Abstract Expressions of Affect

Alwin de Rooij

City University London

Joost Broekens

Delft University of Technology

Maarten H. Lamers

Leiden University

Author notes

Alwin de Rooij (corresponding author), Centre for Creativity in Professional Practice, City University London, Northampton Square, London EC1V 0HB, United Kingdom. Telephone: +44 (0)20 7040 8326. E-mail: alwinderooij@city.ac.uk; Joost Broekens, Interactive Intelligence Group, Delft University of Technology, Mekelweg 4, 2628 CD, Delft, The Netherlands. Telephone: +31 (0)15 2786333. E-mail: joost.broekens@gmail.com; Maarten H. Lamers, Leiden Institute for Advanced Computer Science, Leiden University, Niels Bohrweg 1, 2333 CA, Leiden, The Netherlands. Telephone: +31 (0)71 5277033. E-mail: lamers@liacs.nl.

Abstract

What form should happiness take? And how do we shape disgust? This research investigates how synthetic affective expressions can be designed with minimal reference to the human body. We propose that the recognition and attribution of affect expression can be triggered by appropriately presenting the bare essentials used in the mental processes that mediate the recognition and attribution of affect. The novelty of the proposed approach lies in the fact that it is based on mental processes involved in the recognition of affect, independent of the configuration of the human body and face. The approach is grounded in (a) research on the role of abstraction in perception, (b) the elementary processes and features relevant to visual emotion recognition and emotion attribution, and (c) how such features can be used (and combined) to generate a synthetic emotion expression. To further develop our argument for this approach we present a pilot study that shows the feasibility of combining affective features independently of the human configuration by using abstraction to create consistent emotional attributions. Finally, we discuss the potential implications of our approach for the design of affective robots. The developed design approach promises a maximization of freedom to integrate intuitively understandable affective expressions with other morphological design factors a technology may require, providing synthetic affective expressions that suit the inherently artificial and applied nature of affective technology.

Keywords: Abstraction, Affect, Attribution, Computing, Design, Emotion, Expression, Interaction, Morphology, Robotics

Abstract Expressions of Affect

In the last decade human machine interaction research has seen the addition of research aimed at exploring the role of affect within and among humans to develop technologies that can function appropriately and intelligently in personal and social environments. This is fundamental to a variety of techno-scientific research areas such as affective computing (Picard, 1997) and social robotics (Fong et al, 2003). Such technologies can be applied as real-world research platforms for theoretical affective and social science (Cañamero, 2005), but mostly thrives on the promise of practical application in for example healthcare (Broekens et al, 2009), therapy (Dautenhahn et al, 2002), and education (Saerbeck et al, 2010).

At the core of these technologies lies the challenge of how to design an appearance that is intuitive to people in terms of social and affective interaction, but simultaneously satisfies technological and functional requirements. Current design strategies typically attempt to mimic the human or animal form realistically or iconically, often bolstered by design principles from character animation (Bartneck & Forlizzi, 2004; Blow et al, 2006; Fong et al, 2003; Hegel et al, 2009). There can however be situations where anthropomorphic or zoomorphic mimicry constrains the optimal design of affective technologies. For instance, affective communication benefits the design of a rescue robot by facilitating an intuitive warning signal to people, however the configuration of the human body may not be optimal for a rescue robot because it needs to operate in circumstances where humans cannot. Indeed, can you imagine a humanoid design effectively finding its way through small holes in a wall or corridors filled with rubble? This is just one example that illustrates the need for synthetic affective expressions that seamlessly integrate with other, often more important, morphological design requirements of a technology. However, little work has been done to develop such an alternative approach. We present such an alternative.

Recent research on visual emotion recognition offers substantial evidence that the recognition of some emotions neither requires the resemblance to, nor the configuration of, the human body or face per se (Aronoff, 2006; de Gelder et al, 1999; Lundqvist & Öhman, 2004). Instead, the recognition of these emotion expressions can rely on the sole presence of basic motion and form features essential to the recognition of emotion, which are extracted at the highest levels of abstraction in perception (Aronoff, 2006; Lundqvist & Öhman, 2004; Pavlova et al, 2005). Additionally, a large body of experimental research exists on emotion attribution to simple abstract geometrical shapes, based on such essential affective features (Aronoff, 2006; Aronoff et al, 1992; Collier, 1996; Heider & Simmel, 1944; Larson et al, 2008; Locher & Nodine, 1989; Oatley & Yuill, 1985; Pavlova et al, 2005; Rimé et al, 1985; Scholl & Tremoulet, 2000; Visch & Goudbeek, 2009). These theoretical insights motivate us to investigate the possibilities of emotion expression independent of the configuration of the human body and face, based on the minimal essential components of visual emotion recognition. However, developing a design strategy for affective robots based on these insights requires a novel and fundamentally different theoretical framework. This article proposes such a framework.

A similar but more general approach can be found in abstract art. Abstract art focuses on finding essential features and ways to exploit these features in relation to experience through an intuitive process of abstraction (Zimmer, 2003). Recently, the psychology behind abstract art has been taking shape, which proposes that abstract art can inform science on the role of abstraction in perception, and its relation to the construction of experience, e.g. aesthetics and emotions (Di Dio & Gallese, 2009; Freedberg & Gallese, 2007; Ramachandran & Hirstein, 1999; Zeki & Lamb, 1994; Zimmer, 2003). From a design perspective abstract artists defined ways to reflect these perceptual processes of the brain in a design (Zeki & Lamb, 1994; Zimmer, 2003). This approach fits the design requirements posed by our findings from affective science and can be used as design tools that operate on essential affective features. Therefore, taking this psychological perspective on abstract art provides the scientific context to develop practical and theoretical insights that can facilitate the effective presentation of these essential affective features.

Based on these two lines of research we argue that the use affective form and motion features, while explicitly not using configuration features of the human body and face (or any reference to it), combined with lessons from feature based design from abstract art, can facilitate the development of synthetic emotion expressions that pose minimal restrictions to other morphological design requirements. This paper develops a theoretical framework for the design of such synthetic expressions by bringing together the science behind abstract art and research on affect attribution to features that are presented independent of the configuration of the human body and face. To bolster our arguments we present a pilot study that shows consistent emotion attribution to specific combinations of abstract form features. Finally, we discuss the potential implications of our approach using affective robotics as an example application.

The long term goal of this project is to arrive at a design process that maximizes the freedom of designers to invent affective technologies with widely varying morphological design requirements, without being limited by the technological, morphological, and psychological complexities that are inherent to human and animal mimicry. As such, we envision that the proposed abstract expression without resemblance to the human form can help create genuine and believable synthetic expressions that suit the inherently applied and technological nature of affective devices, that are still intuitively understandable to people. We call this approach: abstract expression of affect.

Abstraction

Abstraction can be defined as a strategy for the simplification of the concrete, which through a process of removing all inessential information arrives at its essential universal aspects (Zimmer, 2003). From a psychological perspective abstraction refers to a complex of processes that facilitate the ability to dismiss the irrelevant and focus on essential information only, which is a fundamental operation that is applied at many levels of cognition and perception (Barsalou, 2003; Hampton, 2003; Zimmer, 2003). For example, abstraction is a critical feature in the acquisition and processing of knowledge and it allows for reduced memory storage and rapid processing of information (Barsalou, 2003; Hampton, 2003). This allows people to reason with generalizations instead of being stuck to details (Hampton, 2003).

Visual Abstraction

Abstraction is a fundamental perceptual operation (Zimmer, 2003). The brain perceives an abstraction of the world by selectively extracting features from sensory information, after which it reintegrates this abstraction into a whole and organic experience. Similar to the levels of abstraction involved in perception, people show a remarkable ability to shift the level of abstraction in the real world to extract relevant information (Goldstone & Barsalou, 1998). At the highest level of abstraction individual features are computed from sensory information, i.e., from color, form and movement. Sensory information is relayed to specialized filters, which contains for example specializations for the processing of geometrical form, biological motion or the human face, followed by the reintegration of features into objects, events and finally into an individual-centered reality. We refer to Snowden et al (2006) for an overview of the major processes involved. What is relevant to our research is that attention processes delegate the extraction of these features based on their perceived relevance (Corbetta & Shulman, 2002; Lavie, 1995), and that the processes involved in the extraction of such essential features interconnect with the mechanisms that generate experience, e.g. emotions and aesthetics (Di Dio & Gallese, 2009; Pessoa & Adolphs, 2010). How perceptual mechanisms interact with the construction of experience is still an open problem in science. The way abstraction has been applied within the arts may hint on how perceptual mechanisms relate to the construction of experience (Ramachandran & Hirstein, 1999; Zeki &

Lamb, 1994; Zimmer, 2003), and is particularly relevant to our research because of the way this has already been applied practically within the context of creative design.

Abstraction versus Realism

Perceiving abstraction differs from perceiving realistic artifacts in some key aspects, both are however a means to arrive at the same semantic and experiential qualities. We perceive realistic artifacts against the model we have of the real world. Therefore, the violation of reality is an important factor in realism. Realism facilitates rich and consistent associations due to the wide availability of features and context (Kennedy, 2008), at the cost of increased complexity in information processing. In contrast, presenting information abstractly simplifies information processing, at the risk of more open interpretations due to a lack of contextual information (Kennedy, 2008; Vessel & Rubin, 2010). Indeed, increased abstraction increases the reliance on cognitive processes involved in interpretation and association to fill in missing information, and allow us to understand things in terms they are not (Lakoff, 2008; Landau et al, 2010; Zimmer, 2003). This exactly pinpoints the main challenge in the design of abstract expressions of affect: as the interpretation of abstraction is more vulnerable to context and individual difference, it is important to study the exact affective associations humans have with abstract features, but also the interactions between different features, to trigger exactly those cognitive processes and associations that will result in a specific affective experience.

Abstract Art

Abstraction in art has been documented in cave paintings, and through the ages in for example African, Indian, Islamic and twentieth century western culture (Zimmer, 2003). The core principle in creating abstract art is that through a process of abstraction the artist discards all inessential information of an object or experience in order to represent it by only its minimal and essential aspects. Such a process does not limit itself to objects or scenery, but can also be used to uncover features that exhibit strong experiential qualities. As such, abstract art is argued to visualize the mental representation of emotional and aesthetic experience (Zimmer, 2003). Western abstract art was specifically motivated by the desire to formalize a minimal visual language of color, form, movement and composition through the process of abstraction and artistic methodology, i.e., movement, form and color studies, scale models and introspective evaluation. Such formalisms were to represent a grammar through which the artist could compose specific features into emotional and aesthetic effects (Kandinsky, 1926; Malevich, 1927; Mondriaan, 1925; Van Doesburg, 1925).

The Science behind Abstract Art

Zeki & Lamb (1994) state that since visual art comes from the brain it has to obey the laws of visual processing. As such, the formalisms developed by artists are likely to reflect brain mechanisms governing abstraction and perception in relation to experience (Di Dio & Gallese, 2009; Ramachandran & Histein, 1999; Zeki & Lamb, 1994; Zimmer, 2003). This makes abstract art and the developed formalisms by artists an interesting knowledge base from which the role of abstraction in perception and its connection to the construction of experience can be investigated.

