Evaluating Affective Features of 3D Motionscapes

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Abstract

Abstract motion textures are widely applied in visual design and immersive environments such as games to imbue the environment or presentation with affect. While visual designers and artists carefully manipulate visual elements such as colour, form and motion to evoke affect, understanding what aspects of motion contribute to this still remains a matter of designer craft rather than validated principle. We report an empirical study of how simple features of motion in 3D textures, or motionscapes, contribute to the elicitation of affect. 12 university students were recruited to evaluate a series of 3D motionscapes. Results showed basic motion properties including speed, direction, path curvature and shape had significant influence on affective impressions such as valence, comfort, urgency and intensity, suggesting further directions for applications and explorations in this design space.

CR Categories: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Animation, Valuation/Methodology I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Radiosity;

Keywords: Computational Aesthetics, Motion Textures, Affect

1 Introduction

In nature, fields of motion can usually be seen in rain, snow, fog, smoke, swirling leaves, herds of animals or flocks of birds. Such phenomena share one thing: a large population of agents move in very similar patterns (e.g. a flock of birds usually fly in similar speed and similar directions). Abstract fields of motion inspired by those in nature but explicitly manipulated in pattern and motion are popular in recent media applications. Such artificially generated phenomena of fields of motion in 2D have been termed *motion textures* [Lockyer et al. 2011].

Examples can be found in early experimental animation pieces, abstract films, film special visual effects, TV motion title design [Museum of Contemporary Art (Los Angeles, Calif.) and Hirshhorn Museum and Sculpture Garden 2005]. In digital media, motion textures have become significant visual elements in software interfaces, video games, and interactive art. They are typically used for creating atmosphere and eliciting affect. For instance, in the *STARFIELD* [Diagne 2012] interactive installation piece, a simulation sequence of star movements was projected on a large screen to evoke a calm feeling among its viewers (See Figure 1).

This evocation of experience, feeling, impression or emotion is central to the creation of immersive and engaging experiences in advertising, performance, interactive art, and gaming. Affect is important in an ambient context, the result of how an experience or environment feels. Attaining the right affective balance is considered core to user experience [Norman 2002; Peter and Beale 2008; Forlizzi and Battarbee 2004; McDonagh et al. 2009] and is becoming an important aspect of information visualization [Acevedo and Laidlaw 2006; Lau and Vande Moere 2007; Kosara 2007]. Visual designers and artists carefully manipulate visual elements such as colour, form and motion to evoke affect [Collopy 2000], but empirical evidence on how such elements in motion textures should be manipulated to invoke affective impressions is still scarce and an emerging research area. In this paper we report on the results of a study of the effect of motion features in 3D motion volumes on user-reported affective ratings. Our results provide validated design principles into the use of these visual effects.

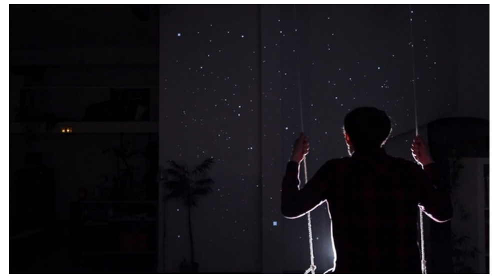

Figure 1: *Abstract motions in STARFIELD evoke calming affects*

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: speed [Amaya et al. 1996; Pollick et al. 2001]; amplitude [Amaya et al. 1996]; acceleration [Pollick et al. 2001]; direction [Tagiuri 1960]; shape [Bartram and Ware 2002; Lockyer et al. 2011]; effort [Laban and Lawrence 1974]; trajectory [Tagiuri 1960; Vaughan 1997], and smoothness [Bartram and Nakatani 2010]. Recent studies of 2D motion textures (fields of particle motions in a two dimensional Cartesian space) reiterated speed and shape as significant [Lockyer et al. 2011; Lockyer and Bartram 2012]. Motion volumes in three dimentional world space, which we term *motionscapes*, differ significantly from motion textures implemented in 2D. They are commonly applied in recent 3D graphical video games, spatial user interfaces and visualizations. This motivated us to explicitly explore 3D motionscape affects.

With dimension of depth introduced, eliciting and evaluating the affective features of 3D motionscapes requires investigation into a fuller set of motion properties. We extend work that explored perceptually affective 2D motion textures (in image space) to 3D motionscapes (created by a field of distributed points in world space), with several questions regarding abstract motionscapes. Do the affective features in 2D textures translate to similar affect in 3D volumes? Are there different or additional properties of motion in motionscapes that contribute to affect? Finally, what can we do with this: what are the operational implications, if any, for the design and use of affective motionscapes?

