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Distinctive Parameters of Expressive Motion

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Abstract

Recent work has shown the potential of basic perceptual properties of motion for notification, association and visual search. Yet evidence from fields as diverse as perceptual science, social psychology and the performing arts suggest that motion has much richer communication potential in its interpretative scope. A long history of research and practice in the affective properties of motion has resulted in a bewildering plethora of potentially rich communicative attributes. What remains to be established is how and whether these perceptual effects and impressions can be computationally manipulated in a display environment as variables of affective communication. In this paper we explore attributes of expressive motion and report initial results from a study in which we explored which attributes might be most important in distinguishing motions meant to convey emotion.

Categories and Subject Descriptors I.3.3 [Computer Graphics]: Animation, perception, affective user interfaces, visualization

1. Introduction

Motion is a powerful visual cue and has been found to be useful for tasks such as notification [BWC03], visual search and emphasis [BW02], and tracking transitions [RMC91]. Motion has been also shown to convey meaning, emotions [LW89], and intentions [DL94]. Character animation relies on the exaggeration of movement to deepen our understanding of behaviour and motivation [TJ81]. The arts of drama, dance and music map very complex emotions and motivations on to gestures and movement. There are vocabularies of movement that formalize expression, notably acting [Zor68], choreography [LL74] and well-known techniques for character animation [TJ81]. However, computer scientists have no rigourously validated model of how these might be computationally modelled to convey meaning in contexts from the abstract representations used in information visualization to highly dynamic interactive user experiences found in games and immersive environments. It is readily apparent that motion is a rich conduit of information flow from our surrounding environment. What remains to be established is how and whether these perceptual effects and impressions can be usefully manipulated in a display environment as variables of affective communication in an information space.

The communication of emotion and the creation of affect are core to creating immersive and engaging experiences in performance, interactive art and gaming. They also play a significant role in ambient cues that determine how any environment "feels".. Our research explores the design space of *affective motion cues*: simple, small motions that can contribute to affect. Although there are multiple definitions of affect, the most relevant to our work is that of experience: when we are *affected* by something we *experience* an *emotion* as a result. Our long-term goal is to understand and characterise the dominant attributes that may enable us to encode meaning into motion (i.e. a visual grammar for motion). We hope to extend this work into the development of interactive tools and techniques that provide a language of affective and expressive motion patterns for artists, visualization specialists and interaction designers. However, before we begin to explore the interpretative scope of motion coding, we need to more precisely characterise what distinguishes one motion from another. In particular, we are concerned with how *emotional motions* are differentiated: that is, motions used to express basic emotional experience.

Much of the work in exploring motion affect has concentrated on appropriately produced movement for objects and articulated figures. We differentiate *motion* from *movement*. Movement comprises two semantic elements: what the moving *object* implies or affords (a waving hand is aesthetically and communicatively different than a waving flag, for example), and what the *motion* of the object suggests (e.g. waving as opposed to pointing or stabbing, bouncing as opposed to jittering). Isolating the motion from the object begs the question of how communicative the motion alone may be. Various studies show that humans are capable of perceiving and even identifying emotions from sparse, abstracted animations of point-light displays [DTL96, PPB01]. A rich history of performance, animation and the construction of engaging experiences suggest that motion can be highly evocative in both *focused* and *diffuse* applications. Focused communication

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involves directly applying motion to a particular object to convey properties associated with that object: a common interface example might be an icon. Diffuse applications are more experiential, in that motion may be applied as a sort of environmental "texture" or brush to create an aesthetic effect or evoke an impression. The analogy to lighting, sound effects and design is obvious. Particularly with respect to the latter, we are interested in the expressive scope of relatively small motions.

1.1. What's in a motion? The research question

While there are a number of parameters by which a motion can be described, little is known about which dimensions are most responsible for conveying meaningful information through motion. Previous studies have suggested the following as candidates: velocity [ABC96,Bac98,PPB01], amplitude [ABC96,Vau97], acceleration [PPB*01], direction [Bac98,Tag60], shape [BW02], effort [LL74], and trajectory [Bac98,Tag60,Vau97], including smoothness and jerkiness. While these studies point out how particular attributes of motion contribute to convey certain meaning, each considered only a subset of the attributes above. Further, this set does not represent a clean space of orthogonal dimensions, but rather a list of influential factors that "overlap" each other (e.g. direction, shape and trajectory are neither exclusive nor isomorphic).

