# Beyond Data: Abstract Motionscapes as Affective Visualization

Chao Feng Lyn Bartram Diane Gromala


## Abstract

Abstract *motionscapes* – the extensive compositions of visual forms in motion – are often used for the evocation of affective experience in many recent interactive artifacts and environments. The aesthetics of motionscapes can be informed by case studies and from close readings in the fields of experimental animation, abstract cinema, and generative and interactive art and design. Recent empirical research investigating the affective affordances of motionscapes [13, 14, 26, 27] also brings new perspectives to the design language of motionscapes. In this paper, we summarize key findings from previous research on the affective expressiveness of abstract motionscapes, and argue that abstract motionscapes that are commonly employed in artistic contexts can be appropriated for the design space of HCI as a rich modality for affective visualization. We propose an initial set of principles and guidelines for communicating, evoking and creating affect through abstract motionscapes in immersive and engaging environments such as games, meditation and performances. While these principles are commonly understood by artists, we translate and posit these principles so that can be utilized by HCI practioners.


**Keywords**: Affective visualization, virtual worlds, virtual environments, cinematography.

**Index Terms**: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Animation, Evaluation/ Methodology; I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Radiosity;

## 1 Introduction

In nature, fields of motion can usually be seen in rain, snow, fog, herds of animals, schools of fish, or flocks of birds. Some common characteristics are visible in the above phenomena; that is, they are all comprised of many similar agents moving in coordinated patterns: flocking crows fly in an identical speed and direction; and countless snowflakes fall along similar wavy curves in a winter storm. Such phenomena in nature create a new type of landscapes: metaphorical landscapes that are not constructed by rocks or earth but by the dynamic transformations of natural organisms. In this paper, we term such dynamic phenomena of moving elements *motionscapes*.

In recent practices of the visual arts and visual design communities, a similar type of motionscape manifests itself in massive but coordinated repetitions of visual form and motion, often resembling some of the motionscapes found in nature. A great number of artworks and design artifacts – from fields such as kinetic art, abstract cinema, motion graphics, and generative design – are notable for the ways that their creators approached expressive qualities. Notable examples of such artificial motionscapes, for example, can be found in John and James Whitney's computationally animated films, Saul Bass's motion title sequences, or Casey Reas's generative drawings (a greater range of examples of works of such can also be found in [10, 25, 42, 47]). In such works, motions created using abstract visual forms are often extensively manipulated and composed to further construct and focus the aesthetic and affective aspects of these more abstract motionscapes. Such heavy manipulation of visual motion has been cited as accounting for the affective expressiveness of many works that employ abstract motionscapes [11, 38, 52]. While there is some debate that generally optimizing the affective scope of visual communication can be challenging with regard to abstract representations (e.g. [24] provides multiple perspectives and insights on this topic, through examining theories from abstract expressionism), our research highlights the expressive and affective capacities of abstract motion. We argue that by better understanding the underlying principles, it is possible to indeed imbue abstract motions with affect, or to evoke affective responses with a better degree of certainty, thereby enriching the palette of visual forms available for affective impact.

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*For video documentation and demonstrations, please visit: http://cargocollective.com/rekii/motionscape*

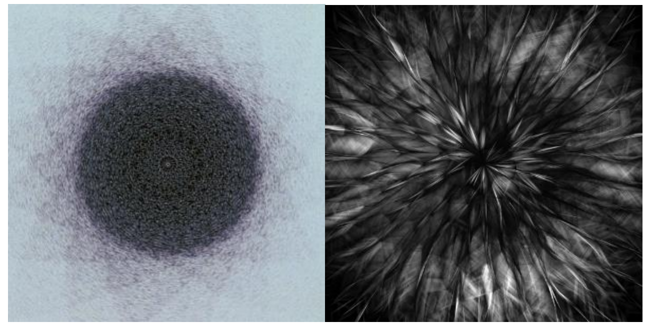

Figure 1: Image from *Lapis* (left) by James Whitney (1965) [51] © Center for Visual Music, and excerpt from *Process Compendium* by © Casey Reas (2010) [45].

Affective expression has been recognized as a critical aspect of the visual presentation of interactive artifacts and environments [37, 39, 40, 43]. However, the affective potential of motionscapes has only recently gained interest in the scientific, computational domain of visualization (e.g. [13, 14, 26, 27]). These more recent scientific studies revealed that motionscapes have a rich potential to be employed as an expressive medium or as components in diverse forms of media for the communication and evocation of affect. While the design language of motionscapes can be informed through close readings of or case studies from fields of experimental animation [47], abstract cinema [38, 53], and generative art and design [10, 42], supporting perspectives and knowledge are still needed to elicit the affective aspects of motionscapes, and further, how they can be borrowed and utilized as affective visualization alternatives for interactive environments. Although such interests in artistic practice have existed for some time, significant and multiple differences between fields of art and visualization (or visualization from scientific and computational domain in specific) have presented barriers that prevent open and frequent exchange of knowledge. For instance, the scientific method often requires a focus on testing one attribute; but for artists, who are concerned with context, this approach is problematic. The converse also applies. However, we contend that trying to understand motionscapes beyond such differences – as far as that is possible – may result in a greater understanding of affect by artists and scientists alike.

We propose that understandings of the "formal" qualities of abstract motionscapes can be borrowed from visual arts and can be utilized as an approach for affective visualization in interactive environments, particularly where affect is important. Therefore, we are not arguing that motionscapes (such as works by the artists cited in this paper) belong to a genre that is designated as affective; rather, we pay attention to the fundamental properties that comprise motionscapes, and study the affective affordances of such very primitive properties. In this paper, we propose an initial set of empirically validated principles and guidelines for communicating and creating affect through abstract motionscapes, and apply them in immersive and interactive environments such as video games, virtual and augmented reality, and computationally-mediated meditation and performances.

## 2 MOTIONSCAPE AS AFFECTIVE VISUALIZATION

### 2.1 Beyond Data: Affect in Visualization

Information visualization has traditionally been defined as the use of graphical and spatial representations of inherently abstract data to facilitate cognitive reasoning. However, until recently, the affective context in which those data representations are communicated and interpreted is often an accidental or at best a secondary consideration, discussed as a topic of aesthetic design. The importance of aesthetics and good design is generally acknowledged as fundamental to engagement, interest and pleasure [39, 40], but this discourse has only touched on the larger design space of affect in passing.

In this paper, we argue that affect, defined as a set of detectable or observable manifestations of a subjectively experienced emotion forms an important dimension of many visualizations. Its use in information visualization applications is an emerging field of study in our traditionally ''objective'' discipline, as researchers identify its importance in narrative [23, 39], audience engagement [30] and contextual framing [20, 27]. We term this emerging field affective visualization: the principled use of visual elements to change the affective nature of a visual presentation. The fundamental difference between data and affective visualization is in communicative intent. Information visualization seeks to represent data with visual features for effective cognitive interpretation. Affective visualization has the goal of using visual features to evoke an affective state: an experience, emotion or impression. (We thus distinguish the latter from the growing body of emotion visualization, in which the data to be represented are emotions, feelings or moods, as those are simply data of another kind.) In short, information is a *reasoning* construct, where affect is *experiential*.