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2 Background

2.1 Affect and Emotion

Affect is traditionally considered to have an emotional context. The basic emotions (universal and distinguishable) identified by emotion theorists include anger, disgust, fear, sadness, sensory pleasure, surprise, courage, joy, worry, pride, shame, and guilt [Ekman 1992]. Emotions are primarily taxonomised by hedonic valence [Ortony and Turner 1990] and arousal (intensity) [Osgood 1957]. The dimension of valence covers hedonic state, from positive states (happiness, pleasure, love) to negative (pain, anger, sadness, fear). The dimension of arousal reflects the activation aspect of affective experience and ranges from unaroused (calm, relaxed, sleepy, etc.) to high arousal (excited, stimulated, nervous, alert, etc.). A secondary dimension is dominance (related to aggression) [Lang et al. 2005]: while anger and fear are both negative and intense, they differ in dominance. While these core emotions are fundamental to human psychology, they serve as touchpoints in a wider design space for affective representation. We expand our operational definition of affect to one of experience: when we are affected by something we experience a feeling as a result, and this might be an identifiable emotion, a sense of interest, an atmospheric impression, or other such feelings related to but not exactly one of the basic emotional states [Lockyer and Bartram 2012]. Moreover, the communicative challenge of evoking or even identifying a specific emotional reaction may be overly onerous. Our previous research suggests these feelings may be highly contextualised: that is, rather than a generalisable distinction of happy, pleasant or proud, the affective impression may be one of positive valence, and the more fine-grained interpretations subject to the particular narrative or experiential context [Bartram and Nakatani 2009].

2.2 Affective Motion

Research has shown that visual encoding features such as colour [Adams and Osgood 1973], visual imagery [Lang et al. 2005] and animation [Johnston and Thomas 1995; Yun Yoo and Kim 2005] evoke a wide range of affective responses. Motion is a powerful visual cue and a rich modality for affective expression. The arts of drama [Zorn 1968], dance [Laban and Lawrence 1974], animation [Johnston and Thomas 1995], cinematography and music map very complex emotions and motivations on to movement. Researchers have attempted to categorize movement derived from performance [Laban and Lawrence 1974; Zorn 1968] into parameters discernible and distinguishable by humans, suggesting as important speed and tempo; area/space; direction and path (the line the moving object creates) [Vaughan 1997; Bacigalupi 1998; Mancini et al. 2007]. These reflect techniques used by animators, who rely on speed, extent and amplitude to convey emotional state of their characters [Johnston and Thomas 1995]. Where this work focused on the representation or re-mapping of movement attributes, researchers have also investigated what attributes of simple motions influence affect. Studies into affective judgment of such abstract motion indicate that even very basic animated representations evoke highly complex responses. In [Heider and Simmel 1944; Lethbridge and Ware 1989; Bartram and Nakatani 2010] participants attributed very sophisticated motivations and emotions to a set of animated geometric primitives. Observers attributed emotions such as aggression, joy and anxiety from the motions alone. Tagiuri investigated single dot animations and found different trajectories elicit particular behavioural impressions [Tagiuri 1960]. More recently, [Lockyer et al. 2011] studied how basic properties of 2D motion textures influenced user affective ratings of valence, intensity and interest. They found that speed, shape (linear or radial patterns), path curvature (the wiggliness of the individual particle trajectory), and in certain shapes, direction all contributed to affect. Not surprisingly, speed mapped strongly to intensity, with slow motions seen as more calming. Path curvature was significant: jerky particle motions are perceived as more negative, exciting, threatening, urgent, and rejecting, while straight motions are more positive, calming, reassuring, relaxed, and attracting. The impact of some features differed dependent on textural shape. Direction proved affective with respect to valence only in linear textures: leftwards motion were rated as more negative.

3 Study

We conducted a study to explore a fuller set of 3D motionscapes, building on our earlier work in 2D [Lockyer et al. 2011; Lockyer and Bartram 2012]. Participants were shown different motionscape stimuli and asked to rate them on 5 semantic differential affective scales. Motionscapes were composed from 4 different properties (the independent variables in the study): shape, speed, direction and path curvature. Although motionscapes in this study were not presented stereoscopically, they were implemented in 3D computer graphics, incorporating 3D graphical properties such as standard shading, perspective and occlusion techniques to convey the 3D image (Subsequent studies, outside the scope of this paper, consider stereoscopic and immersive display conditions [Feng 2014]).

Recent affective computing research suggests besides basic emotions, non-basic affects are also core to the user experience of many interactive artifacts [D'Mello and Calvo 2013]. In this study we employ an affect measurement model by focusing on the following 5 affective ratings (the dependent variables): (NP) valence: positive negative; (CE) intensity: calming exciting; (RT) dominance: reassuring threatening; (AR) interaction: attracting rejecting; and (UR) urgency: urgent relaxed. While we draw first 3 (NP, CE, RT) from emotion theory [Osgood 1957; Ortony and Turner 1990], we also include the latter 2 non-basic affects. In fields of visualization and interface design, attracting viewer attention directionally within a spatial environment is often of interest to visual designers [Ware 2010]. [Lockyer and Bartram 2012] also suggest that the communication of urgency is critical for contexts such as real-time and supervisory visualizations. These 2 affect measurements (interaction and urgency) also reflect commonly communicative intent in games [Moura et al. 2012], performance [Maranan et al. 2013], and visualization [Moere 2007]. We also note that our 5 affective dimensions are not mutually exclusive, and cannot serve as comprehensive dimensions to describe all possible affects. Instead, they are utilized to evaluate motionscape affects that are critical in general contexts of 3D dynamic visual environments.