For computational tractability we need to reduce this parameter space to a set of dimensions that can be algorithmically identified and manipulated. Therefore, a first step is to determine what the dominant dimensions are in discriminating different types of motions. In this paper we report initial results from a study in which we explored the correlation of such attributes to identifying similar motions. Our reasoning was that the properties that determine whether one motion is like another likely represent important criteria for characterising that motion. Thus the investigation of similarity judgments between motions may suggest useful dimensions for affective encoding.

2. Background

2.1. Emotion and affective movement

Body movement is highly expressive of emotion and highly affective [Bac98,Tag60,Vau97]. Researchers have studied a variety of emotions elicited by animations of both veridical figures (depiction of a body) and more abstract point-light displays that convey an articulated figure [Joh74]. The basic emotions (those that are universal and distinguishable) indentified by emotion theorists include anger, disgust, fear, sadness, sensory pleasure, surprise, courage, joy, worry, pride, shame, and guilt [Ekm99]. The recognition of at least six of these has been shown to be consistent across cultures: fear, anger, surprise, sadness, happiness and disgust [Ekm99]. Body movements have been shown to communicate these emotions effectively (although sadness is the least effectively conveyed) [DL94]. Emotions have traditionally been ranked on a "pleasantness" dimension (positive/negative). Recent research considers two additional dimensions: arousal/activation (intensity) and dominance-vulnerability (related to aggression) [DTL*06,SS06]. These provide more nuanced ways to empirically distinguish emotions.

While many studies rely on the depiction (however abstract) of an articulated figure, several researchers have investigated the affects of more abstract motions. In a landmark study [HS44] participants attributed very complex motivations and emotions to a set of animated geometric primitives. Lethbridge and Ware created stimulus-response animations, where a dot responded to stimuli such as its own velocity or the velocity of another dot [LW89]. Observers attributed emotions such as aggressiveness and anxiety from the motions alone. Tagiuri investigated single dot animations and found out different trajectories elicit particular impressions [Tag60]. Straight paths were perceived as "determined, ambitious, and purposeful" while meandering paths were perceived as "immature, confused, and curious." Highly erratic paths led to the impression of a drunk and disorderly dot!

2.2. The elements of affective motion

Vaughan [Vau97] attempted to categorize movements derived from performing arts into parameters discernible and distinguishable by humans, suggesting as important speed and tempo; area/space; direction and path (the line the moving object creates). These reflect the well-known techniques used by animators, who rely on speed, extent and amplitude to convey emotional state of their characters [TJ81]. Chi et al. created a 3D character animation system called EMOTE (Expressive Motion Engine) which incorporated the Laban Movement Analysis from dance [CCZ*00]. The system captures the motion generated by human movement and then manipulates parameters such as path curvature and timing to generate arm and torso movements for virtual depiction.

Other studies attempt to tie together movement parameterization and emotional perception of gesture and collectively analyze the computational models generated as a result of expressive gestures. Cunningham et al. examined the possibility of generating realistic, recognizable facial expressions in computer-generated animation by conducting studies on human perception of captured facial expressions and rigid head motion [CBK*03,CKW*04,WBC*05]. The EyesWeb Expressive Gesture Processing Library supports the analysis of human movements with respect to velocity, acceleration, shape, orientation and contraction of the body, and fluidity of the trajectories, from real-time expressive human movements and gestures [CMV04,MC07]. The system extracts expressive cues from these parameters such as sadness or pleasure. The authors state that we can use these extracted measurements to group similar gestures that convey the same meaning [CMV04], but provide no empirical validation. Amaya et al. [ABC96] on the other hand attempted to focus on differences in speed and spatial amplitude and created a technique called *emotional transform* to derive emotional human movements from neural movements. Their study showed high similarities between recorded real emotional human movements and "new" emotional movements rendered by applying the transforms. Omlor and Giese demonstrated that it is possible to reduce the dimensionality of joint-angle motion trajectories by using regression techniques to identify spatio-temporal primitives that are important for visual perception of emotional gaits [OG07]; they did not, however, further define the critical motion properties of these primitives that elicited the effect.