We propose that affective encoding is important in both explicit and implicit representation: to explicitly evoke a feeling or experience core to the information in the visualization and the context in which it is framed, or as implicit support for the cognitive processes of using a visualization, by enhancing problem solving, sharpening focus or reducing boredom and frustration [43]. We note that in the early days of deliberate affective coding, our main challenges may be to avoid unintended effects of representations in which affect has not been deliberately considered.

We react emotionally as well as cognitively to visual and audio imagery [15, 28], and those emotions can influence both how we use the information presented to us and how we are affected by its presence in our visual environment. The interpretation of that visual imagery involves two information processing systems: the *cognitive* and the *affective*. The affective system rapidly "judges" the environment according to factors such as valence, excitement and threat; the cognitive system interprets and makes sense of the world [22, 40, 41]. These systems are not independent; emotion can result from cognitive reasoning, and affect influences cognition [16, 22]. This underscores the importance of examining the role affect may play in enhancing or impeding information visualization.

The evocation of experience, feeling, impression or emotion is central to the creation of immersive and engaging experiences in advertising, performances, interactive art, and gaming. Affect is also important in an ambient context, the result of how an experience or environment ''feels''. Attaining the right affective balance is considered core to interaction design and user experience [9, 15, 32, 39]. This often relies on atmospheric cues that influence how an environment feels. The design of such visual cues for affect is an elusive topic that has been studied by painters, theatre directors, scenic designers, lighting designers, filmmakers and producers for years. Contemporary visual designers and artists also explore and manipulate visual elements of a scene to enhance affect, but the knowledge of how to communicate these subtle meanings remains largely rooted in professional craft and design principles that are not computationally operational. That is, there are few models that define how to create, amplify or reduce the affect by changing elements such as colour, shadows, iconography or animation (notable exceptions are recent work on adaptive computational lighting for game environments [33, 34] and studies in affective properties of motion [13, 14, 26, 27]). This suggests that the development of operational principles for evoking affect presents a fertile research area for visualization science, drawing from a long history of the study of affect in cognition, psychology, design, and the visual and performing arts.

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 [12]. Emotions are primarily taxonomized by hedonic valence and arousal (intensity) [2, 41]. 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) [22]: 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 touchstones in a wider design space for affective representation and evocation. We expand our operational definition of affect to one of experience: when we are affected by something we experience a feeling as a result. 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 [27]. Moreover, the communicative challenge of evoking or even identifying a specific emotional reaction may be overly onerous. Previous research suggests these feelings may be highly contextualized: that is, rather than a generalizable 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 [6, 7].

## 2.2 The Affective Motionscape

Research has shown that visual encoding features such as colour [2], visual imagery [22] and animation [19, 54] evoke a wide range of affective responses. Motion is a powerful visual cue and a rich modality for affective expression. The arts of drama [55], dance [21], and animation [19] map very complex emotions and motivations on to movement. Moreover, researchers have attempted to categorize movement derived from performance into parameters discernible and distinguishable by humans, suggesting as important speed and tempo; area/space; and direction and path (the line the moving object creates) [5, 28, 49]. These also reflect techniques used by animators, who rely in part on speed, extent and amplitude to convey emotional state of their characters [19]. Where these works focused on the representation or re-mapping of movement attributes, researchers have also investigated what attributes of simple motions evoke or have an influence on affect. Studies regarding the affective judgment of such abstract motion indicate that even very basic animated representations evoke highly complex responses. In [6, 7, 17] 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. Similarly, [48] investigated single dot animations and found different trajectories elicit particular behavioural impressions.

More recently, [26, 27] and [13, 14] studied how basic properties of 2D motion textures and 3D motionscapes influenced users' affective ratings of valence (positive—negative), intensity (calming—exciting), threat / dominance (reassuring—threatening), urgency (urgent—relaxed) and interest (attracting—rejecting). The five affective dimensions employed in these studies were used to evaluate the affective dimensions of motionscapes that are critical in general contexts of dynamic visual environments: while the first two (valence and intensity) reflect emotion research and theory [41], the latter three reflect commonly communicative intent in gaming [36], performance [30] and visualization [35]. Researchers found that speed, shape (linear, radial, spherical, and circular patterns formed by motion), and in certain shapes, direction and path curvature (the "wiggliness" of the individual particle trajectory) all contributed to influence affect. Not surprisingly, speed mapped strongly to intensity [13, 14, 26, 27], with slow motions seen as more calming. The impact of some features differed, dependent on shape of the motion textures or motionscapes. Direction proved affective with respect to valence only in linear textures and motionscapes: leftwards motions were rated as more negative, while upwards motions were rated as more positive [26]. Inwards motions were rated as more attracting and less rejecting than outwards motion in both linear and spherical motionscapes [14]. Path curvature was significant only in linear motionscapes: jerky particle motions were perceived as more negative, exciting, threatening, urgent, and rejecting, while straight motions were more positive, calming, reassuring, relaxing and attracting [14].

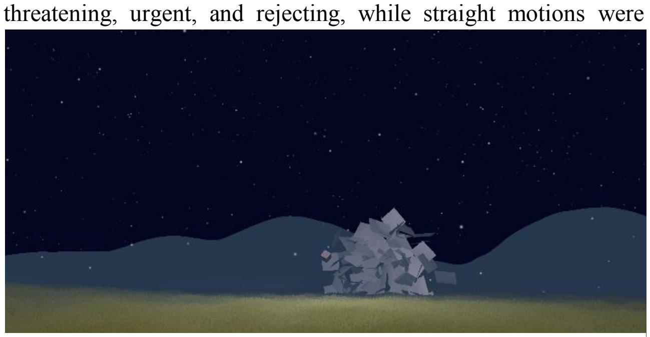

Figure 2: Motionscape in an immersive virtual environment: moving agents are distributed throughout the environment

In this paper, we employ an immersive virtual environment (VE) as a virtual stage or application area for the motionscapes studied in previous research [13, 14, 26, 27]. While this VE attempts to resemble a landscape in nature, the goal of the landscape is to provide the viewer with reference points regarding the location and scale of the motionscapes. We embedded previously studied motionscapes in this VE to depict a number of design scenarios. In so doing, we aim to generalize implications for interactive environments that are both visually more realistic or more abstract.

In the following sections, we organize our discussion thusly: first, we start with design implications based on previous findings regarding shape, and propose that shape functions as the compositional base of motionscape design. Next, based on the general discussion on shape, we will continue to discuss how the three atomic motion properties (speed, direction, and path curvature) enrich the affective expressiveness of motionscapes of varying shapes. Finally, we discuss presentational aspects of the motionscape design, focusing on the scales of motionscape design both in the virtual environment (view point) and the physical realm (display conditions).