There have been several schools from psychology that have attempted to explain abstract art with different implications for psychology. Gombrich (1960) takes the perspective that abstract artistic work requires an artist to decompose an image similar to the way cognition forms abstractions, and tells us something about the formation of knowledge structures, concept manipulation and abstraction. Complementarily, the work of Arnheim (1974) interprets abstract art using Gestalt principles, and shows that from this perspective abstract art informs us on the role of abstraction in perception. More recently abstract art has gained interest from the neuroscience community, which attempts to explain the neurology of aesthetic experience through the analysis of art. Zeki & Lamb (1994) attempt to explain specific formalisms developed by artists from the perspective of visual processing, hence confirming some foundations of formalisms developed by artistic methodology from a neuro-scientific perspective. Ramachandran & Hirstein (1999) attempt to match perceptual mechanisms to frequently used techniques within the creative arts, and explain these in relation to their connectivity to brain function, e.g. how they affect experience, and guide visual attention. Freedberg & Gallese (2007) explain abstract art from the perspective of embodied simulation.

We review the current state of the psychology behind abstract art and focus specifically on design methods used in abstract art that affect the perception of essential features, which are proven to be grounded in human cognition and perception. Literature indicates three processes in abstract design. Therefore we also distinguish between (a) the process of arriving at essential features (as informed by a review on affect attribution research), (b) design operations that affect individual essential features, and (c) design operations that affect the composition of (essential) features, both in terms of the construction of features, the effects on experience and visual attention. Taking this psychological perspective on abstract art provides an empirical and theoretical basis to formalize the design of abstract expressions of affect in a scientific context. The design operations can form a practical basis for manipulating combinations of (affective) features to influence the perception of affective specificity and intensity. We explicitly do not include formalisms developed by artists, because these are not proven using scientific methods.

Design Operations on Individual Essential Features from Neuro-Aesthetics

This section describes the different findings from neuro-aesthetics on the presentation of essential features. Although we provide basic depictions to illustrate the discussed principles, we encourage the reader to take a look at the examples of artworks that are mentioned to gain a better and more complete understanding of the described design operations.

Isolation of Essential Features

A fundamental aspect of abstraction in visual art is to isolate a modality, e.g. colors, shapes, contours or movement, which conveys the essence of a sensation or object in an image, by removing or reducing any other visual information that does not contribute specifically to conveying that essence. As such, isolation emphasizes essential features by purging the image of non-essential information, allocating attention to the essential features we normally must search for (Ramachandran & Hirstein, 1999; Zimmer, 2003). Hence the cliché: less is more.

This is well illustrated by for instance 'La Gerbe' (1953) by Henri Matisse, who shows that by using simple outlines, i.e., the absence or reduction of other structural and detailed visual information than contour, essential visual aspects are well communicated and understood. Leaving out inessential information differentiates the essential features from the environment and guides attention towards its essential aspects more quickly and easily (Ramachandran & Hirstein 1999).

The downside of such abstraction is that by reducing an object to its essential features you reduce the amount of contextual information available as well. Research shows that indeed people make very specific and consistent attributions to representational and realistic pictures, but interpret abstract imagery more openly (Vessel & Rubin, 2010).

Exaggeration of Essential Features using the Peak-Shift Principle

Ramachandran & Hirstein (1999) identify the peak-shift principle as one of the fundamental perceptual mechanisms behind abstract art but also artistic practice in general. This principle states that a human or animal will show a stronger response to a feature when it is exaggerated as opposed to a previously presented similar instance of that feature. The general idea is as follows. If we learn to respond, for example, positively to a rectangle and negatively to a square, then, when presented later with several rectangles, the strongest response will be to the rectangle with the most elongated aspect ratio rather than to the rectangle most similar to the one that was used in training (Figure 1).

As such, we know that we do not respond to the object, but we respond proportionally to the underlying pattern.

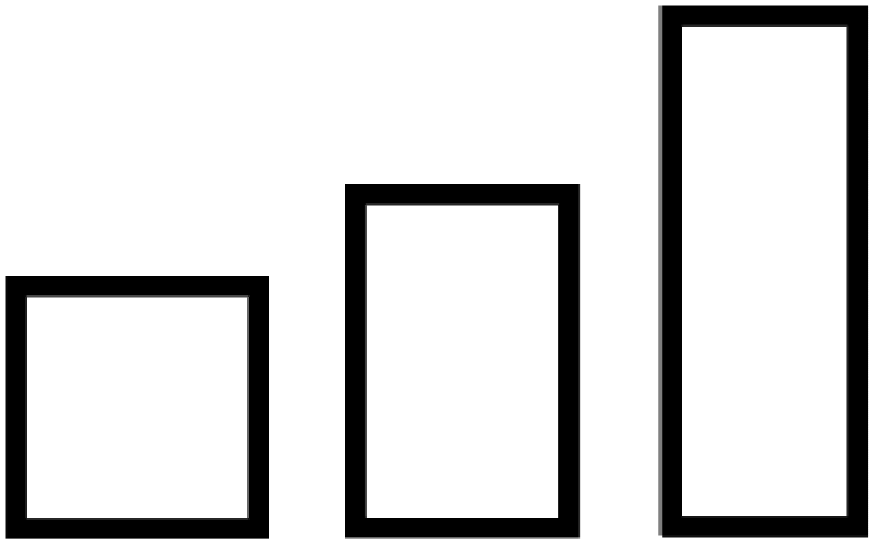

Figure 1. The peak-shift principle: People respond proportionally to the underlying pattern of a learned feature (such as the elongation ratio of a rectangle) instead of to the object itself.

In practice applying the peak-shift principle starts with isolating an essential feature or set of features (Ramachandran & Hirstein, 1999). Based on the characteristics of the essential feature, an anchor point and a path away from that anchor point needs to be determined. This path should represent a continuum of the exact perceptual characteristics of the essential feature. If we travel along the path away from the anchor point, then in principle we increasingly exaggerate the essential characteristics. This exaggeration creates a starker contrast between similar instances of features (the anchor point), emphasizing the essential feature (Ramachandran & Hirstein, 1999; Zimmer, 2003). Hence exaggeration leads to specification; as such an exaggerated feature stands out in terms of visual perception and easily captures attention. It was shown that peak-shifting increases visual information processing both in terms of speed and intensity, and in some cases manipulates visual information to the point that it turns out to be better recognizable than its realistic counterpart (Ramachandran & Hirstein, 1999). This is a promising finding for the possibility to create abstract affective expressions that are still interpreted by the majority of people as a specific emotion (e.g., the expression of fear).

The peak-shift principle is well illustrated by the work of caricaturists (Ramachandran & Hirstein, 1999). A caricaturist is trained to identify the essential features of for example the human face. If the caricaturist caricatures Barack Obama, the essential features, in this case the features that we use to distinguish between faces, of Obama are compared to those of the average face of all people. This average face becomes an anchor point, and the differences between essential features determine the path away from the anchor point. Perceptually this makes for a clearer Obama-experience. It is clear that the success of using the peak-shift principle in visual art is highly dependent on the anchor point and chosen path away from it. Naturally this phenomenon is not exclusive to caricatures or any other type of figurative depiction and thus can be applied to realistic as well as abstract, and representational as well as non-representational features. In that sense one could for example say that in his work 'Number 207 (Red over Dark Blue on Dark Gray)' (1961) Mark Rothko peak-shifts some iridescent feature of color.

In summary, exaggeration using the peak-shift principle affects essential features in such a way that their experience is intensified, and attention is allocated to these features. In practice exaggeration can be used to prevent misinterpretation as well, as it is easier to distinguish between similar instances of essential features. In any case, the challenge remains how to identify essential features, the anchor point and the appropriate direction or path away from it, which is always dependent on the qualities of the essential feature.

Translation of Essential Features to other Modalities

A different fundamental aspect of abstract art can be found in the way experiences natural to one modality, e.g. form, movement, color, sound, can be conveyed using another modality. Indeed, some features may be specific to one modality, however, others have been shown to translate to different modalities as well. In other words, essential features specific to one modality can sometimes be mapped to another, different, modality. This suggests that essential features can mediate an experience or characteristic natural to one modality to another through a process called cross-modal abstraction, or translation. Such phenomena are fundamental to the work 'Composition VIII' (1923) by Wassily Kandinsky. Kandinsky wanted his paintings to evoke the experience of sound through sight, a painted equivalent to the musical symphony that would not only stimulate the eyes, but the ears as well, through vision alone. Such vision-sound correspondences have been evidenced by Köhler (1947), who showed that there exist cases where sound is consistently translated to shape based on corresponding features. In his experiment he found that when using nonsense words, rounded vowels (bouba) translate to rounded shapes and sharp angular vowels (kiki) translate to angular shapes (Figure 2). Additionally, research on synaesthesia elaborates on such correspondences (Ramachandran & Hubbard; 2001, Ramachandran & Hubbard, 2003). For different known strategies and building blocks for translation see Lakoff (2008) for a good discussion and overview.

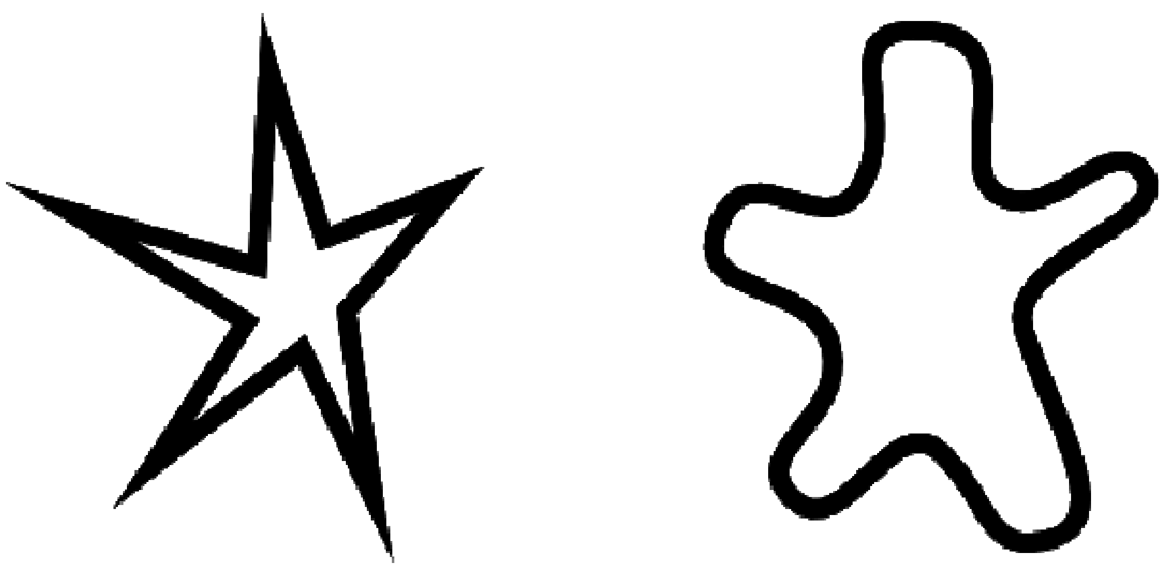

Figure 2. The word Kiki is more often associated with the left shape, while the work bouba is more often associated with the right shape. This is a classic example of cross-modal abstraction, or translation.