3.1 Method

3.1.1 Apparatus and Task

Participants were shown different 3D motionscapes projected on a white canvas screen at a frequency of 60hz with 1280×960 resolution. On-screen projection (2.8m by 2.1m) was left as the only light source in the experiment room. Participants were seated in a chair 3.6 m in front of the screen and provided with a mouse and a keyboard to enter affective ratings and comments. A 400×350 pixel window with five semantic-differential sliders for entering affective ratings was displayed on the down right corner of the motionscape scene. Each slider represented one affective rating and was scaled from -100 to 100, with negative value representing the affective rating labeled on the left and positive value representing the opposite rating on the right. The default value of each slider was set to 0: thus all affective ratings were initially set as neutral. In each trial, participants were instructed to enter their ratings of the 5 affective

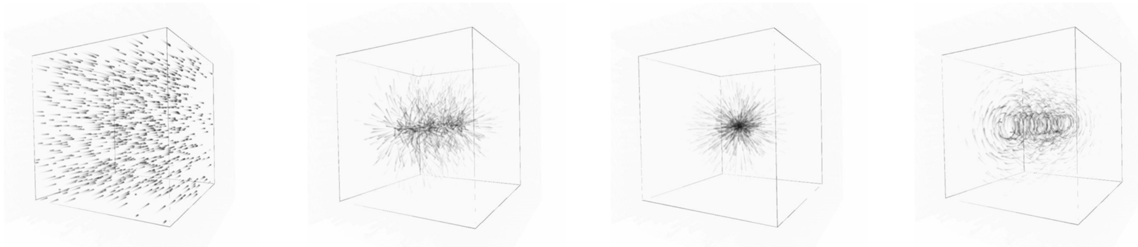
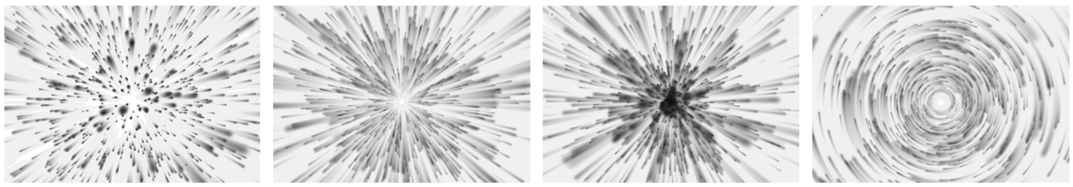
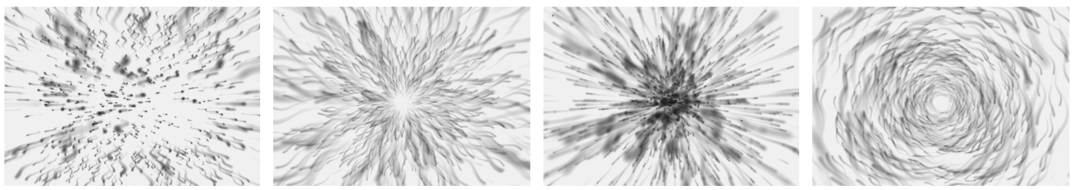


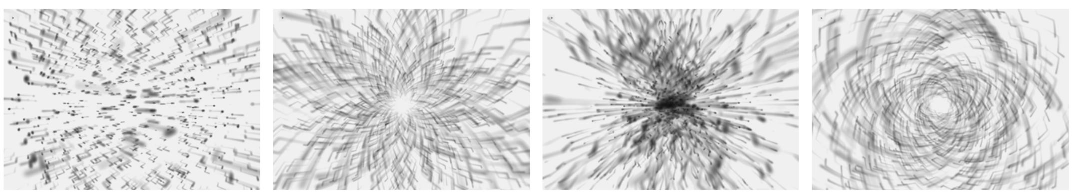
Figure 2: *4 variations in shape: linear, radial, spherical, and circular (from left to right)*



a) Linear, Radial, Spherical, and Circular motionscapes with straight paths



b) Linear, Radial, Spherical, and Circular motionscapes with wavy curvatures



c) Linear, Radial, Spherical, and Circular motionscapes with angular curvatures

Figure 3: *Motionscapes with all 3 path curvatures*

impressions where appropriate by dragging the slider. For example, rating a motionscape on the positive-negative slider with a high value to the positive (e.g. 90) indicated the participant interpreted it as strongly positive. There was no requirement to enter a rating if the participant felt no particular impression, so any or all ratings could be left as neutral. Once finished evaluating the current motionscape, participants selected the NEXT button below the slider set. The current motionscape would fade out until the screen was left blank, then a new one would fade in (each transition took 2 seconds) and stay till the button was clicked again. There was no time limit on trials.