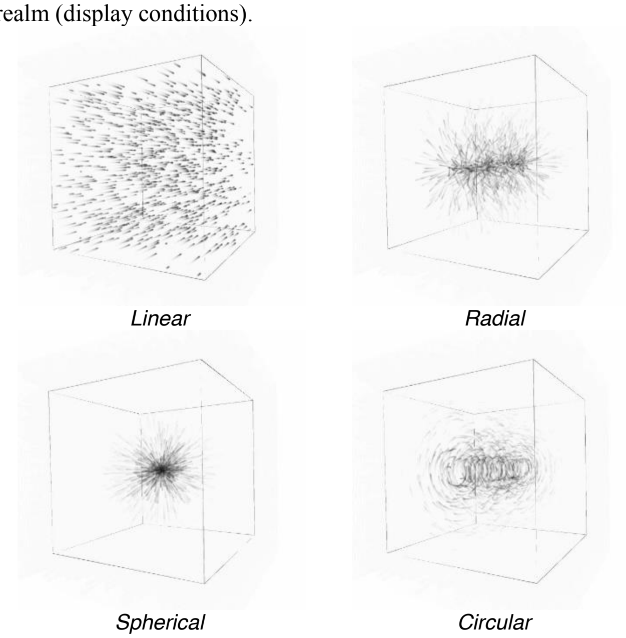


Figure 3: Four base variations in shape of motionscapes: linear, radial, spherical and circular (reconstructed from [13, 14])

## 3 Dimension of Composition: Shape as the Composition Base

Shape, or the dynamic layouts of motionscape composition (Figure 3), has been found to be a significant factor for affective expressiveness of both 2D motion textures [26, 27] and abstract motionscapes [13, 14]. For the latter, the shape effects held in all conditions: stereoscopic, immersive and desktop display [13].

Motionscapes with linear layouts, for instance, are neutral in their affective expressiveness. That is, when compared to the affective impressions produced by motionscapes of other shapes, linear motionscapes were not rated as pronounced on most affect dimensions [14]. However, this doesn't mean that linear motionscapes are less affective. From the studies, they proved to yield a calming, relaxing, and reassuring effect on the viewer. This means that linear motionscapes are suitable for many design scenarios where providing comfort to the viewer is important. Notably, as linear motionscapes were generally ranked lower in affect dimensions such as interaction, threat, and urgency, they seem more suitable for ambient visualization, where visual elements should be more neutral, less attentionally demanding and less intrusive [46].

In contrast, non-linear motionscapes were associated with more pronounced affective impressions of urgency, threat, interaction and valence. Among the various non-linear shapes covered by previous studies, spherical layouts were found to have a strong effect on multiple affect dimensions. Spherical motionscapes were generally rated as more exciting, urgent, threatening, and rejecting. The above affect dimensions are key to emotional aspects of many interactive systems. As discussed in [40], users need to be constantly reassured when computational systems work properly; they also need to be warned when things go wrong. 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 visual notations for warning or for strongly suggesting areas of high intensity experience. This is reinforced by the use of circular motionscapes in action games such as *Ratchet and Clank*™ (2012) [56] that use circular patterns to guide the player towards the next challenge.

While the above generalizations on the possible applications of linear and non-linear motionscapes are based on their diverse affective expressiveness of various motion properties, another path can be followed to study the application directions of the two categories of motionscapes. The linear and non-linear layouts can be categorized under the two categories of basic composition systems summarized by Rudolf Arnheim [4]. The spherical layout, along with radial, circular layouts visited in [13, 14], represent the system of centricity, where the inner compositional forces (formed by the structured movements of the particles within motionscape) are related to an internal centre (or an internal axis in space). The linear layout, on the other hand, represents a system of eccentricity, where the composition forces react to no such centre or axis. These two different composition systems imply two types of motionscape applications. To ease the following discussion, these two types of applications are categorized according to which effects are intended: local effects or ambient effects.

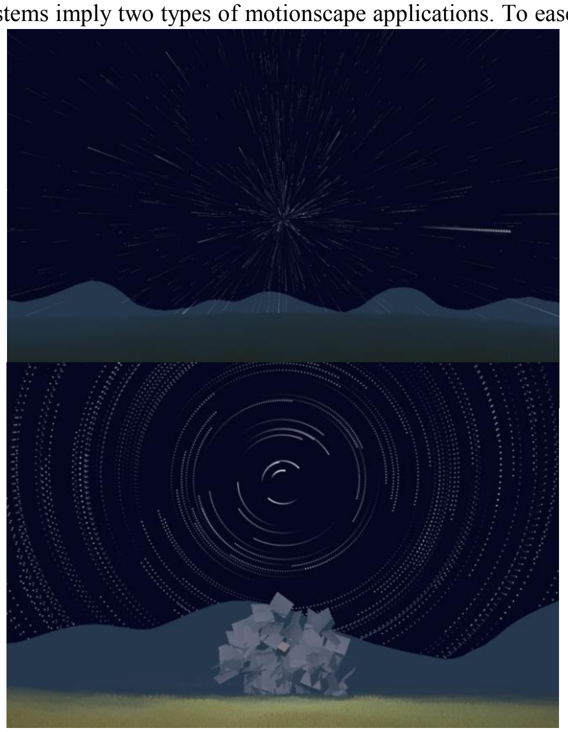

Figure 4: In a spherical motionscape (up), inidividual particles radiate out from a spatial centre; in a circular motionscape, inidividual particles move along circular paths.

## 3.1 Local Effects

Non-linear motionscapes are always attached to certain positions within the virtual space wherein they reside, the motionscapes can be made relevant to specific positions in the visual space for a range of local effects. For instance, as shown in Figure 4, both the spherical and spherical motionscapes are located at distant points in the virtual space. Here the two motionscapes can be applied as a visual cue to communicate the feeling of excitement, and its compositional centres suggest the positions where the excitement arises in the space.

Specifically, the spherical motionscape in this case is useful both as a visual cue to evoke an exciting atmosphere for the position to which it is attached as well as to make an evoked affective impression associated with specific positions within a visual space. On the one hand, as spherical motionscapes were 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 motionscapes aren't always associated with attracting affect according to the findings in [14] (to the contrary, spherical motionscapes were often seen as more rejecting), it should be noted that motion in general is highly efficient in directing the viewer's attention (e.g. visual designers often rely on changes in colour, texture, and motion of visual elements to direct visual attention on screen [50]). The spherical motionscapes discussed here can therefore serve as a motion cue to address a specific position within space, when the colour, form, and motion pattern of the motionscapes are designed to differ from the background environment.

According to Janet Murray, it is crucial for any virtual environment to inform the interactors about their position within the whole [37, p.167]. In the scenarios depicted in Figure 4, the resulting local effects serve as landmarks that both remind the interactor of his relative position in the virtual environment and to make certain places in the environment visible. Although the motionscapes shown in the figure are implemented in large scale, the motionscapes' effects are all associated with a specific point in space. Similar to the spherical motionscape's effect discussed above, the circular motionscape in this case may indicate the point at which visual force and excitement may be attached or directed.

It should be noted that similar local effects can be achieved by linear motionscapes as well. However, as there's not a definite central point or axis in linear motionscapes, the local effects can only be achieved by locating the linear motionscapes in a specific area within the greater environment.

