imagining being made of different materials (sticks, glass, rubber). We asked ourselves how visuals could be designed in order to promote a certain quality of movement for a user. Based on these experiences, we selected two visuals that we expected to yield contrasting movement qualities as characterized with Laban theory of effort. The user interaction with the visuals was made using a Rokoko motion capture smartsuit[1].

Figure 1: Metal visualization displaying the character depicted as made of metal.

Two visualizations were implemented as Unity scenes, each displaying an avatar using different effects chosen to display two contrasting combinations of efforts. The 'Metal' visualization displayed a 3D humanoid model made out of metal (Figure 1) using available Unity materials [2], giving an impression of a hard and metal-like skin surface. In relation to the Effort dimensions of LMA, this avatar was expected to reveal Effort resembling the stereotypical movements of a stiff rigid-boned figure. Rigid 'metal' movements would suggest somewhat bound and restrained movements in the Flow continuum, consisting primarily of direct movements in Space with relatively strong Weight behind these. As to the time factor, medium to quick movements would be expected with this avatar.

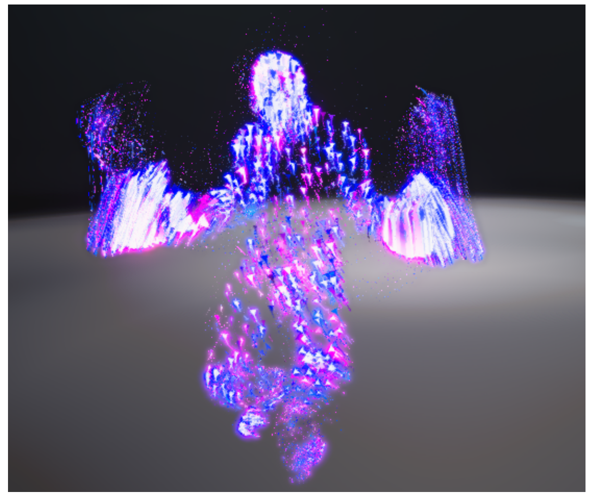

Figure 2: Particle visualization displaying the Skinner trail renderer [23]

The 'Particle' visualization utilized a particle system, indicating movements with soft particles and trails (Figure 2). The particle system used for the second avatar utilized the "Skinner" special effects collection [3] [23] and used the "Skinner trail" effect. With vibrant diffuse colors and constantly changing and flowing silhouette by the particles, this avatar was expected to produce almost opposite Effort movements by users, flexible in the Space domain and free in the Flow domain. The Weight would be expected to be differentiating between light and strong movements with tendency to more light movements. The same may be expected from the Time continuum with movements traversing the mid ranges of the scale, with a tendency to sustained movements.

The Skinner trail render creates smooth lines from the vertices of the avatar mesh. We used a human mesh as a base in order to map user movements as precisely as possible. Although the mesh mirrored a human body the mesh itself is not visible. The lines are being rendered as a result of the mesh moving - that is, whenever the user moves, these trails of particles will be visible. The width of the lines further

[1]https://www.rokoko.com/en
[2]https://assetstore.unity.com/packages/2d/textures-materials/metals/metal-floor-rust-low-texture-40351
[3]https://github.com/keijiro/Skinner

enhance movement, increasing and decreasing in reaction to the velocity of the vertices [23].

We used the Rokoko motion capture smartsuit to map the body movements of the user onto the avatars and display these in real-time on the screen. Unity was used to set up the scenes and incorporating the particle script used for the avatar visualizations. Real-time transfer of motion capture data from the smartsuit to Unity was handled by Smartsuit Studio and plugins. Unity's own post processing stack was used for realtime colour grading. In order to change between scenes, a simple script was used. When starting up the application, the list of figures (the metal and particle man) is first randomised using the Random library class of Unity to ensure a different order of presentation of the two characters for each play through. When a scene has been chosen the surroundings of the figures will remain the same neutral and empty environment in order to ensure consistency between tests.

4 EXPERIMENT

We hypothesise that the design for different movement qualities will affect how a user will move when given the designed visual feedback. Specifically, we hypothesise that a user will be more prone to use light, quick and indirect movements and Free flow with the Particle as compared to the Metal visualisation.