3.1.2 Participants

After a 2-participant pilot study, we recruited 12 university students to our formal study (5 women aged from 20 to 44 and 7 men aged from 21 to 36). All had normal (or corrected-to-normal) acuity and were unaware of either our research questions or hypotheses. The participants were either paid or granted standard course credits when completing the study.

3.1.3 Design

A combination of the following factors crested the experimental conditions: motion shape (4), speed (2), path curvature (3) and direction (2). This $4 \times 2 \times 3 \times 2$ design led to 48 different conditions (motionscapes). All conditions were replicated twice and displayed in randomized sequence to avoid first and second order effects. Therefore the experiment comprised 96 trials in total and was completed in a single session.

3.2 Motion Factors

We constructed the motionscapes through randomly distributing 1024 moving particles in a 3D Cartesian space (Figure 2). Based on feedback from a pilot study, the amount, sizes, opacity, and tail lengths of particles were adjusted to decrease the influence from visual features of individual particles. While previous research in motion textures studied linear and radial texture shapes in 2D [Lockyer et al. 2011], we re-constructed these shapes in 3D, creating linear and radial motion volumes. Along with these, in this study we also introduced 2 new shapes: circular and spherical. Variations in shape and the 3 other motion properties (direction, path curvature, speed) are described as follows.

Shape: Figure 2 shows the 4 variations in shape of motionscapes: (1) linear motionscapes, in which all particles move in parallel paths to a same direction along z axis; (2) radial motionscapes, in which particles move into or radiating out from a central axis in space; (3) spherical motionscapes, in which particles move from or towards a spatial center; (4) circular motionscapes, in which particles move in circular paths about a central axis. All motionscapes were shown to the viewer from a perspective view, with x axis and y axis parallel to screens edges along width and height, and with z axis perpendicular to the screen. All (1) linear motionscapes were manipulated to move parallel to the z axis; (2) radial and (3) circular motionscapes were attached to the z axis; and (4) spherical motionscapes were located to a point inside screen on the z axis.

Path curvature: Figure 3 shows the three variations of path curvatures. In Figure 3a, motionscapes with straight paths produce perfectly straight tails; in Figure 3b, motionscapes with wavy curvatures produce tails with smooth curves; in Figure 3c, motionscapes with angular path curvatures generate jerky paths with sharp angles.

Direction: for motionscapes of each shape, two variations in direction were applied. (1) linear motionscapes moved either inwards or outwards with respect to the screens plane along the z axis; (2) radial or (3) spherical motionscapes moved inwards (radiating out) or outwards (sucking in) to the z axis or the central point on z axis; (4) circular motionscapes moved either clockwise or counter clockwise along z axis.

Speed: Particles within all motionscapes moved in either slow speed (1 voxel per second) or fast speed (5 voxels per second).

3.3 Hypotheses

Previous research [Lockyer et al. 2011; Lockyer and Bartram 2012] identified that path curvature, speed, shape, and direction as significant contributors to the affective impression of abstract motion textures. Among these motion properties, path curvature and speed had significant effects on multiple affective impressions and experiences; direction was found to produce notable effects on ratings in valence (NP) (in linear textures) or in interaction (AR) (in radial textures). Notably, in linear or spherical motionscapes introduced by this study, particles appear to move either towards or away from the viewer. These new variations in direction were not visited in [Lockyer et al. 2011; Lockyer and Bartram 2012], but were suggested by our pilot study as significant contributor to interaction (AR) affects. The pilot results also showed direction had notable effect on ratings for valence (NP) in circular motionscapes. The above findings from previous research and our pilot results led us to the following four hypotheses:

- **H1 (Path Curvature)**: Path curvature in linear motionscapes will strongly influence the affective ratings, where motionscapes with straight curvature will be seen as positive, calming, relaxed, reassuring, attracting, whilst those with non-straight curvature will be seen as opposite.
- **H2 (Speed)**: Speed will significantly affect ratings in intensity (CE), urgency (UR), and dominance (RT). In motionscapes of each shape, fast motions will be generally perceived as more exciting, urgent, and threatening than slow ones.
- **H3 (Direction)**: Direction in linear, radial, and spherical motionscapes will significantly affect ratings for interaction (AR), with inwards being perceived as attracting and outwards being perceived as more rejecting. In circular motionscapes, clockwise motions will be rated as positive and counter-clockwise motions will be rated as negative.
- **H4 (Shape)**: Circular motionscapes will be perceived as highly negative.