The flexibility of translation is well illustrated by the work 'Number 18' (1950) by Jackson Pollock. Freedberg & Gallese (2007) showed that the emotional impact of the work is guided by the painted evidence of the motion and gestures made, and as such translates movement to a static image (Figure 3 provides an example of this principle). Do note that although features can be translated over modalities, it is not always clear to what extent its experiential quality is retained, let alone the affective experience.

Figure 3: An example of how movement traces and kinematics are translated from the movement itself to a static image.

Design Operations between (essential) Features

Apart from design operation on single essential features, there exist operations that operate between multiple essential features, such as copying or multiplying a feature to make it more apparent. We now review such operations.

Multiplicity of Essential Features

Multiplicity is a design operation fundamental to abstract art and comes in part from a recent development called generative art (Whitelaw, 2007). In most cases the quality of essential features is the focal point of abstract work. Multiplicity extends this by exploiting quantity as well (Figure 3).

Multiplicity is characterized by the use of very simple features such as basic geometric primitives in very large multitudes. It is believed that the quality of this approach relies in part on the formation of gestalts (see section on grouping and binding) (Whitelaw, 2007). Complementarily, Aronoff (2006) evidences that the intensity of affective quality is partly determined by the amount of affectively meaningful features present. This is well illustrated by the work 'Process 9' (2005) by Casey Reas. So, to rephrase: the more of a certain feature, the higher its intensity is perceived.

Contrast between (Essential) Features

We can define contrast by the difference between features or modalities. This is relevant in composition because high contrast areas are shown to be more attention grabbing than homogeneous areas (Ramachandran & Hirstein, 1999). As such contrast can be used to accentuate essential features by contrasting different features. Contrast often appears between dissimilar features that are close together, for example, aligning different textures next to each other will create a highly contrasting area where the textures meet, creating an edge, which automatically captures the eye's attention (Figure 4). Next to allocating attention to specific contrasting regions, contrast is also of importance because of the relative nature with which features can be perceived (Figure 4). For example, a bright color is perceived brighter if it is contrasted to a dark color. Contrast plays a role across modalities as well. This is well illustrated by the work of kinetic artist Alexander Calder, who wrote that motion was most efficiently represented by the juxtaposition of highly contrasting surfaces (Zeki & Lamb, 1994). To attain the desired contrast, Calder limited the color use in his work to black, white and red, for which he claimed that red was the color that contrasts the most with black and white, while the use of other colors confuses the clarity of motion. Calder's intuitive understanding is confirmed by findings in neuroscience that suggest that motion is indeed perceived more clearly by contrasting surfaces as motion perception is sensitive to luminance (Zeki & Lamb, 1994).

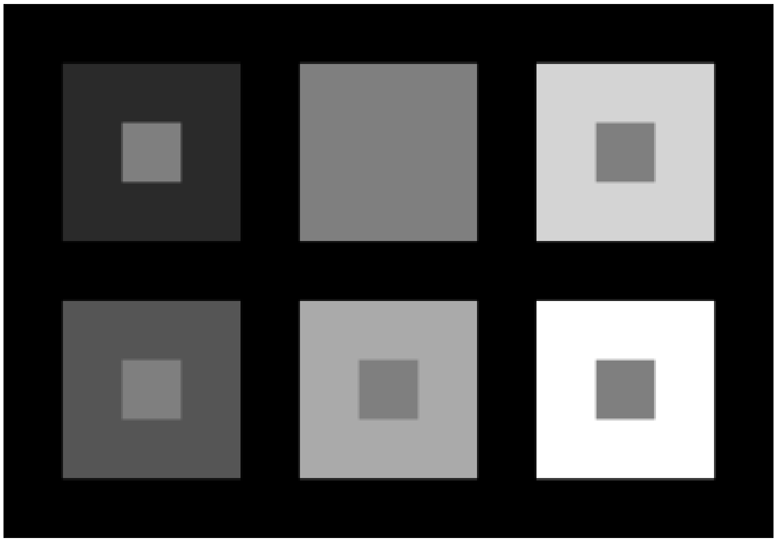

Figure 4. The large squares illustrate the principle that increased contrast is attention grabbing. The small squares illustrate the relative nature of perception. Even though the small squares are the same shade of grey, they are perceived as darker or lighter.

Grouping and Binding of (essential) Features

Grouping and binding mechanisms are concerned with the emergence of objects in visual processing. Gestalt psychology describes the perceptual mechanisms used to perceptually unify features into a group or into a whole. This shows that combinations of features can be interpreted in ways that cannot be explained by considering each single feature in isolation. As such, interpretation depends on the focus of attention of a person. For example, features may group together when they are symmetrical to each other or configured in parallel, move in the same direction or change simultaneously, as is explained by the gestalt grouping principles (Figure 5). Similarly, binding principles may cause the illusion of contours because of the form and configuration of objects (Figure 6). For an overview of the gestalt grouping and binding principles we refer to Wolfe et al (2005) and Snowden et al (2006). The importance of grouping and binding mechanisms in relation to affect is shown by the work of Aronoff (2006) who evidenced in a study on 17th century Dutch art that people attributed emotions based on the amount of angular versus rounded forms found in a work of art. The angular forms were associated with negative emotions and rounded forms with positive emotions. Emotion attributions were in part based on the formation of angularity resulting from the configuration of how people were distributed over the painting, i.e., grouping. These emergent forms were shown to have the same effect as those forms would have if they were perceived singular and isolated (Aronoff, 2006). In other words, forms created by grouping also convey meaning and affective quality as if they would be singular. For further use of Gestalt psychology in abstract art and design we refer to van Campen (1997) and Arnheim (1974) for an extensive overview.

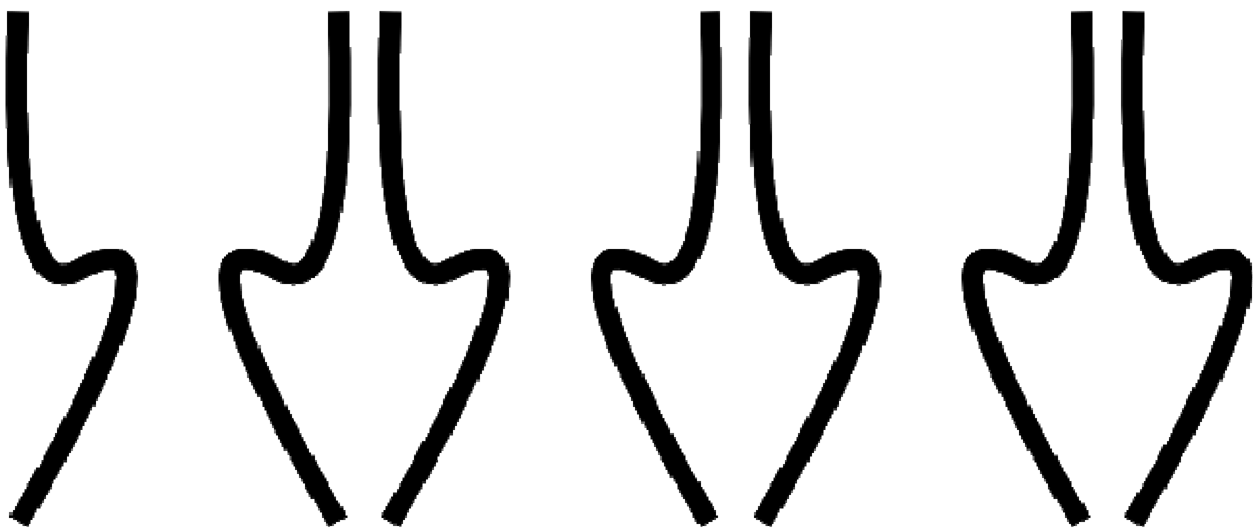

Figure 5. Feature grouping: The similarity between features mediates the perception of groups and whole making. Do you see the cups or the vases?

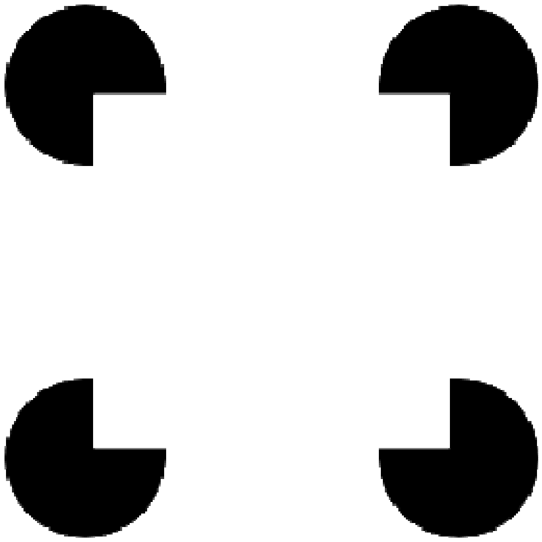

Figure 6. *Feature binding. A configuration of four shapes implies a square in the middle.*

Conclusion on Abstraction

Abstract art provides empirical evidence that we can construct experience from perceiving an abstraction alone. The reviewed literature implies that the brain constructs experiences based on the extraction of specific essential features, which constitute such perceptual abstractions. We have reviewed basic perceptual mechanisms governing abstraction and how these perceptual mechanisms relate to the processing of essential features in terms of the formation of features, the intensification of experience, and the allocation of attention. We have specifically distinguished between design operations that affect individual features and design operations that affect the composition of features. However, we did not touch upon the specifics of essential features themselves, i.e., what features are essential in the recognition of affect, which we will review in the context of affect attribution in the next chapter. As such, the reviewed design operations found in the discussed neuro-aesthetics research are the basis for manipulating features used in the design of abstract expressions of affect.

Note that the science behind abstract art is just starting to take shape. As a consequence, this review is by no means complete, it is meant to be illustrative. Most current day research in neuro-aesthetics treats static works of art (e.g. painting or sculpting). The work on kinematic art by Zeki & Lamb (1994) is an exception to this. It does for instance dismisses a whole body of work on abstract animation (and visual music),e.g. the work of Oscar Fischinger. Therefore, it is important for future developments for the design of abstract affective expressions to keep track of new developments into research that investigates the construction of experience form and movement perception, such as neuro-aesthetics, but also the creative arts.

Affect

Affect can be defined as the experiential quality common in emotion, mood, and affective attitude. Affect is thought to be woven through the whole of human functioning and as such plays a fundamental role in cognition (Damasio, 1994; LeDoux, 1998), perception (Atkinson & Adolphs, 2005; Pessoa & Adolphs, 2010) and behavior (Fischer & Manstead, 2008). Emotions are relatively short but intense episodes that influence attention, action selection, action preparation, memory, motivation and homeostasis. Emotions are typically directed to some cause (Izard, 2009) (I am angry at a friend when he wrecks my car because he was drunk). In contrast, emotions differ from mood in the sense that mood is typically not consciously attributed and is a less intense but longer-term affective state (I feel relaxed). For example, a mood may arise when an emotion is repeatedly activated, accumulating into an overall affective state. Affective attitude refers to the affective attribution to objects, events and persons, learned or innate, but not necessarily as a cause of that object, event or person (I like Chinese food). Feeling refers to the experience of affect.