Motionscapes intended for similar local effects are popular in a range of interactive environments. For instance, similar non-linear motionscapes are often employed as special visual effects for video games, movies, advertisements, and motion title design. But they are not as widely used in more scientifically oriented visualization. In the field of visualization and interface design, the mechanism of a user's attention is usually of great interest to the designers. The motionscape may thus serve as an alternative approach for their efficiency in directing attention and in producing affective local effects.

## 3.2 Ambient Effects

The composition of linear motionscapes requires no specific centre but does need space within the virtual environment in which the motionscapes reside. Therefore agents within a linear motionscapes can be equally distributed to a large space to create an environmental effect. It is hard to decide whether the neutral affective impressions of the linear motionscapes are a result of lacking the composition centre, but when controlling carefully, linear motionscapes' neutral impressions are suitable for ambient, natural effects.

In Figure 2, the linear motionscape applied in this scenario is designed to simulate a cosmic environment, where particles within the motionscape move gently to produce a calming atmosphere. Here, as there's no specific centre or axis within the linear motionscape, the arrangement of the particle movements is therefore less threatening or aggressive than that in spherical or circular motionscapes. Therefore the viewer does not have to pay attention to any specific point within this environmental motionscape.

Just as linear motionscapes can be applied for local effects, the previously discussed spherical and circular motionscapes are also capable of evoking certain environmental effects. In fact, the two scenarios of local effects can also be seen as ambient or environmental because the visual motions within the two non-linear motionscapes take up a great ratio of the virtual environment. However, such non-linear motionscape applications are with clear references to specific position or axis within the environment. Thus it should be noted that the environmental effects therefore differ from those evoked by the linear motionscapes.

## 4 Dimension of Individual Motion: Motion Control on Atomic Level

The variations in shape also leads to variations in the effects of several other properties, such as those resulting from direction and path curvature. And it should be noted that through manipulating the other properties under different compositional form, the affective affordance of such motionscapes can be altered. In the following, several motion properties that are applied on atomic level (i.e. fundamental motion properties of the single particle movements within motionscapes) are demonstrated respectively, with each section aiming to demonstrate relevance to the possible design scenarios.

### 4.1 Speed

The influence of speed on the affective experience of motion has been established in a range of studies [5, 14, 6, 7, 26, 27, 28, 49]. The findings regarding speed in motionscapes are quite consistent with the general knowledge of and understanding in motion research: the speed of individual or the atomic motion agents that comprise the motionscape was confirmed as a significant factor for almost all affective impressions studied in [13, 14, 26, 27]. Motionscapes with fast motions, for example, are considered to be more negative, exciting, urgent, threatening and rejecting than those with slow motions. This amplification of effects was found to be consistent in both linear and non-linear motionscapes [14]. This finding suggests that speed is a motion factor strongly associated with the intensity of the above affective impressions. That is, the change in speed will very likely influence the relative levels of certain affects.

To take a glance at the implication above, let’s take a look again at the two scenarios of non-linear and linear motionscape applications. In Figure 4, non-linear motionscapes can evoke the feeling of excitement, urgency, and threats; manipulating the speed of the particles’ movements therefore influence the strength of the intended affective message being communicated. Such adjustments are necessary or desireable for a range of applications, as the affective message not only lies in the quality of perceived movement, but also in the intensity of affects as well. For instance, imagine when multiple urgent situations emerge: a quick decision about which one should be solved first should be made. Because the affective aspects can provide important information about the relative levels of urgency, they can act as key indicators in such scenarios.

Another finding from [14] regarding speed is critical to the design of motionscape effects: speed influences not only the quantitative level of motionscape effects, but also the qualitative nature of the affects. For example, because increasing the speed may lead to an increase in the impression of excitement, it may also lead to the change in the affect being communicated. In Figure 2, for instance, the particles that comprise the linear motionscape act together as a simulation of a cosmic field, where particles moving along linear paths all appear to come toward or at a user. When the particles are slow-moving, they may be experienced as calming and relaxing. When, however, those particles start to move incredibly fast – keeping the linear velocity constant – the calming affect evoked by the very same motionscape might be altered; in this case, the affective experience of excitement and urgency may also arise. Similarly, slow motionscapes were usually perceived as more attracting, while fast motionscapes were rated as more rejecting. Thus, when motions are applied with the purpose of drawing and keeping a user's attention, the control of the speed (both velocity of the particles and the speed of movement of the particles themselves) in motionscapes is again a crucial aspect that should be considered by the designers.

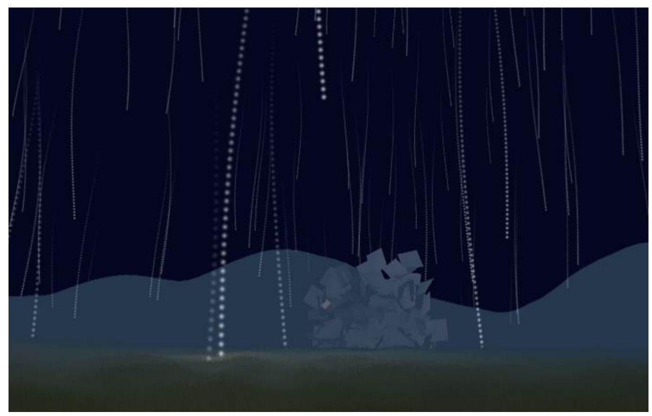

Figure 5: Linear motionscape applied with wavy path curvature

### 4.2 Path Curvature

The role of path or trajectory in expressiveness of simple motion has been visited in both scientific studies and in theoretical work in the domain of art and design [5, 28, 48, 49]. But generalizations for design from these efforts need to be informed with new perspectives here, as the motion patterns are performed by large amount of visual elements in motionscape. We term the variations in the local trajectories of the atoms in the motionscape *path curvature*. Findings from this research in motionscapes suggest that both that the role of path curvatures of the individual elements should not only be studied by investigating the expressiveness of each single particle but also by examining the dynamic forms achieved by the interplay of all agent movements. We report on two such directions of application of path curvatures in motionscapes: each is observed and discussed according to the two main variations in the compositional base of motionscapes.

#### 4.2.1 Curve as reference to nature

The affective impression of path curvature created by a single object may be accumulated when the same paths are followed by multiple agents. In particular, linear motionscapes are significantly influenced by the path curvature applied to the moving agents within them, and the resulting effect is usually consistent with the effect produced by a single object. For instance, a wavy motion is usually interpreted as more exciting than the straight motion [6, 7, 48], a same affective impression can be obtained by motionscapes with linear layouts and wavy curvature [13, 14, 26, 27].

"The straight lines belong to men, the curve lines belong to God." This quote from Antoni Gaudi may be the explanation for another finding regarding path curvature. In our studies, wavy path curvature was constantly noted by participants as a visual effect resembling those in nature [13]. As when applied in linear motionscapes, the wavy path curvatures formed by the traces of particles may be seen as a visual reference to waves in ocean, forests, or grass land. The design implication here is therefore a direct result from such references to nature. Wavy paths, when manipulated carefully, may produce the impressions that are more natural, and thus are capable of communicating certain calming, reassuring, and relaxing affects.