These studies all concentrated on the representation or re-mapping of *embodied* motion attributes. Researchers have also investigated what attributes of simple, periodic motion applied to small, abstract elements are effective for information visualization tasks. Shape, phase and direction are important attributes for notification, filtering and grouping [BW02,BW03]. Direction, flicker, and velocity can efficiently encode multiple data values [HH53].

3. Motivation and Approach

The study reported in this paper involved an initial empirical classification of simple, small, abstract motions derived from "emotional" gestures. The classification involved people making a single judgement of similarity between two motions that had been produced by a human (the *performer*) instructed to express particular emotions or states. We had two goals. First, we seek to ascertain what motion attributes, or combinations thereof, may differentiate these motions. Our goal is reducing the dimensionality of the parameter space. Second, we are interested in how these parameters relate to the three dimensions of emotional classification. As stated, the long-term objective is the development of a model that can be implemented algorithmically to analyse motions in a scene as well as to manipulate and transform its effects.

We captured hand motions to express emotions as hand and arm movements are more significantly associated with emotions than the movements experienced in other body parts [Wal98]. After reviewing motions generated by different people, we used a music conductor as our *performer* for this study. Conductors are experienced with a visual language of motion for both highly specific and emotionally expansive communication. We realise that the formation of emotional gestures may be highly culturally and professionally specific, but as our concern for this study is to examine what properties of motions affect how viewers differentiate or associate motion types, rather how they affect interpretation, we were less concerned with the cultural differences between performers. (Subsequent studies are comparing effects across different performers).

We captured the motions of two sensors attached to the performer's arm: one to one to the elbow and the other sensor to the wrist. We instructed him to move his right arm freely with one of the following thirty-two expressions in mind: contentment, discontent, pleasure, pain, pride, shame, joy, sadness, anger, calm, excitement, indifference, fear, fearlessness, innocence, guilt, amusement, annoyance, interest, boredom, worry, relief, admiration, contempt, attraction, disgust, important, unimportant, relaxed, urgent, welcoming and rejecting. These expressions include basic emotions [Ekm99] as well as more abstract qualities, such as urgency, importance and interest. Each motion was then mapped to a simple dot, normalised into a common frame size and time (5 seconds) and analysed according to the following dimensions:

- Velocity
- Amplitude (maximum distance between two points in the trajectory)
- Accelerations (number of times acceleration occurred)
- Decelerations (number of times deceleration occurred)
- Fluidity (smooth, jerky or combined)
- Path Shape (curvy, angular, straight, or combined)

We note that fluidity can be considered as a combination of acceleration/deceleration and velocity, and is closed related to the shape of the trajectory. By dealing with these separately, we hoped to examine which aspects of fluidity (if any) might prove influential. In addition, each motion was characterised by a rating according to the 3 dimensions of emotional classification: pleasantness, arousal and dominance.

We set each to either positive or negative with the exception of pleasantness, to which we added a third level of "abstract" to describe the abstract types (such as importance). Table 1 illustrates the paths of the motion set.

4. Experiment

10 users participated in an experiment that had them rate the similarity of the 32 different motions in pairwise comparisons. Prior to having the users compare the motion, we analytically characterised each motion combination. A difference vector that calculated the absolute distance between each of the motions' dimensions (the factors) uniquely described each pair. When the difference was nominal (as in the fluidity and shape factors), we used a simple distance metric by assigning an ordinal value to each level in the factor and calculating the difference between these ordinal values. So, for example, in the Fluidity factor motions were assigned the ordinal values of smooth=1, combined=0, and jerky=-1, thereby ensuring that a smooth motion was evaluated as being more distinct from a jerky motion than it was from a combined motion.