We tested this hypothesis by setting up an experiment where we manipulated the visual feedback to the participants (Particle or Metal) and recorded their actual and perceived movements in a between-group design. Participants' responses were obtained in a structured interview, combined with a card-sorting task.

Participants

34 participants (19-30 years old), predominantly students and employees at Aalborg University, signed up for the study. The participants were recruited by advertising the experiment on campus and online. Some of the participants were participating in an elective master course on Embodied Interaction offered for media technology students. Participants signed up via a link to an online doodle, where they could choose one of the times available. All participants received a movie voucher.

Before the experiment, we obtained participants' informed consent. We informed them that their participation was anonymous and that no names or identifiers would be matched to the recorded motion capture data or responses to questions. Although recording their interview, the recordings would be destroyed after transcribing the data.

Material

For motion capture a Rokoko motion capture suit was connected to a computer via WiFi and recorded via Rokoko Smart Suit Studio. The Smart Suit Studio linked the suit with the build of the program containing the visualisations, made in Unity, to enabled participants to control the visuals. The Visuals were shown to the participant on nine 55" screens forming a large multi-screen display covering most of a wall.

The test included three visuals: 1) 'Default'(the mannequin used as visual feedback in Rokoko Smart Suit Studio), 2) 'Particle', and 3)'Metal'. Particle and Metal visuls were described in section 3, and are demonstrated in a short video within the experimental setup by one of the authors[4].

Procedure

The experimenters helped the participant to dress in the Rokoko suit and asked for the participants' height and age. Being an inertial motion capture system, the height was used to fit a human model to the output of the sensors, which helps to set up the visualization and makes the recorded data correspond to the movements of limbs and joints more accurately. When the wireless connection of the suit was established the participant was asked to stand in the required calibration posture - with their feet pointing forward and arms vertical down the side. After confirming that the data from the suit was properly corresponding in real-time movement of the mannequin displayed in smart suit studio, we recorded a first movement session with the participants with the following instructions: 1) imagine picking up a small object from the floor, throwing it up high through the ceiling. 2) picking up a large but light object from the floor, throwing and catching it repeatedly. 3) Move a large and heavy object between two defined positions on the floor. We asked the participant to pay close attention to how it felt to when doing these predescribed tasks and during an additional 15 s where they were free to move however they wanted to explore the suit and its visualization.

Following the initial movement session, we held a brief structured interview where the participant was asked to describe how it felt moving in the different ways. More specifically, we asked participants to use adjectives to describe how it felt when performing both the pre-defined tasks as well as during the free movement. After the short interview, the scene was changed and the participant now received visual feedback with either the 'Particle' or 'Metal' visuals depending randomly assignment to one of the two groups. The participant was invited for a second movement session with the following instructions: Now we would like you to imagine that you are the person/creature in the visualisation. Please pay close attention to the avatar and your own

[4]https://drive.google.com/file/d/16ZUjsEs529cCCM06sEPrTMxdsGPnsUef

movements when performing the tasks. Again we recorded the participant doing the same set of pre-defined tasks as before (picking up objects of different sizes and weights and handling them), and an additional 15 s where the participant could move freely and explore the suit. Immediately after the second movement session we again asked the participant to describe how it felt doing the different pre-defined as well as the free movements with the visuals.

In addition to the open questions, the participant was also invited to participate in a card sorting task related to the 15 s of free movements made with the visuals (particle or metal). We asked the participant to select and rank three to five cards among a set of 56 (see Table 1) adjectives. The terms were chosen to describe the intended Laban efforts of the two designs, as well as other qualities related to motion. After picking and ranking the three cards according to what best described the movements, the participant was asked to explain why they choose those cards and why they ranked them in that particular order.

Finally, we asked the participant to think back to the free movements done with the default (first) visualisation used in the first session and to redo the card sorting so that it corresponded with that experience. The participant was asked to look at the cards again to either choose new cards or use the the same ones as previously chosen and ranked.

After two sessions and card sorting, the participant removed the suit and was debriefed about the experiment. We asked participants to please not discuss the aim of the experiment with other potential participants and lastly thanked for their participation by giving them a movie voucher. A typical experiment session took 30 minutes.