Figure 5 provides an instance of such calming effects from wavy curvatures. In this scene, the linear motionscape is comprised of agents moving in wavy paths. Although other visual features (distribution of white dots, moving upwards) are of no references to natural phenomena, the waves of the movements within this motionscape increases its naturalness. Thus, the motionscape may promote a feeling of calmness and reassurance in the visual environment.

#### 4.2.2 Visual complexity

Spherical motionscapes with straight paths were associated with positive affects; while those with wavy path curvatures were often seen as negative [13, 14]. It should be noted that when particles move in parallel tracks in linear motionscapes, the difference in a path curvature is more likely to be noticed; while in non-linear motionscapes, where particles move along different trajectories, the applied wavy path curvature may therefore increase the visual complexity of the motionscape. Therefore, the wavy path curvature may become hard to distinguish and hard to predict. This may sometimes lead to other affective impressions that are not often associated with wave curvatures. For instance, spherical motionscapes with a wavy curvature can achieve certain threatening effects. In games, these are thus popular visual effects and are often extensively used. While game designers and researchers pay much attention to manipulate visual load regarding the gaming experience of visual elements in games [34], the wavy curvature will then be another contributing factor to such visual loads. In this case, comprises between such visual loads and intended affective impressions must be made. Similar implications will also applicable in other affective visualization applications, as such negative effects are useful for various design scenarios. However, the application of a path curvature must be carefully designed and carried out with consideration of the compositional layout, that is, with the shape of the motionscape.

The interplay among the moving agents does not only lead to an accumulation of the expressiveness of each of them. For instance,

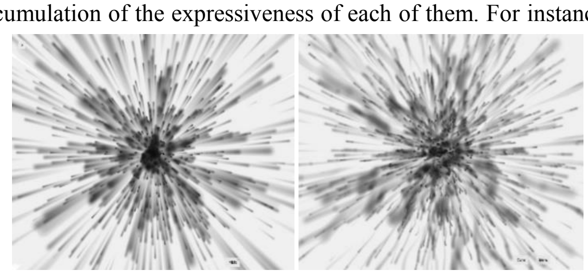

Figure 6: Spherical motionscapes with straight paths (left) and wavy curvatures

[13, 14, 26, 27] suggest that path curvature contributes little to the affective impression of motionscapes with non-linear layouts. This may further imply that the articulated meaning and impression achieved by a movement performed by single object may become blurry when the same movements occur under the more structured compositional effort (Figure 6).

### 4.3 Direction

The effects of directionality were not found to be consistent for linear motionscapes and non-linear ones [13, 14, 26, 27]. In linear motionscapes, direction was found to be a crucial factor for affective dimensions such as valence, intensity, and interaction. But in non-linear motionscapes direction was found to be a less of an expressive motion property.

#### 4.3.1 Up and down

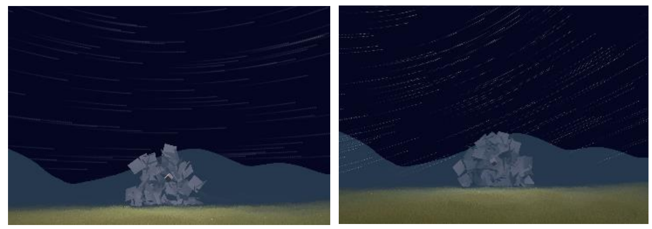

Figure 7: Linear motionscape with variations in direction. Particles moving to (a) right or to (b) right upward

Linear motionscapes with particles moving upwards were usually seen as more positive and exciting than those with particles moving downwards. Upward motions are seen as positive (and vice versa) and are therefore relevant for visualizations that require articulating positive or negative characteristics. For instance, in Figure 5, the upward motions of the linear motionscapes can serve as ambient cues for a positive dimension. While the wavy curvatures render the motionscape calming and relaxing, the upward motions may send a positive message, such as encouragement or cheer.

Another design implication lies in the association of the direction with affects on the intensity dimension (calming—exciting). In previous studies [13], such an association was attributed to natural references, and is similar to the interrelationship between wavy path curvature and calmness or reassurance. Indeed, downward motions seem natural because of the universal effect of gravity; therefore, upward motions may be seen as more exciting than the more natural and expectable downward motions. This implication is useful when the message of changes should be sent out. In the scene depicted in Figure 5, a change in motions of the particles from static to moving upward may indicate certain situation arises, and such change is very likely interpreted as positive and exciting. Figure 7 shows another scenario where direction is controlled to alter the affective impression of the scene. In Figure 7 (a), the particles within linear motionscape are moving to the right, while in Figure 7 (b) the particles are moving to a right upper direction. The atmosphere may be thus altered slightly (the scene may therefore be seen as slightly more positive and exciting) resulted from the change in the motion's direction.

#### 4.3.2 Engaging the viewer

Outwards motions within linear motionscapes were rated as more rejecting and threatening, while inwards motions were rated as more attracting [13, 14].

Figure 8: Linear motionscape as mist simulation

In the discussion provided in [14], we have learned that when particles fly towards the viewer, the viewer usually felt the rising of threats or of being rejected. This effect might be very similar to some of the visual effects in 3D cinema, where things such as a knife, baseball or snake are thrown ‘out of the screen’ towards the audience members to surprise them. An explanation was previously given in [14]: with visual elements constantly moving towards the viewer, a sense of intrusion of personal space may arise. This explanation requires further experimental evidence, but it is pertinent because it suggests design strategies regarding viewer involvement. For instance, inwards motions were seen as more attracting while outwards motions were seen as more rejecting; this implies that viewers’ involvement in the visualization can be influenced by choosing which direction the particles are flying toward. However, this implication is only relevant for inwards or outwards motions. When agents within motionscape move to a direction parallel to the plane of the window (or the scene the viewer is facing), the visual elements may become less influential for the viewer [13, 27].

An instance of the manipulation of inward and outward motion is provided in Figure 8. In this case, the linear motionscape is intended to simulate mist over a grassland. The mist can be controlled to move either toward or away from the viewer’s virtual position in the scene, where a sense of rejection or attraction may arise. Based on the visual feedback in the virtual environment only, the viewer may feel that he or she is being pushed away by the dense, approaching mist and thus feel the scene (or in this scenario, the whole virtual environment) is in a sense rejecting (or unaware of) her or his or virtual existence.

An instance for opposite effects can be observed in Figure 2. Here, the linear motionscape with a similar motion pattern can be set to move away from the viewer’s position. Thus, all particles within the motionscape move towards a direction to the distant point in the virtual environment. With the particles surrounding a viewer as he or she moves forward, the viewer may feel attracted to the same direction, which may further encourage the viewer to explore this environment.

The implication regarding inward and outward motion can be similarly relevant for certain non-linear motionscapes as well. For instance, in spherical and circular motionscapes, inwards motions may also be applied to engage or reject viewers’ activities within the virtual environment. However, the resulting effect may be different from that achieved by linear motionscapes, because the visual motions within the non-linear motionscapes will only be directed toward or away from a certain point or axis within the environment.