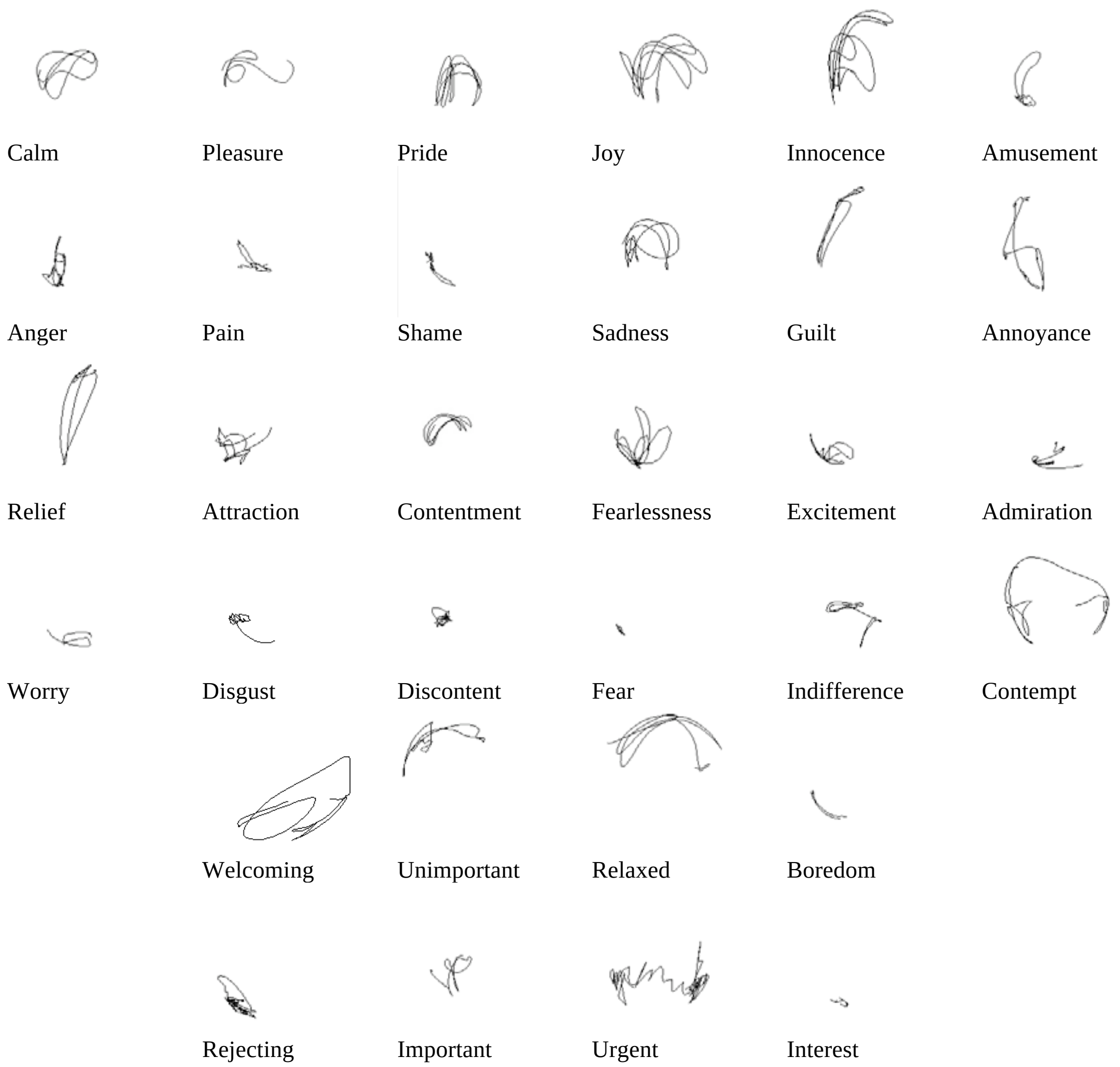

Table 1. Motion shapes. Animations are at http://www.hvilab.iat.sfu.ca/MeaningFromMotion/motions.html.

This approach of assigning ordinal values was also extended to the emotional parameters of the motion where boolean values were assigned to each comparison. A value of 0 implied that the motions were similar in their emotional factor and 1 implied that the motions were representing dissimilar emotional states. Participants were then asked to rate the similarity of two motions on a 5-point semantic differential scale where +2 meant "very similar" and -2 meant "very different."

4.1.1. Hypotheses

We had three hypotheses:

- Fluidity and smoothness of shape would be the most influential factors.
- Speed would be extremely important in associating motions.
- Subjects would be able to distinguish positive and negative emotions.

4.1.2. Stimuli

All movements were captured at 60 frames per second. Each of these motions is represented on the screen as an image of size 110x110 pixels to give equal weight to every motion. The duration of each motion was five seconds, and the motion repeated itself thereafter in a loop.