Theories of Emotion

Contemporary affective science has developed three major views on the structure of emotion: discrete, continuous and componential. First, the discrete view of emotion states that emotions are distinct categories (Izard, 2009). Emotion categories can be described as a complex of expressive, physiological, behavioral and experiential characteristics. For example, joy could be described by exhibiting a happy facial expression, being physiologically highly aroused, exhibiting playful behavior and experiencing a good feeling. Many basic sets of emotion categories have been proposed, a famous example is Ekman's six basic emotions: anger, disgust, fear, joy, sadness and surprise (Ekman, 1993). Second, the continuous approach states that affect can be described along (orthogonal) dimensions (Russel, 2003). Typically, a two-factor model is used to describe emotions using the dimensions of pleasure/displeasure and arousal/relaxation. Other dimensions have been proposed as well, depending on the focus of research. The dimension dominance/submission can for instance be used to account for affect attributed to relations between the individual and his/her environment (Mehrabian, 1980). Third, the componential view states that emotions are formed by the combined activation of different underlying cognitive and physiological components (Scherer et al, 2001). Typically, componential theories regard emotion as the result of an evaluation of the environment against personal relevance (cognitive appraisal theory) (Scherer et al, 2001). Famous examples include Scherer's stimulus checks, where the evaluation of an event in terms of appraisal dimensions (novelty, pleasantness, goal and need conduciveness and coping potential), culminate into specific emotional episodes, and the OCC model (Ortony et al, 1980). Most of the affect attribution studies to abstract features review in this chapter, study affect in terms of factors (pleasantness, arousal). Only some study emotion specific effects in terms of attribution to a particular category of emotion. None focus on cognitive appraisal, for obvious reasons (what should the subject cognitively appraise about an abstract feature?).

Affective science is still very much in debate on the nature of emotions, and these three different views are often seen as complementary. A further review of affect per se would not do justice to current developments. Instead we would like to refer to some of the major contemporary literary works in the field (Davidson et al, 2009; Lewis et al, 2008). We will now continue towards reviewing essential affective features.

Visual Emotion Expression

An emotional episode can manifest itself physically in what is called an emotion expression, e.g. facial expressions (Matsumoto 2008), body postures and gestures (Wallbott, 1998). Emotion expressions play a fundamental role in interpersonal communication (Clark & Brissette, 2003), e.g. non-verbal communication and efficiency (affective channel) (Fischer & Manstead, 2008; LeDoux, 1998) as well as inducing empathy and evoking pro-social behavior (Hoffman, 2008), and can occur with or without being aware of the expression (Picard, 1997). Facial expressions are thought to communicate emotions by expressive muscles resulting in minute differences in the relative position of facial features (e.g. the eyebrows, nose, and mouth) (Duchenne, 1990). Facial expressions are governed by social display rules, which determine the specific actions and intensity of expressions appropriate in particular social situations (Matsomuto, 1990). Similarly, emotions may result in specific muscle tensions that influence movement behavior and postures (Lowen, 1971), as well as the relative configuration of anatomical features, e.g. head, shoulders, upper body, arms, hands and movement qualities (Wallbott, 1998).

Visual Emotion Recognition and Attribution

The role of visual emotion recognition is evident as it mediates the interpretation of emotion expressions (Atkinson & Adolphs, 2005; Izard, 2009; Pessoa & Adolphs, 2010; Russel, 2003, Scherer et al, 2001). Recent research evidences the involvement of and interaction with a variety of visual processing mechanisms, object recognition and salience, delegation of attention, and the mechanisms that generate emotions (Pessoa & Adolphs, 2010). Particularly relevant to our work is the separation between two major processing mechanisms: the extraction of configuration information, i.e., the relative positions and limitations of anatomical features of the human body and face (Atkinson et al, 2007; Lundqvist & Öhman, 2004), and the extraction of affectively essential features (Aronoff, 2006; Lundqvist & Öhman, 2004). Though essentially a separate process, it is thought that when configuration information is present, it interacts with the extracted essential features, and weighs them according to a specific hierarchical structure (Lundqvist & Öhman, 2004). Experimental evidence shows that the involvement of configuration information is not a prerequisite for recognizing basic affect (Aronoff, 2006; Atkinson & Adolphs, 2005; Lundqvist & Öhman, 2004), and very likely some basic emotions as well (de Gelder et al, 1999). Configuration overrides and contextualizes the effect of individual features on the condition that configuration information is available (Lundqvist & Öhman, 2004). As such it is not clear to what extent specific emotions can be recognized from essential affective features, independent of the configuration of the human body and face. What is clear is that the absence of configuration weakens the affective effects of essential features (Lundqvist & Öhman, 2004). Recognizing emotions independently of configuration is evidenced to not only enable the recognition of affect from the human body and face, but also mediates the (mis)attribution of emotions and basic affect to places and things. Such evaluations are evidenced to be mediated by sheer presence of essential affective features in visual emotion recognition (Aronoff, 2006). Additionally, there exists a relatively large body of work on emotion attribution to simple geometrical shapes. These are shown to evoke specific emotion attributions, devoid of any resemblance to the human body or face, and independent of its configuration, based solely on the presence of specific essential affective features of visual emotion recognition.

Review of Essential Affective Features from Affect Attribution

Following these findings, we review emotion attribution research and limit this review to research related to movement and form. The reviewed literature shows experimental evidence of emotional attribution towards simple two dimensional shapes based on the presence of essential affective features independent of the configuration of the human body and face. This is important for the design of abstract expressions of affect as it indicates that it is possible to define abstract features that still convey specific affective meaning to humans. Together with the abstraction operations previously reviewed, this indicates that given further research it should be possible to select, combine and enhance abstract features for basic affect expression and potentially for the expression of specific emotions.

Movement Features

Literature suggests that motion is sufficient to evoke basic affective attributions. Such attributions are shown to be automatic and consistent, and independent of form (Oatley & Yuill, 1985; Pavlova et al, 2005; Rimé et al, 1985). In general, essential motion features can be distinguished at two levels of abstraction: movement described by kinematic and by dynamic features.

Kinematic Movement Features

Affect from movement can be described by the interaction between different kinematic and other movement features and in some cases by individual kinematic features. Research shows that the relative interpretation of kinematic features is more informative than the absolute interpretation of kinematic features (Lee et al, 2007; Pollick et al, 2001; Saerbeck & Bartneck, 2010; Sawada et al, 2003). Furthermore, kinematic features relate strongly to the arousal factor of an emotion, and the general intensity of specific emotions (Pollick et al, 2001).

Particularly, average speed and movement time have been shown to be strong features in affect attributions towards movement patterns (Pollick et al, 2001; Sawada et al, 2003). The combination of increased speed and jerkiness evokes attributions of anger, where fearful and sad emotional states are associated with smaller and slower movements (Pollick et al, 2001; Rime et al, 1985; Roether et al, 2010; Sawada et al, 2003). Pollick et al (2001) add that fast and jerky movements may also evoke attributions of happiness. Furthermore, Pollick et al (2001) state that energetic motion is characterized by shorter direction, acceleration, jerkiness, and greater magnitudes of average and peak velocity. Additionally, individual kinematic features are found to relate to specific emotion dimensions: Lee et al (2007) evidence that the smoothness of a movement is an indicator for pleasantness, Saerbeck & Bartneck (2010) found the level of acceleration can be used to predict the perceived arousal of a motion pattern, while Lee et al (2007) show activation is correlated to average velocity.

Additionally, a relatively large body of experimental work exists on social and emotional attributions to the relative movement of shapes opposed to other shapes. One of the first of such experiments was performed by Heider & Simmel (1944), who revealed that people attribute a human-like role and intention to simple animated shapes based solely on their relative directional and kinematic features. Subjects tend to describe such animations in terms of shapes vigorously chasing one another, getting ready for attack or being madly in love. Especially the combination of the kinematic features speed and acceleration, and direction relative to another shape play an important role (Dittrich & Lea, 1994; Scholl & Tremoulet, 2000). The emotional attributions are evoked through some perceived intentionality of the shapes. See Scholl & Tremoulet (2000) for a complete overview of such attributions and their essential features.

Dynamic (Movement) Features

Movement described in terms of its dynamic characteristics is also shown to play a role in emotion attribution. Pavlova et al (2005) argues that the dynamics implied by a static image also enables specific emotional attribution, and as such a dynamic feature does not require the actual movement per se.

Perceived instability was found to be an essential feature in emotion attribution (Pavlova et al, 2005). The perceived instability is dependent on form at the perceptual level, but the emotional attributions made are consistent with the measure of perceived instability, and as such do not directly rely on form. Perceived instability increasingly entails attributions of negative emotions. This is especially true for negative emotions such a fear and suffering. Vertical orientation was found to evoke positive attributions, especially joy and surprise. It has been suggested that these findings correspond to the dynamics in bodily expression in terms of balance and imbalance. We tend to take upright postures and make upright movements when we are joyful or surprised, take slumped and downward postures when we are sad, and lose our dynamic balance and fail to hold ourselves upright when we are fearful or suffering. As such, the perceived instability is shown to have a strong effect on valence.

Additionally, dynamics expressed in the perceived effort of a movement have been shown to evoke emotion attributions. It is suggested that dynamic features from Laban analysis can evoke emotion attribution. For example, the emotion sadness described by shape dynamics can be expressed by enclosed, descending and retiring movements (Fagerberg et al, 2003; Zhao, 2001). Furthermore, de Meijer (1989) shows the involvement of motion dynamics described in for example force and directedness in emotion attribution, where increased force contributes mainly to attributions of anger. However, to the knowledge of the authors of this paper it has not been investigated to what extent these dynamic motion features depend on the specific configuration of and reminiscence to the human body with respect to emotion attribution.

Form Features

Complementary to movement features, literature suggests an important role for form features in visual emotion recognition. Essential form features evoke emotion attributions independent of movement. From literature, we distinguish essential affective form features extracted from shape contour, symmetry, and size.

Shape Contour Features

Studies by Aronoff (1988; 1992; 2006) provide empirical evidence that the contour of a shape plays an important role in emotion attribution. It was evidenced that the angularity of a shape contour evokes negative, arousing and potent emotion attributions, and rounded shape contours evoke positive, less arousing emotion attributions and have no effect on the perceived potency. Similarly, diagonal lines evoke negative emotion attributions, and curvilinear lines evoke positive emotion attribution (Aronoff, 2006). There exists some evidence for the exception that curvature can also evoke negative valence, low arousal attributions (Collier, 1996). The effects of shape contour features on emotion attribution are found in gestalts (grouping and binding) as well (Aronoff, 2006). The origin of geometric form features is thought to be in the recognition of facial expressions, and is thought to be essential in the evaluation of the holistic face (Bassili, 1978) and the expressive facial features, e.g. eye brows and the mouth (Aronoff, 2006; Lundqvist & Öhman, 2004). A similar role for contour features has been shown in several preference studies where it is shown that people prefer rounded over angular shapes (Bar & Neta, 2006; 2007; Silvia & Barona, 2009).