Being aware of the likely effect of a motionscape’s direction is crucial. While direction has strong effect on the impression of attraction or rejection, and reassurance or threats, the manipulation of direction thus has significant impact on the viewer’s attention and feeling of the atmosphere in scenarios where motionscapes are applied.

The converse of this implication can also be applied. For instance, downwards motions can be used to evoke calming effects, but such a motion pattern should be applied with caution since moving downward may suggest negative affects as well.

## 5 Dimension of Presentation

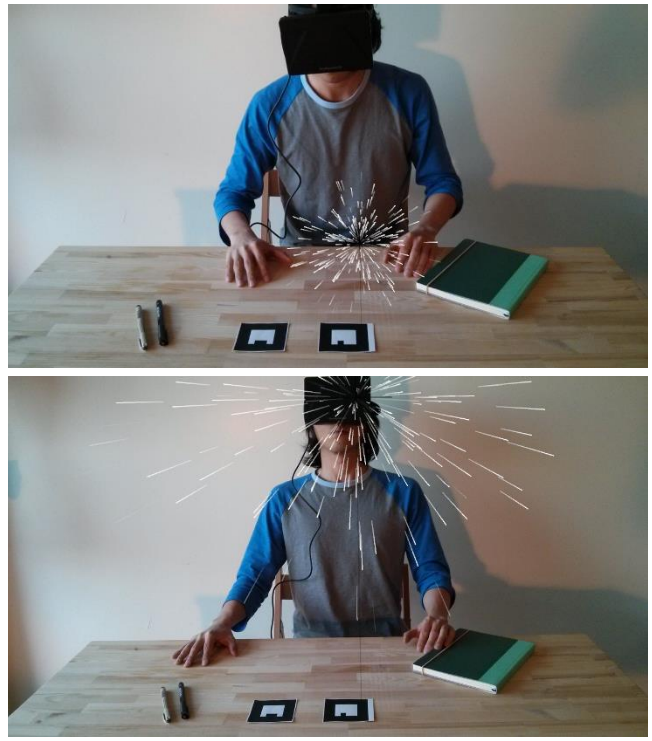

Figure 9: Viewing a spherical motionscape through HMD from either an inside viewpoint (up) or outside viewpoint.

### 5.1 View Point: Amplification and Alternation

The simulation of the two viewer positions in [13] can be seen as variations in the scales of the motionscape. Figure 9 gives an example of motionscape being viewed from two viewpoints. The inside view point, from which viewer is virtually positioned among the particles within motionscape, enlarges the motionscape’s effect to a full-screen (or a full virtual space in the VR scenario) scale. When the viewpoint is outside of the viewer’s immediate space, on the other hand, the effect of the motionscape is within a smaller area on screen or a small district within the virtual space. In this version, it is also possible that the motionscape may appear to be more of object, depending on its scale and distance from the viewer.

The above two simulated scales of motionscapes that result from variations in view points (or the relative positions of the viewer and the motionscape), lead to quite consistent effects in both linear and non-linear motionscapes. Such differences in expressiveness of the motionscapes viewed from an inside and outside view point is possibly influenced by the level of the experience of immersion (full screen vs. local), which further leads to the two different effects discussed previously: the ambient effects and local effects.

As discussed in section 3, local and ambient effects have been associated with the compositional manipulation of motionscape shape. Here the discussion expands by incorporating the factor of scale. While ambient or local effects can be achieved by the variations in the shape, they can also be implemented by manipulating the scale of the motionscape. While the ambient effects discussed previously were intended for calming, relaxing, or reassuring effects (and local effects for exciting, urgency, threatening impression), similar motionscapes that are intended to achieve such ambient and local effects can be manipulated in terms of scale for certain amplified or altered affects.

As discussed, the linear motionscapes can be applied to achieve certain ambient effects when applied at a full-screen scale. While it has been pointed out that such ambient effects can be associated with calming, relaxing, or reassuring impressions, it should also be noted that such affects yielded by linear motionscapes can be altered or amplified particularly when a large scale encompasses the viewer. Compared to the motionscapes viewed from an outside point of view, the full-screen motionscapes can therefore evoke affects that are more exciting, urgent, and threatening.

Similar altering and amplifying effects are visible among non-linear motionscapes [13]. In addition to dimensions such as intensity, urgency, and threats, a view point also significantly influences the affective impressions on valence dimension: those viewed from inside are seen as more negative than those viewed from outside. As discussed previously, non-linear motionscapes can be applied for a sense of warning of urgency and threat. Such effects can be amplified by increasing the scale. The visual effects can therefore achieve these relatively negative affective impressions with greater intensity. Indeed, when viewed from the inside, where the motionscape takes up the entire screen, or seems to surround the viewer under stereoscopic conditions, the resulting effect may overwhelm the viewer.

In summary, the two simulations of viewer position represent two categories of design fields based on the scale of the motionscape effects: visual effects designed for certain local space or ambient effects applied to an entire environment. Motionscape effects applied to a local position in a visual field is seen as more subtle and less pronounced than those applied to the entire visual field or virtual environment. Therefore, the scale of the motionscape can be seen as a “slider” for indicating the intensity of the intended affective impression, and should be carefully considered by visual designers who face the choice of creating local visual effect or large scale ambient effects.

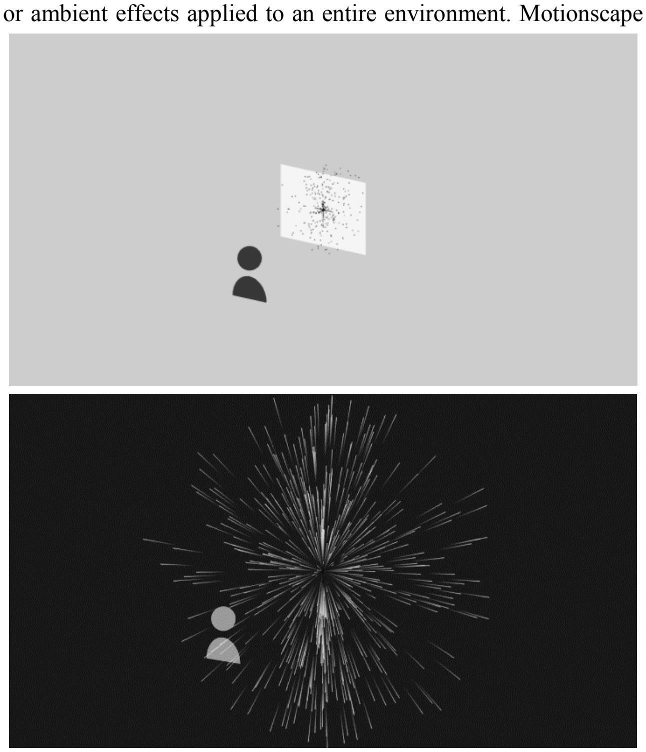

Figure 10: Two viewing conditions that were tested in [13]: the upper image shows vierwer viewing motionscape through standard desktop display, while the lower image attempts to resemble viewer’s experience in VR, where the motionscape is the only visible visual component to the vierwer.