4.1.3. Participants

Ten university students were paid to participate in the experiment. All had normal or corrected-to-normal acuity and normal colour vision. None had participated in previous experiments in this area. All were naïve to the purpose and hypotheses motivating the study.

4.2. Method

The participant sat in front of a display in which was centred an experiment screen (Figure 1) with a set of 32 motions (as discussed above). These were structured with a *source* motion in the centre surrounded radially by 31 *target* motions. Each of the target motions had a rating slider underneath it ranging from -2 to +2 by increments of 1. Each screen constituted one trial and involved 31 comparisons (source-target$_n$, n=1..31).

When a trial started none of the motions were active. The participant selected "Start" to activate the source motion. Then (s)he activated a target motion by holding the mouse over its area. Moving the mouse away stopped the motion. Thus only two motions were concurrently active: the source and the particular target of interest. After viewing a motion for a minimum of 5 seconds the participant could then rate the motion for its similarity to the source using the slider, where -2 meant "very different" and +2 meant "very similar." There was no timing constraint on the trial, and subjects could play a motion as often as they wished and could adjust their ratings as desired. Once a motion had been rated its slider was shaded to indicate it had been done. When all the target motions had been rated, the subject was advanced to the next trial/ subjects could not advance without completing all comparisons.

The participants were given unlimited practice time to explore all 32 motions in advance to form a scale of their judgement on similarity. Throughout the experiment, they could replay the animation or change the rating at all times for as many times as they wanted, before pressing the finish button to go to the next trial.

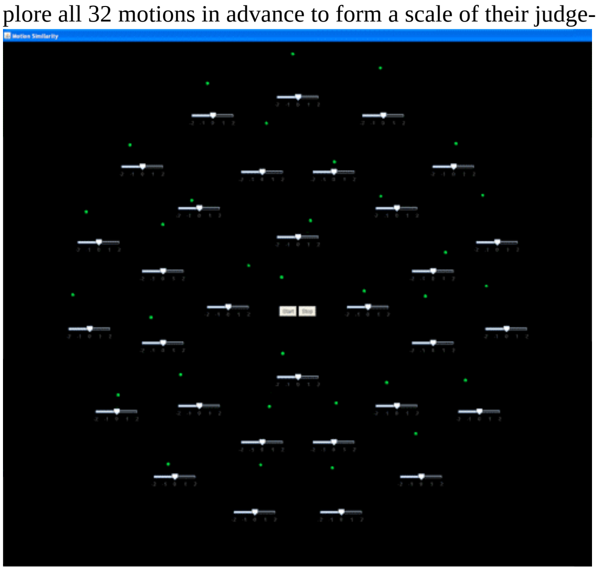

Figure 1. Experiment screen

4.3. Design

32 motions produced 496 distinct combinations, presented to the participants in screens of 32 motions, with 1 screen comprising 1 trial. Since 32 trials proved too onerous a task for a single participant, we balanced the combinations across 2 participants so that each processed 16 distinct source motions. We used each motion as the source motion for the same number of times across all our participants. Every subject, however, saw all target motions, so every subject was exposed to all combinations. Thus this was both a between-subjects (for source motion) and within subjects (for comparison motions) design.

Target motions were laid along three rings around the stimulus motion (Figure 1). As the distance between the stimulus motion and each target motion may affect the participants' judgement, the number of times each motion appears on each ring was also balanced across all participants. A simple randomization was done to position target motions inside the rings. Sixteen trials were divided into four blocks, each consisting of four trials, for each of our participants. Statistically balanced randomisations were used to avoid first and second order effects both with respect to the sets of combinations and the radial layout of the motions.

5. Results

Our first examination of the results led to the insight that our participants did not judge similarity and dissimilarity symmetrically: judgements of dissimilarity were more pronounced and there were more of them. For our purposes, either type of rating is informative. Figure 2 shows similarity rankings by the pairs of motions, where the size of the square indicates the rank. From this it was clear that motions performed for "similar" emotions did not evoke correspondingly strong similarity rankings. This indicated that subjects' judgments were based primarily on low- to mid-level motion properties (our factors).