A special case has to be made for V-shapes and downward pointing triangles. V-shapes and downward pointing triangles were shown to receive significantly more negative attributions than similar shapes with an angular contour in a different orientation (Aronoff, 2006). V-shapes and downward pointing triangles are shown to elicit a specific threat response (Larson et al, 2007; 2008).

Additionally, there also exist cases where geometrical form features are translated to movement traces. For example, the angularity and curvature of movement traces is shown to evoke emotion attributions (Aronoff, 2006; Bassili, 1978). Saerbeck & Bartneck (2010) add that the attribution of valence in movement is, at least in part, mediated by interaction of acceleration (kinematic feature) and the curvature of movement patterns.

Asymmetry and Symmetry

Locher & Nodine (1989) show that asymmetrical shapes and configurations (grouping and binding) evokes attributions of heightened arousal while symmetry evokes attributions of low arousal. Their work shows a connection to the complexity of visual processing and the perception of arousal in general (Bedyne et al, 1963; Reber et al, 2004). Additionally, symmetry also plays a central role in preference studies, where it is shown that symmetrical shapes are preferred over shapes that are asymmetrical (Reber et al, 2004).

Size Features

Evidence exists that the size and height of people and animals increases their perceived dominance and social status (Ellis, 1994). Studies using simple geometrical patterns show that the surface area of a shape is associated with attributions of potency, where increased size entails increased potency (Aronoff, 2006). Similarly, the height (and position) of a shape is positively correlated to the perception of dominance (Schubert, 2005).

Combining Essential Affective Features

The reviewed literature predominantly shows attributions of basic affect to essential features of motion and form. Research by Visch & Goudbeek (2009) for example indicates that for basic emotions different parametric movement descriptors contribute to the attribution of different basic emotions, and also contribute with a varying strength. As such, it shows that combining specific essential affective features, according to a specific structure, can result in the attribution of at least some specific emotions instead. We have obtained similar results for combining essential affective form features in our pilot study, which is presented later in this paper. The specifics for multimodal combination of essential affective features are not known.

Hierarchy and Dependence among Essential Affective Features

Additionally, it is unknown whether there exists a specific hierarchy and dependence among essential affective movement features, essential affective form and between movement and form features. It has been speculated that when combining form and movement, movement is used to distinguish between basic emotions, while form may complement motion and allows for the recognition of more specific emotions (Atkinson et al, 2007). These findings suggest a hierarchy among the two modalities movement and form. However, no research exists that investigates the combined effects of form and movement features specifically.

Conclusion on Affect Attribution

The above review shows that basic affect can be recognized through the presence of emotionally essential features independent of the configuration of the human body and face, and that the combination of these essential features can result in the recognition or attribution of some specific emotions. The review shows that explicitly not using configuration features of the human body and face still enables the recognition or attribution of at least some emotions. The review also shows that there are some grand challenges that are fundamental to the development of abstract expressions of affect.

First, the reviewed research is fragmented concerning the existing types of essential affective features, e.g. the role of dynamic movement features at the highest level of abstraction remains to be investigated.

Second, to the knowledge of the authors of this paper no experimental evidence is available on the hierarchy and dependence among different levels of abstraction, e.g. motion features expressed in kinematics and dynamics, and among different modalities, e.g. the relation between motion and form features.

Third, even though some evidence exists, it is unknown to what extent specific emotions can be recognized from combining essential features independent of configuration features of the human body and face. So, the emotional vocabulary we can express with abstract features remains subjected to further research.

Such open questions are fundamental to the future development of affective devices that can benefit from abstract affective expressions and require further research. Keeping track of developments in attribution research and visual emotion recognition can also aid our research. Developing abstract expression of affect may in turn contribute to these research areas as well.

Designing abstract expressions of affect (summary of the reviews)

Until now we have reviewed the science behind abstract art and research on affect and emotion attribution to abstractly presented essential affective features. To inform the development and design of abstract expressions of affect we present these results in table form, to provide easy lookup to find how affect attribution is influenced by the selection of essential features, and operations on the essential affective features. This informs the design of abstract expressions of affect.

The reviews also indicate a design approach that can be followed when one aims to design abstract expressions of affect. The process of abstraction indicates three design phases. In the first design phase essential affective features from visual emotion recognition are selected (Table 1 and Table 2). Essential features are the fundamental building blocks of abstract affective expressions, (combinations of) such features facilitate affect and emotion attribution and can therefore be used to express affective states using an artificial medium such as an affective technology. The second design phase involves operations on the selected essential affective features (Table 3 and 4). These operations change the appearance of individual features (e.g. exaggeration). The third design phase involves operations between (essential affective) features (Table 5). These operations change the relation between features (e.g. contrast).

Design operations in phases two and three can be used to guide attention towards essential features, to express different intensities of expression, and to increase specificity of the expressed affective state. The effect of such operations is, however, subject to future research. These design operations provide the necessary tools to design a range of different abstract affective expressions and associated expressions. Please note that design operations described in the second and third design phase can be applied, but do not have to be applied per se.

Table 1

Effects of essential affective movement features on emotion attribution.

Essential Feature	**Attribution**	**Reference**
Perceived instability	negative emotions, fear, suffering	Pavlova et al (2005)
Perceived stability	positive emotions, joy, surprise	Pavlova et al (2005)
Acceleration	perceived arousal	Saerbeck & Bartneck (2010)
Velocity	activation	Lee et al (2007)
Smoothness of movement	pleasure	Lee et al (2007)
Fast, jerky movement	happiness	Pollick et al (2001)
Large, fast, jerky movement	Anger	Pollick et al (2001), Rime et al (1985), Sawada et al (2003)
Small, slow movement	Sadness, fear	Pollick et al (2001), Rime et al (1985), Sawada et al (2003)
Rounded movement trace	Positive emotions	Aronoff (2006), Saerbeck & Bartneck (2010)
Angular movement trace	Negative emotions	Aronoff (2006)

Relative motion and perceived goal-directedness	Social attributions, animacy, emotional attributions through perceived intentionality	Dittrich & Lea (1994), Heider & Simmel (1944), Scholl & Tremoulet (2000)

Table 2

Effects of essential affective form features on emotion attribution.

Essential Feature	**Attribution**	**Reference**
Roundness, curvilinearity	Positive valence, lessened arousal, no effect on potency, happy, warmth	Aronoff (2006), Collier (1996)
Roundness	Negative valence, low arousal, sadness	Collier (1996)
Angularity, diagonality	Negative valence, heightened arousal, heightened potency, threat, coldness	Aronoff (2006), Collier (1996)
V-shapes, downward pointing triangles	Threat	Aronoff (2006), Aronoff et al (1988), Larson et al (2007, 2008)
Asymmetry	Heightened arousal	Bedyne et al (1963), Locher & Nodine (1989)
Symmetry	Low arousal	Bedyne et al (1963), Locher &

		Nodine (1989)
Size, height, surface area	Arousal, potency, surprise	Aronoff (2006), Schubert (2005)

Table 3

Summary of design operations on essential affective features

Design Operation	**Effects on Feature**	**Reference**
Isolation	Attention	Ramachandran & Hirstein (1999), Zimmer (2003)
Exaggeration	Attention, attribution (intensification)	Ramachandran & Hirstein (1999), Zimmer (2003)
Translation (see also table 4)	Formation of features, using features in other modalities	Freedberg & Gallese (2006), Lakoff (2008), Ramachandran & Hubbard (2003)

Table 4

Cross-modal abstractions or translations that mediate affective experience.

Essential Feature	**Translation**	**Reference**
Kinematics, movement traces	static image that reflects movement and kinematic traces	Freedberg & Gallese (2007)

Roundness	Movement traces	Aronoff (2006), Bassili (1978), Saerbeck & Bartneck (2010)
Angularity	Movement traces	Aronoff (2006), Bassili (1978)

Table 5

Summary of design operations between (essential affective) features

Design Operation	**Effects between Features**	**Reference**
Contrast	Attention, formation of features	Ramachandran & Hirstein (1999), Zimmer (2003)
Grouping & Binding Principles	Attention, formation of features	Ramachandran & Hirstein (1999), Zimmer (2003)
Multiplicity	Attribution (intensification)	Aronoff (2006), Whitelaw (2007)

A pilot study to test the feasibility of combining essential features

Here we present a brief rationale and the results of a pilot study that implements the design guidelines presented in the previous chapter. In principle, essential affective features can be combined to target a set of intended emotion expressions. However, it is important to realize that the structure of visual emotion recognition poses restrictions to combining essential features (see our review on essential affective features). Hence interactions between features must be taken into account. However, the effects of such interactions are often unknown. For kinematic and movement trace features Visch & Goudbeek (2008), Sawada et al (2003) and Pollick et al (2001) are a good starting point. Little is known about the effects of combining form features, but also the effects of multimodality, on emotion attribution. We have performed a pilot study (n=44, age mean=32, sd=12, 27 male, 14 female) on the effects of combining essential affective form features on specific emotion attribution. We tested if combining abstract features into one dynamic form (2D blob; controlled by contour, symmetry, size, and rotation; see Figure 7), using isolation as a design principle, resulted in consistent affective attributions. We used a within subject design in which participants were presented with a series of 16 forms. The participants were asked to rate the associated emotional intensity on with each form using Shaver et al’s (1986) six semantic emotion categories. These forms were based on the outer 8 corners of the feature space and the points in feature space halfway the neutral point and those outer corners (as an example see figure 1, shape contour). A repeated MANOVA (Table 6a) and subsequent univariate analysis was performed (Table 6b) to analyze the effect of essential affective form features on emotion attribution. Results are promising for effects of individual features but also for combinations of features; in particular the combination contour and asymmetry seem to have specific influences on affect attribution (see Table 6). Our results indicate the feasibility of combining essential affective form features to trigger specific affective attributions (and hence use these combinations for the expression of affect).