Analysis

Due to bad connection between the suit and Rokoko Smartsuit studio during some sessions there was some data loss. Specifically baseline data was not saved during some sessions. This, in turn, resulted in different number of participants between the groups. We therefore randomly resampled the larger (Particle) group in order to balance the sample size. Thus, the final number of participants entering analysis were N=13 for the Metal and N=13 for the Particle group. Despite the smaller sample, the experiment yielded variety of qualitative and quantitative data which can be analyzed extensively. For this paper, we chose to concentrate the analysis on 1) the card sorting task made by participants and 2) the motion of the hip (root) joint. We describe the details of the analysis here below.

Card sorting data. The selected cards were analyzed by calculating how many cards (across participants) that were chosen according to the Laban effort dimensions (Space: Indirect – Direct, Weight: Light – strong, Time: Quick–Sustained, and Flow: Free– Bound), as indicated in Table 1. We hypothesized that distribution of cards selected by participants in one group would be different compared to those selected by participants in another group.

	Indirect	*Direct*
Space	ambiguous, unforseen, accidental, wandering, unexpected, random, spontaneous	blunt, expected, anticipated, restricted, focused, directed, intended
	Light	*Strong*
Weight	light, effortless, painless, delicate, dainty, fluffy, weightless	strong, demanding, effortful, heavy, loaded, pressure, dense
	Quick	*Sustained*
Time	sudden, abrupt, quick, surprising, unexpected, hasty, brief	slow, calm, moderate, sluggish, delayed, lingering, long-windowed
	Free	*Bound*
Flow	fluent, flexible, changing, airy, free, graceful, uncontrolled	limited, inflexible, bound, finite, continued, controlled, reserved

Table 1: Terms used in the card selection task. The terms are organized according to their intended link with the contrasting Laban efforts used in the design. We hypothesized that terms in the left column would be chosen to a larger degree for the particle visualization while terms in the right column would be selected more for the metal visualization.

Motion data. For each participant, we segmented the motion capture data in Rokoko smartsuit studio according to the two experimental blocks (default and visuals) and exported as bvh files which were analyzed in Matlab using the MoCap toolbox [5]. Since the Rokoko Smartsuit uses inertial sensors, the data does not accurately reflect translational movements along the floor. Also, different morphology can make movements of the peripheral parts somewhat difficult to compare across participants (especially for the free movements). As a point of departure, we therefore chose to focus on the hip (root) joint which would be close to center of gravity and reveal adjustments in balance related to both trunk, arm and leg movements.

After a visual inspection of data we differentiated and filtered the position data (second order Savitsky-Golay filter, 7-point window) and calculated the velocity profile, that is the magnitude of the combined velocity vector in x,y,and z directions (Euclidian distance). In order to further enable comparisons across participants of different stature and movement characteristics, we normalized the velocity profiles according to the first maximum from the first task in the control condition (reaching down to pick up a small object). That is, for each participant the magnitude of the velocity profile during the visuals (metal or particle) was normalized to the first maximum in the velocity profile from the first task in the the first movement session with the default visuals. Thus, the motion of each participant was compared to their own "standard" movement pattern. Following, we calculated the acceleration and jerk (filtered across 11 and 15 points respectively). Finally we calculated aggregated mean values of acceleration and jerk across 15 s in the first movement task for both default and visuals, as well as for the last 15 s of free movement with visuals.

As outlined in [18], Time and Flow effort can be estimated by the aggregated acceleration and jerk, respectively. However, although jerk is an indication frequently used to indicate smoothness of movements (although not always reliably, see [2]), jerk-based description may not fully capture the bound characteristic of the Flow effort dimension. An alternative descriptor for this dimension may be *Fluidity* defined by Castellano and Mancini [6] as the uniformity of motion. We therefore chose to calculate the aggregated Fluidity as the ratio between the magnitude of velocity and acceleration (similar to [4]).

5 RESULTS

Card sorting. Figure 3 shows how the distribution of selected cards for the different cells in Table 1 and the different visualizations (denoted by different line styles). As can be seen, the distribution of selected terms differ between the three conditions. For the Particle visualization a total of 23 different words were chosen, with 'Free'7, 'Quick' 6, 'Weightless' 5, 'Effortless' 4, 'Flexible' 4, and 'Spontaneous' 4. Whereas for the Metal visualization the participants chose 29 terms with the most frequent ones being 'Controlled' 5, 'Effortless' 4, 'Heavy' 4, and 'Restricted'.