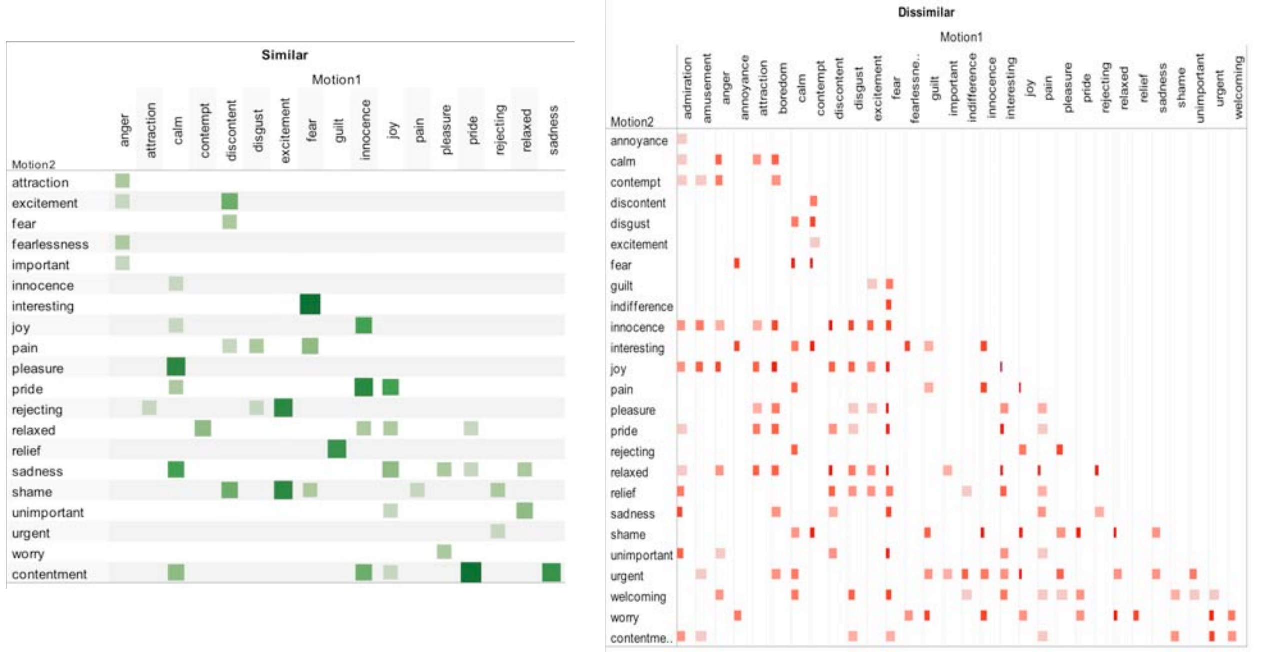

Figure 2. Similarity (a) and Dissimilarity (b) Ratings

As our goal was to examine how judgments of similarity might be related to the identified factors (fluidity, speed, etc.), we used regression techniques to relate the subjects' similarity rankings to the analytically derived similarity measurements described above. [1]We used backwards elimination in a random coefficients model to accommodate both fixed effects from the controlled factors and random effects from the variation between subjects. (We note that there is variability in the range of the scales that subjects tended to use and have not yet corrected for this variation.)

Factor	**Significance ***	**Effect**
Fluidity	F(1,9) = 26.47, p=.0006	-0.37
Amplitude	F(1, 2924)=21.02,p = .0143	-0.33
Dece.	F(1,4924,)=17.55,p<.0001	-0.16
Speed	F(1,9) =9.81, p=.012	-0.16
Amp*Speed	F(1,4924)=4.13, ,p =.04	-0.57
Amp*dec	F(1,4924) =10.19,p=.0014	1.45
Arousal	F(1,4924)=27.66,p<.0001	-0.16

*Table 2. Significant effects. * indicates some subject variability, although not enough to negate the significance.*

Of the motion attributes that we examined, speed, amplitude, fluidity, and deceleration proved to be statistically significant: only fluidity and amplitude had a noticeable size of effect (Table 2).