Table 1: *Main effects of shape on all affective ratings*

Valence (NP)	$F(3,33) = 7.377, p = .001$
Intensity (CE)	$F(3,33) = 19.390, p < .001$
Urgency (UR)	$F(3,33) = 20.087, p < .001$
Dominance (RT)	$F(3,33) = 16.343, p < .001$
Interaction (AR)	$F(3,33) = 5.163, p = .005$

4 Results

We began our analysis with 5 one-way ANOVA of shape (linear, radial, spherical, and circular) for all 5 affective ratings. Shapiro-Wilk tests revealed that the sample was not significantly deviated from normality. Mauchlys tests were performed to detect violations of the assumption of sphericity. When the assumption of sphericity was violated, we employed the Huynh-Feldt correction to produce a valid F-ratio. The results showed that shape yielded significant main effects on all 5 affective ratings (Table 1). Post hoc analysis with Bonferroni adjustment revealed that spherical motionscapes were rated significantly different from linear motionscapes. While spherical motions were in seen as negative ($M = -22.85$), exciting ($M = 14.07$), urgent ($M = -23.48$), threatening ($M = 26.17$), and rejecting ($M = 13.11$), linear motions were more positive ($M = 9.75$), calming ($M = -8.79$), relaxed ($M = 11.84$), reassuring ($M = -11.73$), and attracting ($M = -9.29$) (Figure 5). This finding led us to further conduct 20 (5 for motionscapes of each shape) three-way ANOVA separately to detect effects of speed, curvature and direction within motionscapes of each of the 4 shapes. Table 2 shows the results.

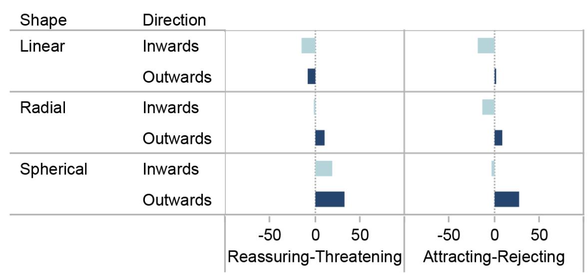


Figure 4: *Means of Dominance(RT) and Interaction(AR) ratings of linear, radial, spherical motionscapes (by direction)*

4.1 Linear Motionscapes

Speed had significant effects on all five affective ratings (Table 2). For valence (NP) ratings, Post hoc analysis with Bonferroni adjustment indicated that affective ratings of slow motions ($M = 21.91$) were much higher than those of fast motions ($M = -2.40$). i.e., slow motions were rated as positive, while fast motions were rated as slightly negative. Urgency (UR) ratings followed a similar pattern with regard to speeds effect: slow motions ($M = 39.33$) were seen as relaxed, while fast motions ($M = -15.64$) were seen as urgent. In intensity (CE) ratings, slow motions ($M = -29.70$) were rated as more calming than fast motions ($M = 12.12$). Dominance (RT) ratings have slow motions ($M = -29.05$) rated as reassuring and fast motions ($M = 5.6$) rated as slightly threatening. In interaction (AR) ratings, slow motions ($M = -20.96$) were more attracting compared to fast motions ($M = 2.39$).

Path curvature also had significant effects on intensity (CE), urgency (UR), and interaction (AR) ratings (Table 2). Post hoc analysis with Bonferroni adjustment for intensity (CE) indicated that straight motions ($M = -21.08$) were rated as more calming than

Table 2: *Significant main effects from speed (S), path curvature (PC), direction (Dir) on all affective ratings by shape. Inconsistent parameters for F values are due to corrections to sphericity violations.*

	Linear	Radial	Spherical	Circular
NP	S: $F(1,11) = 9.203$,$p = .011$	S: $F(1,11) = 7.7170, p = .021$	S: $F(1,11) = 28.192, p < .001$	S: $F(1,11) = 8.486, p = .014$ PC: $F(1.539, 16.928) = 4.555, p = .034$
CE	S: $F(1,11) = 22.513, p < .001$ PC: $F(1.584, 17.429) = 5.604, p < 018$	S: $F(1,11) = 28.037, p < .001$	S: $F(1,11) = 24.486, p < .001$	S: $F(1,11) = 31.455, p < .001$
UR	S: $F(1,11) = 59.446, p < .001$ PC:$F(1.635, 17.986) = 16.001, p = .002$	S: $F(1,11) = 41.781, p < .001$	S: $F(1,11) = 53.207, p < .001$	S:$F(1,11) = 40.856, p < .001$
RT	S: $F(1,11) = 22.513, p < .001$	S: $F(1,11) = 10.007, p = .009$	S: $F(1,11) = 41.969, p < .001$ Dir: $F(1,11) = 4.883, p = .049$	S: $F(1,11) = 31.147, p < .001$
AR	S: $F(1,11) = 11.741, p < .006$ Dir: $F(1,11) = 8.602, p = .014$ PC: $F(2,22) = 5.399, p < .012$	S: $F(1,11) = 9.910, p = .009$ Dir: $F(1,11) = 6.718, p = .025$	S : $F(1,11) = 19.658, p = .001$ Dir: $F(1,11) = 7.854, p = .017$	S: $F(1,11) = 21.466, p = .001$