By comparison a total of 38 different terms were chosen to describe movements with the default avatar (dotted black line in Figure 3). Most frequently selected cards were 'Calm'8, 'Effortless'8, 'Flexible' 8, and 'Fluent' 6, across participants in the two groups.

Fluidity data. A general assumption was that participants would move differently with respect to movement quality between the two sessions, where the visual feedback changed.

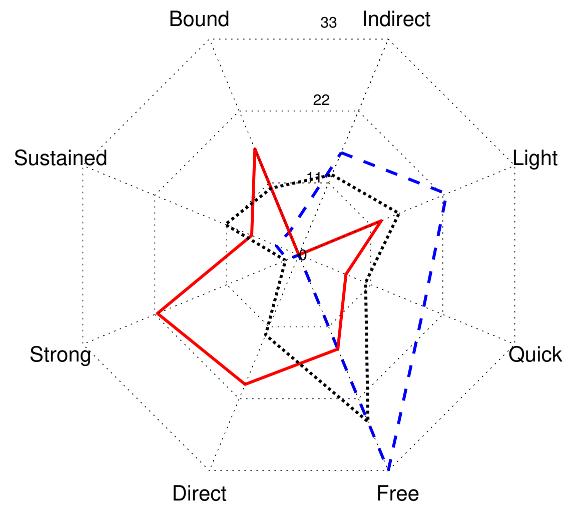

Figure 3: Radar plot of terms selected for the Default (dotted black), Metal (solid red), and Particle visualization (dashed blue). Numbers are in percentages of total cards selected for each visualization.

We tested our hypothesis that the visuals influenced movement quality *within* participants using Wilcoxon Signed-Rank test for non-parametric data. The aggregated fluidity was significantly higher for the first 15 s of the standard movement task with the default visual feedback (Mdn=10.35) compared to the visuals condition (Mdn=26.78), $T = 348, p < 0.001, r = 0.8597$. Thus, compared to the first session, participants in general moved with more fluid movements the second session (with either the metal or particle visuals).

In order to test the hypothesis that groups differed with respect to movement quality, we made comparisons *between* the two groups (Metal and Particle) for the last 15 s of free movement in the second sessions. A Mann-Whitney test for signed ranks showed no difference in mean aggregated fluidity between the Particle (Mdn=40.30) and Metal (Mdn=39.76) groups (U=174, n.s.).

6 DISCUSSION

The objective with the experiment was to test the hypothesis that participants' movements (as described and measured) would display different qualities depending on the visual feedback their movements were mapped to. Our first analysis of the qualitative and motion capture data does indeed indicate some differences depending on visuals. Arguably, the small sample size makes it difficult to generalize but we believe that the data can serve as an indication for future work. Here below we discuss the results together with some of the limitations of our study and what could be done in the future.

Comparing the distribution of selected cards between the different visuals (default, particle and metal) in Figure 3 there were clear differences. For instance, about 20% of cards chosen by participants in the Metal group were from the 'Strong' and 'Direct' categories, whereas participants in the Particle group hardly chose any of them. Conversely, 33, 22, and 14% of cards chosen by participants in the Particle group were in the categories 'Free', 'Light', and 'Indirect', respectively. For the same categories the percentages of cards chosen by the metal group were about 14, 13, and 0%.

As Mentis et al [21] noted, we also observed that users struggle to use and describe movement qualities. When asking participants to explain how the movements felt, they would often resort to describing what they had done rather than the feel of it. This is perhaps not surprising, given that in every day life we often tend to verbalize actions and may treat movement qualities as part of moods or states (e.g. 'stressed', 'relaxed'). The card-sorting therefore provided an input for participants that they could pick what best corresponded to their experience.