Two directions (total immersion vs. jumping back and forth between application interface and user) of interface design for virtual applications/environments are discussed in [18]: computer / virtual applications should function not as a total immersive environment, but as an interface that allows users to ‘enter’ the virtual world and that physical reality. Applying motionscape effects to information visualizations or interface design is not so much intended for immersive experiences per se (i.e., positioning the user within the motionscape that functions as a total immersive environment). Rather, motionscape effects should invite the user’s attention when necessary: to keep the user outside the chaos and to allow her to jump back and forth between interface or application and herself.

The above discussion appropriated from [18] is on the level of aesthetics or poetics, but it can also be applied in more practical contexts. The fundamental difference between the two categories of motionscape applications (local or environmental) results from the scale of motionscapes that take up the entire screen or 3D virtual environment. As interactive environments, such as those of video games, VR artworks, or interactive rides in theme parks, are often aimed for both immersive experiences and emotional engagements [37], full-screen or environmental motionscape effects can be applied in such fields. And in the following section, we will continue to the topic of immersive virtual reality.

### 5.2 Display: From Screen to Virtual Reality

Previous study on stereoscopic motionscapes [13] revealed that stereoscopic displays (Figure 10 resembles two viewing conditions investigated in the cited study) contributed to greater attracting and rejecting ratings. This indicates that stereo visual presentations perform better in directing user attention than the non-stereo ones do. In addition, motionscapes presented through the desktop stereoscopic display were rated as more positive [13]. This can be partly attributed to the visual clarity brought about by incorporating the third dimension: depth. Scott McCloud attributed many terrifying effects in comics to how knowledgeable we are about the situations or objects we are facing, "we tend to fear what we are not familiar with or what we don't understand" [31]. A similar point of view can be appropriated here as the visual depth achieved by the stereoscopic display grants us a greater level of visual clarity, and this further leads to the more positive affects achieved by the motionscape under stereoscopic viewing condition.

The stereoscopic display has been widely employed to help cinema achieve a greater level of realism [29]. A similar trend in the field of visualization and interaction design is still less visible, and a possible prospering in the stereoscopic applications may not be only due to the appeal of realism, but also because of the informativeness achieved by the incorporation of depth. Indeed, as stereo motion cues are possibly better at directing attention and visual appeal, 3D display applications are likely to contribute to better interface performance and higher efficiency in information retrieval. However, the application of abstract motionscapes (especially those rendered under stereoscopic conditions or implemented in physical set ups) is still relatively less thoroughly and less frequently explored. Thus, the design for such 3D, stereoscopic motionscape-affects may become crucial to many emerging efforts within the above-mentioned fields.

## 6 Conclusion and Future Work

Applying abstract motionscapes for the communication and evocation of affect is a promising design space. Artists have long understood and mobilized affective aspects of their work, however, the specific ways in which they have been formalized and communicated outside of artistic practice has only recently gained interest in the computational domain of visualization. Previous studies [13, 14, 26, 27] have revealed that shape (or compositional layout), simple motion factors (speed, direction, and path curvature), and presentational aspects (view point and display conditions) are key contributors to motion affects. Based on such findings, we provide design implications for applying motionscapes for affective intent or enhancement in contexts of the design of immersive virtual environments.

Our current research continues the exploration of how these affective principles can be used in visualization applications related to health, games and interactive performances. Drawing upon the principles we derived from empirical studies [13, 14, 26, 27], we then applied motionscapes to a range of recently produced interactive environments. Abstract motionscapes have been pervasively employed in the visual presentation of these environments to evoke affective experiences among the interactors. For instance, in *Mobius Floe* [57] – an immersive virtual reality (VR) project designed to facilitate pain distraction and pain regulation among chronic pain patients – abstract moving visual components are distributed throughout a virtual environment as affective components. The movements of these components are manipulated to render a diversity of affective evocations, from a calming atmosphere to a frenetic one.

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## References

[1] D. Acevedo and D. Laidlaw, "Subjective Quantification of Perceptual Interactions among some 2D Scientific Visualization Methods," *IEEE Transactions on Visualization and Computer Graphics*, vol. 12, no. 5, pp. 1133–1140, Sep. 2006.

[2] F. M. Adams and C. E. Osgood, "A Cross-Cultural Study of the Affective Meanings of Color," *Journal of Cross-Cultural Psychology*, vol. 4, no. 2, pp. 135–156, Jun. 1973.

[3] K. Amaya, A. Bruderlin, and T. Calvert, "Emotion from Motion," in *Proceedings of the Conference on Graphics Interface '96*, Toronto, Ont., Canada, Canada, 1996, pp. 222–229.

[4] R. Arnheim, *The power of the center: a study of composition in the visual arts*. Berkeley: University of California Press, pp. 2-12, 1983.

[5] M. Bacigalupi, "The Craft of Movement in Interaction Design," in *Proceedings of the Working Conference on Advanced Visual Interfaces*, New York, NY, USA, 1998, pp. 174–184.

[6] L. Bartram and A. Nakatani, "What Makes Motion Meaningful? Affective Properties of Abstract Motion," in *2010 Fourth Pacific-Rim Symposium on Image and Video Technology (PSIVT)*, 2010, pp. 468–474.

[7] L. Bartram and A. Nakatani, "Distinctive Parameters of Expressive Motion," in *Proceedings of the Fifth Eurographics Conference on Computational Aesthetics in Graphics, Visualization and Imaging*, Aire-la-Ville, Switzerland, Switzerland, 2009, pp. 129–136.

[8] L. Bartram and C. Ware, "Filtering and Brushing with Motion," *Information Visualization*, vol. 1, no. 1, pp. 66–79, Mar. 2002.

[9] R. Beale and C. Peter, "The Role of Affect and Emotion in HCI," in *Affect and Emotion in Human-Computer Interaction*, C. Peter and R. Beale, Eds. Springer Berlin Heidelberg, 2008, pp. 1–11.

[10] H. Bohnacker, B. Gross, J. Laub, C. Lazzeroni, and & 1 more, *Generative Design: Visualize, Program, and Create with Processing*. New York: Princeton Architectural Press, 2012.

[11] F. Collopy, "Color, Form, and Motion: Dimensions of a Musical Art of Light," *Leonardo*, vol. 33, no. 5, pp. 355–360, Oct. 2000.

[12] P. Ekman, "An argument for basic emotions," Cognition & Emotion, vol. 6, no. 3–4, pp. 169–200, 1992.

[13] C. Feng, "The Affective Affordance of Motionscape," Thesis, Communication, Art & Technology: School of Interactive Arts and Technology, Simon Fraser University 2014.

[14] C. Feng, L. Bartram, and B. E. Riecke, "Evaluating Affective Features of 3D Motionscapes," in *Proceedings of the ACM Symposium on Applied Perception*, New York, NY, USA, 2014, pp. 23–30.

[15] J. Forlizzi and K. Battarbee, "Understanding experience in interactive systems," 2004, p. 261.

[16] F. Gregory, A. M. Isen, and A. U. Turken, "A neuropsychological theory of positive affect and its influence on cognition," *Psychological Review*, vol. 106, no. 3, pp. 529–550, 1999.