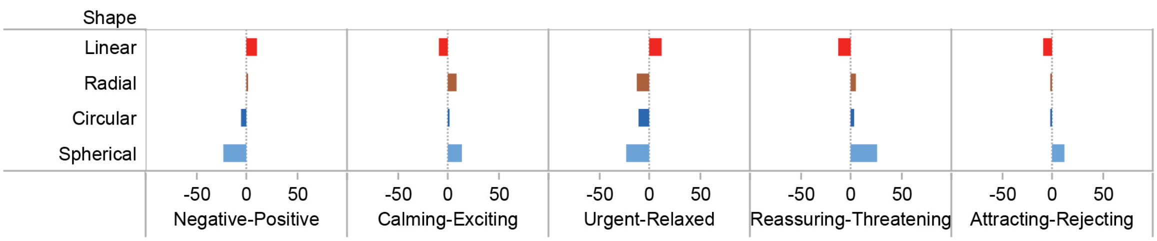


Figure 5: *Means of all affective ratings by shape*

angular motions ($M = -6.56$) and wavy motions ($M = 1.27$). Notably, here effect of wavy path curvatures did not significantly differ from that of angular path curvatures. Urgency (UR) ratings had straight motions ($M = 27.91$) rated as relaxed, while angular motions ($M = 5.42$) and wavy motions ($M = 2.2$) were rated as neutral. In interaction (AR) ratings, straight motions ($M = -21.14$) were seen as more attracting than wavy motions ($M = -0.99$) and angular motions ($M = -5.72$).

Direction in linear motionscapes only yielded significant effect on interaction (AR) rating. Post-hoc analysis of directions indicated that inward motions ($M = -18.77$) were generally rated as more attracting than outward motions ($M = 0.20$).

4.2 Radial and Spherical Motionscapes

Speed, in both spherical and radial motionscapes, was again a significant contributing factor for all 5 affective ratings. In spherical motionscapes, slow motions ($M = -5.76$) were rated as less negative than fast motions ($M = -39.95$). For intensity (CE) ratings slow motions ($M = -11.53$) were rated as calming, whilst fast motions ($M = 39.67$) were rated as exciting. For urgency (UR) ratings, slow motions ($M = 9.60$) were rated as relaxed, while fast motions ($M = -56.57$) were rated as urgent. For dominance (RT) ratings, fast motions ($M = 47.81$) were seen as more threatening when compared to the neutral slow motions ($M = 4.53$). For interaction (AR) ratings, slow motions ($M = -3.21$) were rated as slightly attracting, whereas fast motions ($M = 29.43$) were rated as rejecting. Speed in radial motionscapes was found to have similar effects as those found in spherical motionscapes. Again, slow motions were rated as positive ($M = 12.67$), relaxing ($M = 18.99$), calming ($M = -17.93$), reassuring ($M = -10.52$) and attracting ($M = -15.12$), whereas fast motions were rated as negative ($M = -14.08$), urgent ($M = -44.93$), exciting ($M = 35.53$), threatening ($M = 21.63$), and rejecting ($M = 11.79$).

Direction also yielded significant main effects on dominance (RT) and interaction (AR). For dominance (RT) ratings, inward spherical motionscapes ($M = 19.12$) were less threatening than outward spherical motions ($M = 33.22$). For interaction (AR) ratings, inward spherical motionscapes ($M = -2.31$) were rated as attracting, while outward spherical motionscapes ($M = 28.53$) were very rejecting. In radial motionscapes, directions effects followed a similar pattern for interaction (AR) ratings. Again, inward motions were rated as attracting ($M = -13.12$), and outward motions were rated as slightly rejecting ($M = 9.79$). Notably, path curvature in spherical and radial motionscapes did not produce significant effect on any of our five affective ratings.

4.3 Circular Motionscapes

Speed in circular motionscapes was significant for all five affective ratings. Slow circular motions were rated as slightly positive ($M = 6.41$), relaxing ($M = 17.09$), calming ($M = -26.71$), reassuring ($M = -16.34$) and attracting ($M = -14.23$), whilst fast circular motions were rated as negative ($M = -18.24$), urgent ($M = -37.74$), exciting ($M = 25.36$), threatening ($M = 23.11$), and rejecting ($M = 11.21$). Path curvature was significant for valence (NP) rating. Straight motions ($M = -20.80$) were rated as more negative, when compared to ratings for angular motions ($M = 7.02$) and wavy motions ($M = -3.97$).