Table 6a

*Significant results from repeated MANOVA on emotion categories. Table shows significant affective form features, interaction effects, and F-values. The '**' and '*' denote a significance of $p<0.005$ and $p<0.05$.*

Essential Feature	Emotion Categories (F)
Contour	30.54**
Asymmetry	16.26**

Size	10.86**
Contour · Asymmetry	17.38**
Contour · Size	3.63*

Table 6b

*The relationship we found between essential geometric features and rated intensity of specific target emotions. Table shows F-values, significance and their effect on emotion attribution. Where '**' and '*' denote a significance of p<0.005 and p<0.05, and '+' and '-' denote a positive and negative relation with respect to emotion attribution. For instance, in the case of contour a negative relation denotes a relation with angular contour, and a positive relation denotes a relation with rounded contour. The added 'Δ' denotes a specific structure: if shape contour features are increased, increased asymmetry lessens its effects on emotion attribution, i.e., the negative effect of asymmetry only impacts rounded contour features, but has no impact on angular contour features. The '○' denotes a specific structure as well: when asymmetrical, contour is not relevant, if symmetrical, then angular contour is sadder than rounded contour.*

Emotion Category	**Contour (round vs. angular)**	**Asymmetry**	**Size**	**Contour · Asymmetry**
Love	+129.68**	-75.54**		Δ63.22**
Joy	+177.85**	-36.47**	+23.94**	Δ34.03**
Surprise			+35.86**	
Anger	-127.47**		+11.52**	Δ4.73*
Sadness		+26.72**	-14.98**	○14.55**

Fear	-66.99**			Δ14.69**

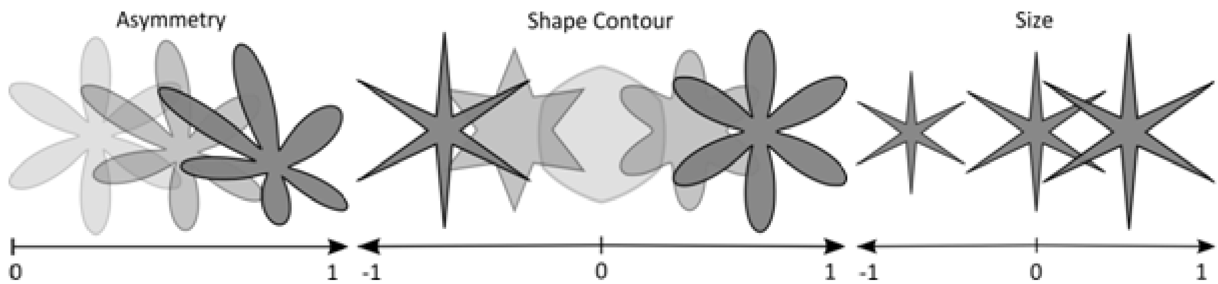

Figure 7. Examples of blob figures resulting from the manipulation of the three essential features contour, size and symmetry. Combinations of these features were used to test affect attributions. If asymmetry is not 0, the shape is randomly rotated on four rotation changes (0PI, 0.5PI, PI and 1.5PI).

Implications of abstract expressions of affect

To discuss how abstract affective expressions might impact the design of affective technologies we feel it is constructive to work out its possible implications using affective robotics as an example application field. Affective robots are artificial agents, usually of electro-mechanical design, that utilize affective behaviors to function in social environments, or at least be able to interact socially (Fong, 2003). An important aspect of the design of affective robots is the design of the channels with which they can convey an affective expression. These expressive capabilities can be utilized to facilitate natural and efficient non-verbal communication (Fong et al, 2003; Picard, 1997), induce an emphatic response in the human user (Picard, 1997; Takeuchia & Hada, 2006), and play a fundamental role in attaining believability for robotic devices (Rose et al, 2008). As we will show, the design approaches that are currently available to the affective robotics community pose a limitation to the applicability and acceptance of affective robots. The use of abstract expressions of affect, such as we develop in this paper, may pose a promising alternative to the current de facto approaches.

Designing expressions for affective robots

The design of an affective robot typically requires the integration of two different design objectives. First, design choices are made about the means by which the robot influences the user's emotional and social information processing. Second, affective robot design requires the integration of widely varying form factors relating to the intended function and technological possibilities of the robot. Such factors can be diverse, such as ergonomic, affordance, or cost effectiveness design requirements (Bartneck & Forlizzi, 2004; Hegel et al, 2009). A successful robotic design integrates the factors required for social and affective interaction with the factors that are relevant to optimally fulfill other, often more important, design requirements. However, the integration of these two objectives often conflicts on a morphological level. For instance, the human form easily facilitates synthetic affect expression, but is not likely to be cost effective, typically affords the things that are associated with another person, and is not likely to be too ergonomic, to name just a few. On the user end, there are also psychological considerations that may complicate the integration of affective with other design requirements. Note that little comparative experimental research has been done on design strategies for social robots (Broekens et al, 2009).

Currently, the de facto approaches in the design of robotic expressions are realism and iconism, often bolstered with animation techniques. We will use these approaches as a point of reference from which we will develop the hypothetical implications of the use of abstract expressions of affect for the design of affective robots.

Realistic expressions of affect

Realism aims to create a robotic morphology that resembles the human or animal body as close as possible. The philosophy is that proper realistic design entails proper affective and social interaction. The complexity and amount of elements needed for successful realistic design transcend implementation of the affective component alone, and requires mimicking the full human or animal embodiment. It has been hypothesized that an increasing amount of realism yields an increasing amount of positive and empathic responses from humans to realistic affective robots (Mori, 1997).

Mimicking people and animals draws heavily on familiarity (Guthrie, 1997), and therefore on the expectations people have of real humans and animals (Duffy, 2003; Fong et al, 2003). This has important consequences for the attitude the user forms about the realistically designed robot. First, the attitude of a user towards a robot is in part informed by a sort of trust relationship informed by the expectations about the robot (Duffy, 2008). So, when such expectations are not met, the illusion is broken, which is detrimental to the attitude of the user towards the robot. Second, people are very well tuned to detect abnormalities in other people, and respond negatively if abnormalities are detected. This response is similar to realistically designed robots and becomes particularly relevant when a robot approaches full realism (e.g. when the tone of the skin is just off someone looks sick or dead). This is particularly true for imbalances in realisms among different modalities (e.g. a realistic physical appearance combined with unrealistic movement lead to the association that something is wrong with that person/ robot). Furthermore, when technological artifacts surface this may be seen as looking unnatural (e.g. a cyborg) or painful (e.g. metal breaking through the skin). Such issues constitute the uncanny valley (MacDorman et al, 2009; Mori, 1997; Vinayagamoorthy et al, 2005), and highlight some of the psychological complexities that need to be addressed with realism.

These psychological complexities also make it difficult, if not impossible, to integrate other design requirements than those posed by the production of affective expressions, simply because realism does not permit another form (e.g. cost effectiveness, ergonomics, functional requirements) than the human form. This limits the use of such devices to situations in which users would naturally expect a human, and can draw on their previous experiences (and perceived affordances) of a human being in that situation (e.g. a receptionist or a dentist's patient). As such, the use of realistic design is intolerant with respect to the technological nature of robots on both a psychological and a design level, while it can be powerful in some situations where one normally interacts with a human being.

Iconic expressions of affect

The iconic design strategy increases the level of abstraction relative to realism. The bodily features used in affective interaction are isolated and exaggerated (Blow et al, 2006; Mead & Mataric, 2010; van Breemen, 2004). The advantage is that affective expressions can be conveyed, without being subjected to the full complexity of realistic mimicry (Duffy, 2008).

The expectations of a user are determined by how the robot looks and acts and to a lesser extent by preformed expectations (Duffy, 2008), a restriction well exploited in character animation (Thomas & Johnston, 1995). As such, expectations are constructed through interaction and observation of the robot's behavior (Duffy, 2008). The detrimental effects described in the uncanny valley theory decrease when the level of abstraction is increased. The advantage of this approach is that when the level of abstraction increases, the integration of non-anthropomorphic features (see for instance van Breemen et al, 2005) or the visibility of technology (see for instance Breazeal, 2002), is increasingly tolerable from a psychological perspective. For instance, the iCat merges appearances of a child and a cat to manage expectations and affordances about the robot's abilities (van Breemen et al, 2005). This is acceptable in an iconic design, but unlikely to be acceptable in a realistic design. Therefore, iconic design of affective expression does not suffer as strongly from psychological complexities as realistic design.

Because the psychological complexities associated with iconic design are more manageable, the iconic designed robot is more tolerant to its inherent technological and applied nature, which benefits the freedom with which the designer can integrates affective expressions with other morphological design requirements. There is however, still one major limitation to iconic expressions. This is simply because iconic design is dependent on the replication of the configuration of the human face and body to convey an expression. In other words, the mouth, eyes, and eyebrows with which an expression is synthesized, must not only be reproduced in some form, they must also be placed such that they acceptably resemble the way they are placed in a real human or animal face and body. Indeed, there are many examples of robotic application areas (e.g. the famous dull, dirty, and dangerous applications) where it is not desirable to mount a face on the device, or to shape the device after the human or animal body, but it could be beneficial to be able to integrate efficient and intuitive affective communication though an expressive channel.

Animation Techniques for synthetic expressions

Character animation is an (applied) art form that is traditionally engaged with techniques to design and stage objects' movements, actions and to some extent appearance such that the animated character is life-like and believable as a (social) actor. Character animation techniques are typically used as a means to attain a suspension of disbelief through which a character is staged and remains believable as a (social) actor even though there cannot be a realistic real-world counterpart. Animators have spent a great deal on uncovering features that enable the recognition of social cues and emotion expressions, but also to present them naturally, clearly and in a compelling way. Design tools and guidelines developed by animators take into account the spectator's perception, and include a wide variety of means to (realistically) convey movement and dynamic patterns after the laws of physics, and after patterns of (social) interaction and behavior, and but also issues related to character appeal, e.g., tricks to make a character likeable or dislikeable such as a baby-face or thick eyebrows, and how to present these signals clearly (Lasseter, 1987; Thomas & Johnston, 1995). See Thomas & Johnston (1995) and Lasseter (1987) for a good overview on animation principles.

Although developed for animation, these techniques are often used in the design of affective robots. Animation techniques can be used to complement iconic design (Breazeal, 2002; Breazeal & Wistort, 2009; Scheeff et al, 2000), and to a lesser extent realistic design techniques. Specifically design tools from animation to present movement and dynamics clearly and naturally can be used to improve the quality of emotion expressions. Also knowledge on the time course and timing of expressions and actions can complement research from psychology, and are thus valuable for the design of robotic expressions (Breazeal, 2002). Though animation proves useful in affective robotics, animation and robotics are not the same media, therefore animation techniques are often retested for implementation and reformulated to fit the medium of robotics (Breazeal, 2002; Breazeal et al, 2003; Breazeal & Wistort, 2009; Hoffman, 2010; Maed & Mataric, 2010; Scheeff et al, 2000; Takayama et al, 2011).

Animation techniques have also been used to endow non-anthropomorphic or non-zoomorphic designs with affective capabilities. Pixar's mascot Luxo Jr. is an interesting borderline example of this approach (for a description and imagery, see Lasseter 1987). Luxo Jr.'s morphology is that of a prototypical desk-lamp which is clearly a technological artifact designed after the cost effective and functional requirements of a lamp. Animation techniques are utilized in such a way that Luxo Jr. becomes an animate, expressive, and compelling character. Animation techniques stage Luxo Jr.'s expressive movements (kinematics, dynamics, direction) and actions clearly and realistic. Additionally, a desk lamp of Luxo Jr.'s design easily translates to the human body (e.g. the cap is used metaphorically as a head) which adds expressive posture based on configuration features to the used kinematics and dynamics for emotion expression, which overall is a very limiting factor in introducing widely varying form factors in a design.

Although clearly a technological object, it's clear reference to the configuration of the human body and realistic (though exaggerated) expressive movements and behaviors create such a strong reference to anthropomorphism that one could argue that Luxo Jr.'s design is actually an anthropomorphic design introducing realism (or sometimes even hyper realism) on movement and behavioral features, and very high abstraction on human form features and there configuration, hence mimicking the human body in a visually metaphoric way. As such its clever design and the use of animation techniques create a strong suspension of disbelief concerning the sociability of the character.