[17] F. Heider and M. Simmel, "An Experimental Study of Apparent Behavior," *The American Journal of Psychology*, vol. 57, no. 2, p. 243, Apr. 1944.

[18] M. Heim, *Virtual Realism*. New York: Oxford University Press, USA, 2000.

[19] T. Johnson and O. Johnson, Disney Animation: *The Illusion of Life*, Collectors edition. New York: Abbeville Pr, 1981.

[20] R. Kosara, "Visualization Criticism - The Missing Link Between Information Visualization and Art," in *Information Visualization*, 2007. IV '07. 11th International Conference, 2007, pp. 631–636.

[21] R. Laban and F. C. Lawrence, *Effort: Economy of Human Movement*, 2nd edition. London: Macdonald and Evans, 1974.

[22] P. J. Lang, M. M. Bradley, and B. N. Cuthbert, "International affective picture system (IAPS): Affective ratings of pictures and instruction manual." NIMH, Center for the Study of Emotion & Attention, 2005.

[23] A. Lau and A. Vande Moere, "Towards a Model of Information Aesthetics in Information Visualization," in *Information Visualization*, 2007. IV '07. 11th International Conference, 2007, pp. 87–92.

[24] E. M. Levine, "Abstract Expressionism: The Mystical Experience," *Art Journal*, vol. 31, no. 1, pp. 22–25, Oct. 1971.

[25] M. Lima, *Visual complexity: mapping patterns of information*. New York: Princeton Architectural Press, 2011.

[26] M. Lockyer, L. Bartram, and B. E. Riecke, "Simple motion textures for ambient affect," 2011, p. 89.

[27] M. Lockyer and L. Bartram, "Affective motion textures," Computers & Graphics, vol. 36, no. 6, pp. 776–790, Oct. 2012.

[28] M. Mancini, G. Castellano, E. Bevacqua, and C. Peters, "Copying Behaviour of Expressive Motion," in *Computer Vision/Computer Graphics Collaboration Techniques*, A. Gagalowicz and W. Philips, Eds. Springer Berlin Heidelberg, 2007, pp. 180–191.

[29] L. Manovich, *The language of new media*. Cambridge, Mass.: MIT Press, 2002.

[30] D. S. Maranan, T. Schiphorst, L. Bartram, and A. Hwang, "Expressing Technological Metaphors in Dance Using Structural Illusion from Embodied Motion," in *Proceedings of the 9th ACM Conference on Creativity & Cognition*, New York, NY, USA, 2013, pp. 165–174.

[31] S. McCloud, *Understanding comics: the invisible art*. New York: William Morrow, 1994.

[32] D. McDonagh, H. Denton, and J. Chapman, "Design and emotion," *Journal of Engineering Design*, vol. 20, no. 5, pp. 433–435, 2009.

[33] D. Milam, M. S. El-Nasr, L. Bartram, B. Aghabeigi, and P. Tan, "Similarity in Visual Designs: Effects on Workload and Performance in a Railed-Shooter Game," in *Entertainment Computing - ICEC*

*2012*, M. Herrlich, R. Malaka, and M. Masuch, Eds. Springer Berlin Heidelberg, 2012, pp. 284–291.

[34] D. Milam, M. S. El-Nasr, D. Moura, and L. Bartram, “Effect of Camera and Object Motion on Visual Load in 3D Games,” in *Entertainment Computing – ICEC 2011*, J. C. Anacleto, S. Fels, N. Graham, B. Kapralos, M. S. El-Nasr, and K. Stanley, Eds. Springer Berlin Heidelberg, 2011, pp. 113–123.

[35] A. V. Moere, “Towards Designing Persuasive Ambient Visualization” in *Proceedings of the 1st International Workshop on Ambient Information Systems*, Toronto, Ont., Canada, 2007, pp. 48–52.

[36] D. Moura, M. S. El-Nasr, and L. Bartram, “Navigation and player progress in 3D games,” presented at the Workshop on Game User Research, 2012.

[37] J. H. Murray, *Inventing the medium: principles of interaction design as a cultural practice*. Cambridge, Mass: MIT Press, 2012.

[38] Museum of Contemporary Art (Los Angeles, Calif.) and Hirshhorn Museum and Sculpture Garden, *Visual music: synaesthesia in art and music since 1900*. [London] : Washington, D.C. : Los Angeles: Thames & Hudson ; Hirshhorn Museum ; Museum of Contemporary Art, 2005.

[39] D. Norman, “Emotion & design: attractive things work better,” *interactions*, vol. 9, no. 4, pp. 36–42, Jul. 2002.

[40] D. A. Norman, *The design of future things*. New York: Basic Books/Perseus Book Group, 2009.

[41] A. Ortony and T. J. Turner, “What’s basic about basic emotions?,” *Psychological Review*, vol. 97, no. 3, pp. 315–331, 1990.

[42] M. Pearson, *Generative Art*, 1 edition. Shelter Island, NY : London: Manning Publications, 2011.

[43] R. W. Picard, *Affective computing*. Cambridge, Mass.: MIT Press, 2000.

[44] F. E. Pollick, H. M. Paterson, A. Bruderlin, and A. J. Sanford, “Perceiving affect from arm movement,” *Cognition*, vol. 82, no. 2, pp. B51–B61, Dec. 2001.

[45] C. Reas, *Process Compendium 2004-2010*. 2010.

[46] J. Rodgers and L. Bartram, “Exploring Ambient and Artistic Visualization for Residential Energy Use Feedback,” *IEEE Transactions on Visualization and Computer Graphics*, vol. 17, no. 12, pp. 2489–2497, Dec. 2011.

[47] R. Russett and C. Starr, *Experimental Animation: An Illustrated Anthology*, New edition edition. New York: Van Nostrand Reinhold Inc.,U.S., 1977.

[48] R. Tagiuri, “Movement as a Cue in Person Perception,” in *Perspectives in Personality Research*, H. P. David and J. C. B. M.D, Eds. Springer Berlin Heidelberg, 1960, pp. 175–195.

[49] L. C. Vaughan, “Understanding Movement,” in *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems*, New York, NY, USA, 1997, pp. 548–549.

[50] C. Ware, *Visual Thinking: for Design*, 1 edition. Burlington, MA: Morgan Kaufmann, 2008.

[51] J. Whitney, *Lapis*. Creative Film Society, 1965.

[52] J. Whitney, *Digital harmony: on the complementarity of music and visual art*. Peterborough, N.H: Byte Books, 1980.

[53] G. Youngblood, *Expanded cinema*. London: Studio Vista, 1970.

[54] C. Yun Yoo and K. Kim, “Processing of animation in online banner advertising: The roles of cognitive and emotional responses,” *J. Interactive Mark.*, vol. 19, no. 4, pp. 18–34, Sep. 2005.

[55] J. W. Zorn, *The essential Delsarte*. Scarecrow Press, 1968.

[56] *The Ratchet and Clank Collection*. Sony Computer Entertainment, 2012.

[57] *Mobius Floe*. Pain Studies Lab, 2014.