What do these statistics tell us in practical terms? First, as we expected, the fluidity of the motions had a strong effect on how similarly they were rated: overall the greater the difference in fluidity the lower the similarity. This effect did differ between subjects on average: 3 of the 10 showed a smaller effect, although still consistent with the trend. Amplitude, on the other hand, played a very strong role as well that showed no subject variation: again, the greater the difference in amplitude, the lower the similarity rating. Speed, while significant, surprisingly had less of an effect, and again varied between subjects, with 1 subject showing it was not significant for him/her and others showing a small effect (in other words, there was a statistically significant correlation, but the difference it actually made was not substantial). We see a similar result with respect to decelerations (although no subject variability). We note however the strong interactions between amplitude and speed, and between amplitude and decelerations. Speed made a greater difference when amplitudes were greater, as did decelerations. When we turned to the emotional axes, we discovered that only the activation/arousal index showed any correlation with similarity: a

[1] An earlier pilot studied used multidimensional scaling methods to identify clusters of motions but provided little insight into the correlation of the identified factors.

mismatch in activation correlated with a small decrease in similarity.

6. Discussion

These results are preliminary and difficult to generalise because they are limited to the motions of one particular performer; thus the relative strengths of the motion properties may reflect his/her predilections to expression as much as they reflect subjects' criteria. However, they do shed some initial light on what may be usable motion attributes to consider for further interpretative investigation in these conditions. Recall that we are looking at very small, short motions. Given that as pattern recognisers we are primed to detect anomalies as well, it seems sensible that people are more attuned to discrepancies than similarities, and this may explain why we had stronger dissimilarity ratings than the inverses.

That several factors remain in the model show that people did not rely on any single property to judge similarity (and suggests further analysis using clustering techniques). However, the results suggest at least two primary candidates for distinguishing these small animate motions: fluidity and scale (amplitude). These results partially confirm our first hypothesis: fluidity, at least the coarse classification we used, proved to be the strongest effect. The associated smoothness of shape had no effect, perhaps subsumed by the larger effect of fluid or jerky motion. Speed, on the other hand, proved far less effective than we anticipated, refuting our second hypothesis. It seemed that where speed or deceleration mildly mattered, they were overshadowed by this larger quality of fluidity. We were also surprised by the asymmetry between acceleration and deceleration.

In retrospect the interactions between speed and amplitude, and deceleration and amplitude, are not surprising: the greater the motion extent, the easier it is to perceive differences in both. This reintroduces the whole concept of what amplitude means in this smaller scale. There are two contributing aspects: the degree in which different motions used amplitude (in other words, the tendency of the performer to rely on amplitude as an expressive mechanism) and the inherent perceptibility. We have, in essence, a small canvas on which to paint these motion effects, and so the extent to which a motion covers this space is very perceptually apparent. It also suggests why fluidity is more apparent than speed: we are very sensitive to abrupt changes and oscillating motion, and while speed contributes to these effects it does not sufficiently explain them.

It may be that the nuances of speed and shape need to be mapped onto more specific measures related to fluidity that are perceptible in these small spaces. We are currently reanalyzing this data using several measures of trajectory and path to explore fluidity, including self-intersections, directional changes and angular turns. We anticipate these measures may help us further explore distinguishing characteristics of emotional motions in the small.

It is also apparent that the intensity of an emotion (at least for this single performer set) can be communicated by these small motions to some small degree. We recall that we are not yet looking for definitively robust mapping of a particular motion attribute to specific emotional meaning: rather, we are seeking to further our understanding if what is possible in this design space and attempting to form a framework that is both computationally feasible (uses appropriate metrics) and visually interesting (provides enough scope for affect that it is useful). The fact that fluidity, amplitude and to a lesser extent, speed appear viable dimensions point us to extensive future work in exploring how these may affect interpretation of motions generated using them.

7. Conclusions and Future Work

We are expanding the scope of this study in several ways to inform our subsequent studies in motion interpretation. First, we are increasing the analytical classification of the generated motions by adding direction and trajectory metrics, as described above. In addition, we are running a larger version of this study with motions captured from several different people, not all of whom are performers. We will revisit our results in the context of the larger data set and the expanded motion properties. In addition, we are combining clustering and scaling techniques such as MDS to identify combinations of dimensions. As we identify candidates – and candidate combinations – of useful attributes for motion distinction, we will use them to select particular motions for a subsequent study of interpretation, where participants will use a variety of interpretative methods to describe the motions. We anticipate this will lead to a set of guidelines for the design and use of small affective motions: algorithmic techniques for reliably conveying affect, and a validated framework for the expressive scope of such small motions in both focused and ambient visualizations.

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