Therefore, animation techniques may in some cases, that realism and iconism may not cover, help to integrate synthetic emotion expressions with morphological design requirements other than those posed by synthetic affective expressions. However, a case can be made that this is in fact a clever way of increasing levels of realism or iconism to the modalities where there is little need for other requirements (in the case of Luxo Jr. this would be movement), and removing or abstracting affective expressive features where other design requirements are integrated (in the case of Luxo Jr. this would be the body of the lamp). However, it is expected that not all robotic devices can offer a full modality (e.g. movement or form) that can sufficiently accommodate the restrictions posed by realism or iconism, or the requirements of animation techniques themselves. Indeed, as described in the chapters on abstraction, affect, and the presented design guidelines (summary), we feel that the integration of affective expressions can be attained at an even higher level of abstraction, using even more minimal requirements.

Abstract expression of affect

Then how can abstract expression of affect benefit an affective technology such as the robot? The design of abstract expressions of affect such as we develop in this paper focuses on how to apply emotion expression in its cleanest form, such that the technological requirements of a technological artifact are minimally compromised. The core idea is that if we maximize the detachment from the human form, while retaining minimal recognizable affect, this satisfies both the requirements of people for affective interaction, and provides a maximum of freedom with respect to the technological requirements of robots as a species.

The novelty of our approach lies the fact that it is grounded in how abstraction plays a role in perception, and how this connects to the recognition and attribution of emotions, independent of the configuration of the human and animal body and face. This perspective allows for an approach that is purely feature based; using essential features from emotion attribution and recognition, and operations on these features which affect their presentation in terms of the discovery of, formation of, and attribution to essential affective features features to designs based on the abstract affective design approach. Using affective features, while explicitly omitting configuration features, provides significantly more freedom to integrate emotion expressions with widely varying form factors such as functional, ergonomic or other product design paradigms, which traditionally require a very different type of behavior and morphology than human behavior and form. Design principles taken from abstract art fit the feature based approach and provide a design process and specific design tools.

The promise is that abstract affective expressions can ensure that essential affective features are attention grabbing, that features are interpreted emotionally as intended, and finally that there are guidelines and restrictions on how to place such features for successful affective design. As such, we argue that constructively combining results from the science behind abstract art, affect attribution and various schools of robot design can contribute to our aims. See chapters on abstraction and on affect for a review on related theories and data, and the chapter on designing abstract abstractions of affect for a summary of the found features and design principles, which can be used for further explorations into the design of abstract affective expressions for robotic media.

Based on the presented theoretical work we argue that the design of abstract expressions of affect is a novel field of research in the design of synthetic emotion expressions. Abstract expressions differ from realism in the fact that it is focused on reproducing only the minimal, instead of the equal, necessary to convey emotion expressions. The role of abstraction in the design approach we develop here is shared partly with iconism (see for instance the sections on isolation and exaggeration in the chapter on abstraction). However, the explicit omission of using configuration features separates abstract affective design from realism and iconism at a fundamental level. This fundamental difference is highlighted by the following findings. First, the knowledge on the features involved, the conditions under which they can be recognized as affective, and how to combine these features such that emotions can be targeted, has proven consistent in some cases, but also requires substantial further investigation (e.g. this requires a partly novel vocabulary for affective expressions). Second, the design process is purely feature based, which in itself is different from realism and limited in iconism, which focus on mimicry. Third, configuration features are a restricting factor in affective robot design. This makes our purely feature based approach especially useful in situations where configuration features will complicate the design of a robotic device.

The difference with animation techniques is less apparent. Abstract expressions of affect and animation techniques share the perception-based nature of design principles involved. Hence there is overlap in the design principles advocated in our review, for instance the feature based approach used in the design of abstract expressions of affect is also found in animation, which also utilizes design tools to present features clearly (e.g. staging and exaggeration principles, but also change-up, which relates directly to our contrast between features). This is historically obvious as well because both are drawn from strongly related art forms. Additionally, there is a lot of knowledge on the kinematics and dynamics of expressive movement uncovered by animators over the years, such knowledge may complement the design of abstract expressions of affect. However, principles to convey biological movements and actions realistically and character design are explicitly not taken into account in the design of abstract expressions of affect. Abstract affective expressions for instance explicitly do not deal with perceived animacy, personality, or character appeal. In principle the goal is to circumvent or overrule the use of features related to such attributions, which are central to animation principles used for affective robot design. Therefore, the main difference between the design of abstract expressions of affect and animation is its focus on minimal requirements for perceiving emotion expressions and the integration of these expressions with other widely varying morphological requirements as freely as possible. In that sense one could frame abstract affective design as a sub-set of animation or as a separate approach which has some overlap with animation, either way we feel this does not contribute too much to the discussion here because their aims differ. Animation is focused on character design, whereas the abstract expression of affect is focused on the generation of recognizable affective expressions constrained by other morphological design requirements.

Although not a robot, an interesting example that served as a source of inspiration for the concept of abstract expressions of affect is the sensual evaluation instrument (SEI) (Isbister et al, 2006; 2007; Laaksolahti et al, 2009). The SEI is a set of simple objects that involve basic form features including variations in shape contour, asymmetry and the amount of features present, but no apparent configuration features. These objects were successfully utilized by people to convey emotional states with just these objects. We argue that these provide a very different approach to equipping non-anthropomorphic and non-zoomorphic designs with affective expressive qualities as compared to the approach based on animation principles in for example Luxo Jr. This illustrates the differences with animation principles and highlights the novelty of the design approach we advocate here.

Such a turnaround in design strategies not only has implications from a design theoretical perspective, but also impacts how people shape their attitude towards affective technologies (such as robots), and has implications for the extent to which the technological nature of robots integrates with the goal of emotionally expressive machines.

We hypothesize that abstract affective design can benefit a user’s attitude towards a robot. First, expectations are shaped in line with the technological nature of the robot. As such, expressing affect without resemblance to the human form is not expected to suffer from issues related to the uncanny valley. Therefore, both issues and advantages that arise due to familiarity do not play a role in shaping the user's attitude towards the robot. On the other hand abstract design may already fit the expectations of technological artifacts better because of its apparent simplicity and detachment from the human configuration. Therefore, there is little illusion. Second, because of its simplicity inconsistencies with preformed expectations do not play a negative role because we under-attribute the robot's affective capabilities. In other words, we do not instantaneously expect affective interaction from very simple or technologically looking artifacts, and this may even come as a pleasant surprise. As such, we hypothesize that expectations of the robot are shaped through observation of its behavior and interaction. Which benefits the attitude of user's towards the robot in terms of believability and acceptance.

The detachment from the human form and additional level of abstraction allows more freedom in developing robots with respect to its inherently applied and technological nature. The structure of visual emotion recognition does pose its limitations; these are however of a more flexible and, with respect to the user´s attitude, forgiving nature compared to the de facto standard in affective robot design. Therefore, we hypothesize that abstract expressions of affect can enable the construction of machines that are less restricted by affordances and perceived affordances of the human form. Instead, this allows more flexibility to match the intended function of a robot to its perceived affordance in a way that matches the general product and machine design paradigms. As such we envision that abstract affective expressions can enable the construction of robots with a whole new range of affordances, which can still benefit from intuitive affective interaction.

The major implication of the design of abstract expressions of affect is the potential integration of affect expressions with the inherent technological nature of robots. Within the context of abstract design balancing form and function takes on a very literal meaning. Essential affective features pose limitations at the level of for example kinematics and shape contour, which is oftentimes the same level of abstraction at which the mechanical functionality of robots is designed. The independence of the human form provides more flexibility in such construction. Therefore, essential affective features can be woven through the construction of a robot. As such, balancing form and function becomes finding a balance between features that are needed for performing a function well, and the emotional interpretation of these features. This transposes the affective requirements posed by the human brain, and technological requirements of robots as a species (such as its function) to the same level of abstraction. Therefore, the development of abstract affective expressions may be the first step towards the actual integration of affect with the functional-technological aspects of robot design.

It is clear that robots as a technological species have very different requirements than human beings. This can be because of the functions we intend for robots to perform, or to create robotic autonomy, with genuine robot affect. It is clear that such purpose requires a morphology that is very different from the human or animal form, and is always restricted by the current state of technology. Following the proposed implications of our approach we hypothesize that the development of abstract expressions of affect is a step towards bridging the requirements of people for affective interaction, and the specific requirements of robotics as a species. Therefore, we envision that abstract expressions of affect can help create genuine robotic expressions of their own kind, that are still intuitively understandable to people.

Conclusion and Future Challenges

In this paper we reviewed and unified knowledge from the science behind abstract art and affect attribution research. This paper aims to constructively bring these fields together within the context of the design of synthetic expression for affective technologies, in order to provide a pragmatic and scientific basis for the proposed design approach. Furthermore, we have presented a pilot study that shows consistent emotion attribution to combined form features, and we discussed the potential implications of the design of abstract affective expressions within an example application field (affective robotics). The developed work proposes an approach of minimal design for affect attribution, which should lead to a maximal freedom in integrating intuitively understandable affect with other morphological design requirements (e.g. functional, ergonomic or product design approaches). On the basis of this work we envision that we and other people can build further to expand ideas surrounding the design of abstract expressions of affect, such that it can develop into a usable novel alternative for the design of affective technologies. However, since this paper is a first step into that direction, our reviews show that there are some important open questions that are fundamental for the success of abstract expression of affect as a design method for affective technologies.

These future challenges include fundamental questions regarding the development of abstract affective expressions for affective technologies. First, abstract affective expressions require a partially novel vocabulary for emotion expressions. Our review on affect attribution shows that although many the basic features involved in emotion attribution are known, how to combine affective feature to target specific emotions is less known, especially with respect to form features and multimodal combinations. We have presented preliminary results showing that the combination of features could be used for specific affective expressions. What is clear though is that interactions can be expected between features, which must be taken into account, and further researched. Furthermore, it is currently unknown what range of emotions can be targeted when we structurally omit the use of configuration features. Second, on the note of man-machine relations we have hypothesized that an abstract design approach to synthetic affect expression liberates affective technology from the (perceived) affordances of the human and animal form, positively impacts the way people construct their attitude towards such a technology, and is a first step towards the integration of affect with the inherent technological nature of such devices. Whether these three hypotheses will hold is the subject of further research.

References

Arnheim, R. (1974/1997). *Art and visual perception: a psychology of the creative eye – the new edition*. Berkeley, CA: University of California Press.

Aronoff, J. (2006). How we recognize angry and happy emotions in people, places and things. *Cross-cultural research, 40*(1), 83-105.

Aronoff, J., Barclay, A. M., & Stevenson, L. A. (1988). The recognition of threatening facial stimuli. *Journal of personality and social psychology, 54*, 647-655.

Aronoff, J., Woike, B. A., & Hyman, L. M. (1992). Which are the stimuli in facial displays of anger and happiness? Configural bases of emotion recognition. *Journal of personality and social psychology, 62*(6), 1050-1066.