One question is whether the participants understood the terms in the same way and whether their interpretation correspond to the intended. The changes in the card sorting related to the default avatar movements can provide some indication. The black line in Figure 3 shows that participants in general perceived the movements as belonging to the 'Free' and 'Light' categories. In the structured interview some participants explained their choice by it being easy and effortless moving in the motion capture suit. Some of this freedom of movement was also retained for the Metal visuals, since body movements were mapped directly and no physical modeling was used to simulate stiff movements. Therefore it can be argued that the metal and particle visuals were not directly contrasting in terms of Laban effort. However, the selection of terms chosen supports that the visuals made a difference between groups.

To compare movements between participants and groups, we chose to concentrate on motion data from the hip, normalized to participants' own movement from a pre-defined task. This is naturally a coarse simplification of participants' movement repertoire, but can serve to get an overall indication of the quality of movements. The fluidity, that is the ratio between aggregated velocity and acceleration, showed differences between sessions for each participant but not between the groups. This is somewhat an expected result, given the non-parametric data and very limited sample, since the within-participant comparisons gives larger N while reducing the effect of unsystematic variability. However, the effect should be interpreted with caution. Since Session 1 and 2 always were in the same order the increase in fluidity can be an order effects.

We chose the hip as a point that would reflect a large portion of movements of the body, while avoiding some possible concerns with the intertial measurement system (e.g. inaccuracies with arm and leg lengths). However, it is likely that our choice also reduced a possible effect of differences in movement quality between groups. A continued analysis of data could include the head, upper arms other points somewhat close to the torso but likely to reflect more of the differences in movement quality.

By aggregating data across a series of movements there is also a loss of detail, which may be perceptually important. While we acknowledge that this is a great simplification it is also a first approximation that allows us to study features of movements that may vary considerably. Similar to the studies on music-induced movement done by Burger and colleagues (e.g. [4]), our study requires metrics to compare movements that can vary extensively between participants. For free movements without alignment to any external stimuli, such as musical tempo, the variability in movement patterns can be extreme. A larger sample and interclass correlation as well as clustering approaches could provide valuable insights in future studies.

Although we aimed at capturing spontaneous movement patterns it was clear that many participants felt that the task of moving freely in front of the experimenter was somewhat awkward. The predefined tasks before the free movements were intended both as baseline tasks for comparison but also to "get them going". However, some participants got nervous and shy and it is possible that they would have moved in different ways if unobserved. An additional factor was that it was not always possible to conduct the experiment without the presence of other people than the experimenters. During the period of data collection, others were sometimes there to use the equipment in the lab and on a few occasions participants would even be let in and waiting for their turn. Even though the persons waiting were standing some distance away, it is reasonable to assume that in some cases their presence would have an influence on the recorded behaviour and data.

Our mixed-methods approach combine several perspectives with respect to describing the quality of movement: The first person from our own and participants' experience of movement and the machine perspective as represented from the computed movement quality [20]. The observers' perspective is missing but could be included in having participants rate the recorded movements with respect to their qualities, for instance using Laban Effort dimensions (see e.g. [11]). Another approach would be to let participants watch and rate their own movements to see how their percept of their own movements correspond to their felt experience. Together with more refined analysis of the motion data and the annotated responses from participants, such a perceptual validation of movement qualities could help to triangulate the more important features and descriptors that can be used also for future movement interactions.

7 CONCLUSION

In this paper we have described an approach to investigate the effect of visual feedback on movement-based interaction. We described the design of visuals with two different intended movement qualities, informed by first-person experience of movement, and an experiment to test whether the movements of users were influenced by the real-time visual feedback. Results from participants' selections in a card-sorting task indicate differences related to whether they saw the 'Metal' or 'Particle' representation of their movement. Analysis of movement data show differences in fluidity of participants' movements during a pre-defined task with sessions showing the default and designed avatar. No differences were found in movement fluidity between groups, a result that is likely to be due to the limited sample size and the large variability of movements used for this comparison. For future investigations a combination of perceptual ratings of quality of movements together with more detailed analysis of motion features would yield more insights of how users move with varying visual feedback.

8 AUTHOR CONTRIBUTIONS

Authors AH, CM and NWA conceived of the study and were responsible for the main part of the design and implementation which was performed as a course project in Embodied Interaction taught by SD and CE. SD designed the experiment together with AH and CM, who collected the data. SD performed data analysis. All authors participated in writing the paper and approved the final manuscript.

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