5 Discussion

5.1 Speed

In motionscapes of all shapes, we detected a clear trend that slow motions were generally perceived as more positive, calming, relaxed, reassuring, and attracting, whereas fast motions were oppositely seen as more negative, exciting, urgent, threatening, and rejecting. Therefore, our hypothesis (H2) regarding speed is con-

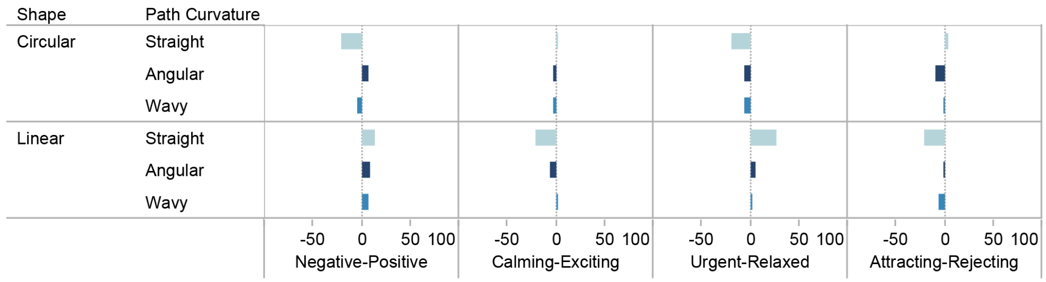


Figure 6: *Means of Valence(NP), Intensity(CE), Urgency(UR), Interaction(AR) ratings of linear and circular motionscapes (by Path Curvature)*

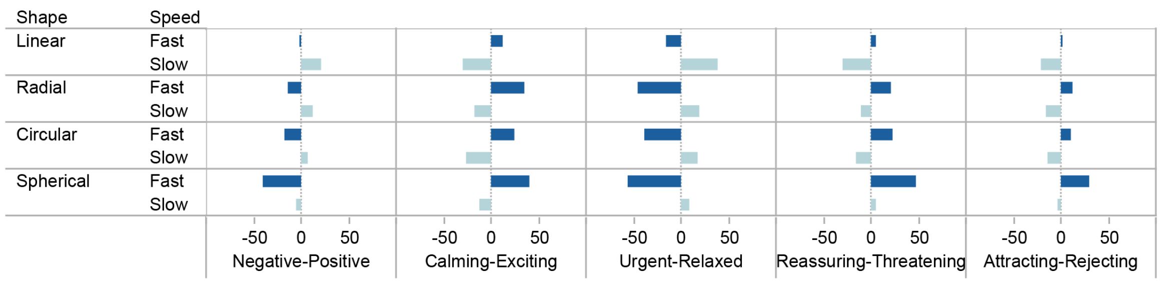


Figure 7: *Means of all affective ratings of all shape motionscapes (by speed)*

firmed. This finding suggests that increasing speed of the motion may lead to changes in the affect being communicated. While motionscapes with individual elements moving in slow speed may be seen as calming and relaxed, but when the elements within them move enormously faster, the affect impressions communicated by the motionscape may be altered as exciting and urgent. Speed also influences affects on valence (NP). That is, as fast motions are usually associated with more negative affective impressions when compared to slow motions, the use of visual elements with high speed should be carefully managed in order to avoid negative impressions. Another implication can be drawn from speed's effect on the interaction (AR) ratings, where slow motionscapes were usually perceived as more attracting than fast motionscapes. Thus, when motions are applied with the purpose of drawing and keeping users attention, controlling the speed may be a crucial aspect that should be considered by the designers.

5.2 Path curvature

Path curvature, in linear motionscapes, had significant effects on intensity (CE), urgency (UR), and interaction (AR). Linear motionscapes with straight paths were rated as more calming, relaxed, and attracting than those with wavy or angular curvatures. These fit previous findings in [Lockyer et al. 2011; Lockyer and Bartram 2012] with exception only in valence (NP) and dominance (RT) ratings, where path curvature did not yield significant effects. Thus, we accept H1. The effects of path curvature on the affective impressions of linear motionscapes is quite consistent with the effect produced by movement of single object: while a wavy motion is usually interpreted as more exciting than the straight motion [Bartram and Nakatani 2010], similar affects of excitement can also be achieved by linear motionscapes with wavy curvatures.

No significant effect of path curvature was captured in radial and spherical motionscapes. It should be noted that when agents move in parallel tracks in linear primitives, the difference in path curvature is more likely to be noticed; while in non-linear primitives, with particles move along non-parallel trajectories and their path curvatures being overlapped or tangled, the applied wavy path curvature may become hard to distinguish and hard to predict (Figure 3, b and c). While game designers and researchers pay much attention to manipulating visual load for the gaming experience of visual elements in games [Milam et al. 2011], the wavy curvature might then be another contributing factor to such visual loads, contributing to stress and frustration [Milam et al. 2012]. Another unexpected finding from this study is that circular motions with straight paths were rated as more negative than those with angular and wavy path curvatures. This finding is quite inconsistent with results from previous motion research [Tagiuri 1960; Bartram and Nakatani 2009; Bartram and Nakatani 2010], where movements with straight path have often been perceived as more positive than those with non-straight curvatures. Our findings regarding path curvature suggest that the effect of path curvature on motion affects can be either accumulated or altered when same path curvatures are formed by multiple visual elements; as similar motion patterns are performed by large amount of visual elements in motionscapes. Therefore, the role of path curvature should not only be studied by visiting the expressiveness of each individual visual element but also by examining the dynamic interplay of all individual motions. The application of path curvature must be carefully designed and carried out with careful consideration of the shape of the motionscapes.

5.3 Direction

Results from linear, radial, and spherical motionscapes showed that direction had significant effect on interaction (AR) ratings: outward motions were rated as more rejecting than inward motions. However, in circular motions, we didn't detect any significant effect of direction (clockwise or counter clockwise). These led us to partly accept H3, with the hypothesis regarding direction in circular motionscapes being rejected. What we didn't expect was the effect of direction in spherical motionscapes on dominance (RT) ratings. In spherical motionscapes, outward motions were generally seen as more threatening. This finding is opposite to the results of previous studies in 2D motion textures, where radial textures in 2D were rated similarly on dominance (RT) dimension regardless of direction [Lockyer et al. 2011; Lockyer and Bartram 2012]. A possible explanation to directions effect in linear and spherical motions is: when particles fly towards the viewer, the viewer usually felt the rising of threats or being rejected. This effect might be very much similar to some of the visual effects in 3D cinema or games where objects or visual phenomena such as flashes are thrown out of the screen towards the audience member or player. With visual elements constantly moving towards the viewer, a sense of personal space being intruded may arise. Further, as inward motions were seen as more attracting and outward motions were seen as more rejecting, spherical motionscapes with inward motions can be applied to attract viewers attention to the direction along which the visual elements within motionscapes are flying to. For instance, the common implosion effect in games that leads a player to follow a certain direction are often utilized to achieve such attraction affect (Figure 8).

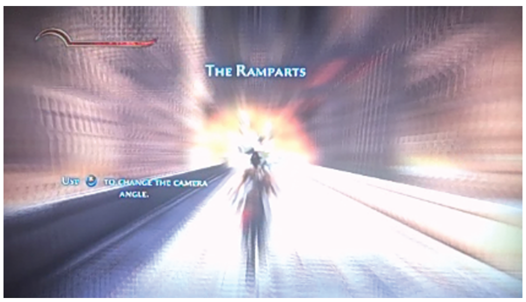


Figure 8: *Implosion effect in Prince of Persia™ attracts user directionally*

5.4 Shape

Shape, along with speed, is another significant factor that affects all 5 affective ratings. However, as circular motionscapes were not detected as a significant contributor to negative affective impression, we reject H4. We found that user affective ratings significantly varied between spherical and linear motionscapes. From the study, linear motionscapes were found to evoke more calming, relaxing, and reassuring affects. This finding suggests that linear motionscapes may be suitable for many design scenarios where comfort is intended. Also, as linear motionscapes were generally rated as neutral on other affect ratings, they may be applied for more ambient and less intrusive visual cues.

Spherical motionscapes are already commonly applied in film and gaming special visual effects. We foresee further applications of such motion affects in other contexts such as visualization and interface design. As spherical motionscapes were rated as more negative, exciting, urgent, threatening, and rejecting, a general implication for visual artists and designers is clear: where the listed impressions are intended, spherical motionscapes may be a legitimate candidate visual element to consider. For instance, users need to be constantly reassured when computational systems work properly, they also need to be warned when things go wrong [Norman 2002]. In this case, a message to indicate the emergency is needed. Therefore, as spherical motions are seen as urgent and exciting, they can be applied as such visual notations for the warning messages. The spherical motionscapes are also eligible as visual cues both to evoke an exciting atmosphere and to attract viewer attention to specific positions within a spatial environment. On the one hand, spherical motionscapes were usually associated with stronger impressions of excitement and urgency, they are therefore useful in design scenarios where the above two impressions are intended. On the other hand, although spherical primitives are not revealed to evoke attracting affect from our study (to the contrary, spherical motions were often seen as more rejecting), it should be noted that motion in general is highly efficient in directing viewer's attention. In the field of visual design, the mechanism of visual attention is largely associated with changes in motion of visual elements [Bartram and Ware 2002]. The spherical motionscapes discussed here can therefore serve as a motion cue to address a specific position within space.

6 Conclusion and Future Work

Applying motion for the communication and evocation of affects is a promising design space. With previous studies showing simple motion factors are key contributors to motion affects, we chose to investigate 4 such factors: speed, direction, path curvature, and shape. Our study has proven that simple variations of such motion factors again significantly influence various affective impressions and experiences of the motionscapes in 3D world space. New findings from this study also revealed that 1) spherical motionscapes were pronounced indicators for negative, exciting, urgent, threatening and rejecting impressions; 2) outward linear and spherical motionscapes contributed to greater rejecting and threatening impressions; 3) path curvatures effects vary significantly among motionscapes of different shapes. We continued to discuss on design implications on applying motionscapes for affects in contexts such as game design and visualization. Our current research continues the exploration of how these affective principles can be used in visualization applications related to health, in games and in interactive performance.

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