Atkinson, A. P., Tunstall, M. L., & Dittrich, W. H. (2007). Evidence for distinct contributions of form and motion information to the recognition of emotions from body gestures. *Cognition, 10*, 59-72.

Atkinson, A. P., & Adolphs, R. (2005). Visual emotion perception: mechanisms and processes. In: Feldman Barrett L., Niedenthal, P. M., & Winkielman, P. (eds.), *Emotion and consciousness*. New York, NY: The Guilford Press.

Barsalou, L. W. (2003). Abstraction in perceptual symbol systems. *Philosophical transactions of the royal society of London: biological sciences, 358*, 1177-1187.

Bassili, J. N. (1978). Facial motion in the perception of faces and emotional expression. *Journal of experimental psychology: human perception and performance, 4*, 373-379.

Bar, M., & Neta, M. (2006). Humans prefer curved visual objects. *Psychological science, 17*(8), 645-648.

Bar, M., & Neta, M. (2007). Visual elements of subjective preference modulate amygdale activation. *Neuropsychologia, 45*, 2191-2200.

Bartneck, C., & Forlizzi, J. (2004). A Design-Centred Framework for Social Human-Robot Interaction. In *13th IEEE international workshop on robot and human interactive communication (ROMAN 2004)* (pp 591-594).

Bedyne, D.E., Craw, M., Salapatek, P., & Lewis, J. (1963). Novelty, complexity, incongruity, extrinsic motivation and the GSR. *Journal of experimental Psychology, 66*, 560-567.

Breazeal, C.L. (2002). *Designing sociable robots*. Cambridge, MA: MIT Press.

Breazeal, C., Brooks, A., Gray, J., Hancher, M., McBean, J., Stiehl, D., & Strickon, J. (2003). Interactive robot theatre. *Communications of the ACM - A game experience in every application, 46*(7), 76-85.

Broekens, J., Heerink, M., & Rosendal, H. (2009). Assistive social robots in elderly care: a review. *Gerontechnology, 8*(2), 94-103.

Cañamero, L. (2005). Emotion understanding from the perspective of autonomous robots research. *Neural Networks, 18*, 445-455.

Clark, M. S., & Brissette, I. (2009). Two types of relationship closeness and their influence on people's emotional lives. In Davidson, R. J., Scherer, K. R., & Goldsmith, H. H. (Eds.), *Handbook of affective sciences* (pp 824-835). New York, NY: Oxford University Press.

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature reviews: Neuroscience, 3*, 201-215.

Collier, G. L. (1996). Affective synesthesia: extracting emotion space from simple perceptual stimuli. *Motivation and emotion, 20*(1), 1-32.

Damasio, A. R. (1994). *Descartes' error - emotion, reason and the human brain.* New York, NY: Putnam.

Dautenhahn, K., Werry, I., Rae, J., Dickerson, P., Stribling, P., & Ogden, B. (2002). Robotic playmates: analysing interactive competencies of children with autism playing with a mobile robot. In Dautenhahn, K., Bond, A., Canamero, L., & Edmonds, B. (Eds.), *Socially intelligent* *agents: creating relationships with computers and robots* (pp 117-124). Dordrecht: Kluwer Academic Publishers.

Davidson, R. J., Scherer, K. R., & Goldsmith, H. H. (Eds.) (2009). *Handbook of affective sciences*. New York, NY: Oxford University Press.

de Gelder, B., Vroomen, J., Pourtois, G., & Weiskrantz, L. (1999). Non-conscious recognition of affect in the absence of striate cortex. *Neuroreport, 10*, 3759-3763.

de Meijer, M. (1989). The contribution of general features of body movement to the attribution of emotions. *Journal of nonverbal behavior, 13*(4), 247-268.

Di Dio, C., & Gallese, V. (2009). Neuroaesthetics: a review. *Current opinion in neurobiology, 19*(6), 682-687.

Dittrich, W., & Lea, S. (1994). Visual perception of intentional motion. *Perception, 23*, 253-268.

Duchenne de Boulogne, G. B., & Cuthbertson, R. A. (1990). *The mechanism of human facial expression*. New York, NY: Cambridge University Press. Reprint of the original 1862 dissertation.

Duffy, B. R. (2003). Anthropomorphism and the social robot. *Robotics and autonomous systems, 42*, 177-190.

Duffy, B. R. (2008). Fundamental issues in affective intelligent social machines. *The open artificial intelligence journal, 2*, 21-34.

Ekman, P. (1993) Facial expression and emotion. *American Psychologist, 48*(4), 384-392.

Ellis, L. (1994). The high and mighty among man and beast: how universal is the relationship between height (or body size) and social status?. In: Ellis, L. (ed.), *Social stratification and socioeconomic inequality: reproductive and interpersonal aspects of dominance and status Vol. 2* (pp 93-111). Westport, CT: Praeger.

Fagerberg, P., Ståhl, A., & Höök, K. (2003). Designing gestures for affective input: an analysis of shape, effort and valence. In *MUM 2003* (pp 57-65).

Fischer, A. H., & Manstead, A. S. R. (2008). Social functions of Emotion. In Lewis, M., Haviland-Jones, J. M., & Feldman Barrett, L. (Eds.), *Handbook of emotions - third edition* (pp 456-468). Ney York, NY: The Guilford Press

Freedberg, D., & Gallese, V. (2007). Motion, emotion and empathy in esthetic experience. *Trends in cognitive sciences, 11*(5), 197-203.

Fong, T., Nourbakhsh, I., & Dautenhahn, K. (2003). A survey of socially interactive robots. *Robotics and autonomous Systems, 42*, 143-166.

Goldstone, R. L., Barsalou, L. W. (1998). Reuniting perception and conception. *Cognition, 65*, 231-262.

Gombrich, E. (1960*). Art and illusion: a study in the psychology of pictorial representation*. New York, NY: Phaidon press.

Guthrie, S. E. (1997). Anthropomorphism: a definition and a theory. In Mitchell, R. W., Thompson, N. S., & Miles, H. L. (Eds.), *Anthropomorhism, anecdotes, and animals*. New York, NY: State University of New York Press.

Hampton, J. A. (2003). Abstraction and context in concept representation. *Philosophical transactions of the royal society of London: biological sciences, 358*, 1251-1259.

Hegel, F., Lohse, M., & Wrede, B. (2009). Effects of visual appearance on the attribution of applications in social robotics. In *The 18th IEEE international symposium on robot human interactive communication (ROMAN 2009)* (pp 64-71).

Heider, F., & Simmel, M. (1944). An experimental study of apparent behavior. *American journal of psychology, 57*, 243-259.

Hoffman, G. (2010). Anticipation in human-robot interaction. In *2010 AAAI Spring Symposium Series*.

Hoffman, M. L. (2008). Empathy and prosocial behavior. In Lewis, M., Haviland-Jones, J. M., & Feldman Barrett, L. (Eds.), *Handbook of emotions - third edition* (pp 440-455). New York, NY: The Guilford Press.

Isbister, K., Höök, K., Laaksolahti, J., & Sharp, M. (2007). The sensual evaluation instrument: developing a trans-cultural self-report measure of affect. *International journal of human-computer Studies, 65*, 315-328.

Isbister, K., Höök, K., Laaksolahti, J., & Sharp, M. (2006). The sensual evaluation instrument: developing an affective evaluation tool. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp 1163-1172).

Izard, C. E. (2009). Emotion theory and research: highlights, unanswered questions, and emerging issues. *Annual review of psychology, 60*, 1-25.

Kandinsky, W. (1923). *Composition VIII.* Retrieved 2 march, 2013, from http://www.guggenheim.org/new-york/collections/collection-online/show-full/piece/?object=37.262&search=&page=&f=Title

Kandinsky, W. (1926). *Point and line to plane*. New York, NY: Dover Publications.

Kennedy, J. M. (2008). Metaphor and art. In Gibbs, E. R. (Eds.), *The Cambridge handbook of metaphor and thought*. New York, NY: Cambridge University Press

Köhler, W. (1929). *Gestalt Psychology*. New York, NY: Liveright.

Laaksolahti, J., Isbister, K., & Höök, K. (2009). Using the sensual evaluation instrument. *Digital creativity, 20*(3), 165-175.

Lakoff, G. (2008). The neural theory of metaphor. In Gibbs, E. R. (Eds.), *The Cambridge handbook of metaphor and thought*. New York, NY: Cambridge University Press.

Landau, M. J., Meier, B. P., & Keefer, L. A. (2010). A metaphor-enriched social cognition. *Psychological bulletin, 136*(6), 1045-1067.

Larson, C., Aronoff, .J, Sarinopoulos, I., & Zhu, D. (2008) Recognizing threat: a simple geometric shape activates neural circuitry for threat detection. *Journal of cognitive neuroscience, 21*(8), 1523-1535.

Larson, C., Aronoff, J., & Stearns, J. (2007). The shape of threat: simple geometric forms evoke rapid and sustained capture of attention. *Emotion, 7*(3), 526-534.

Lasseter, J. (1987). Principles of traditional animation applied to 3d computer animation. Computer Graphics, 21(4), 35-44.

LeDoux, J. E. (1998). *The emotional brain: The mysterious underpinnings of emotional life*. New York, NY: Simon and Schuster.

Lee, J. H., Jin-Yung, P., & Nam, T. J. (2007). Emotional interaction through physical movement. In *Proceedings of the 12th international conference on human-computer interaction: intelligent multimodal interaction environments* (pp 401–410).

Lewis, M., Haviland-Jones, J. M., & Feldman Barrett, L. (Eds.). *Handbook of emotions – third edition.* New York, NY: The Guilford Press.

Locher, P., & Nodine, C. (1989). The perceptual value of symmetry. *Computers & mathematics with applications, 17*(4-6), 475-484.

Lowen, A. (1971). *The language of the body*. New York, NY: Macmillan.

Lundqvist, D., Esteves, F., & Öhman, A. (2004). The face of wrath: the role of features and configurations in conveying social threat. *Cognition and emotion, 18*(2), 161-182.

MacDorman, K. F., Green, R. D., Ho, C., & Koch, C. T. (2009). Too real for comfort? Uncanny responses to computer generated faces. *Computers in human behavior, 25*, 695-710.

Malevich, K., & Wingler, H. M. (1927/1980). *Die gegenstandslose Welt.* Berlin: Mann.

Matisse, H. (1953). La Gerbe. Retrieved March 2, 2013, from http://www.henri-matisse.net/paintings/ex.html

Matsumoto, D., Keltner, D., Shiota, M. N., O'Sullivan, M., & Frank, M. (2008). Facial expressions of emotion. In Lewis, M., Haviland-Jones, J. M., Feldman Barrett, L. (Eds.), *Handbook of emotions – third edition* (pp 211-234). New York, NY: The Guilford Press.

Mead, R., & Mataric, M. J. (2010). Automated caricature of robot expressions in socially assistive human-robot interaction. In *The 5th ACM/IEEE international conference on human-robot interaction (HRI2010): workshop on what do collaborations with the arts have to say about HRI?.*

Mehrabian, A. (1980). *Basic dimensions for a general psychological theory*. New York, NY: OG&H Publishers.

Mondriaan, P., & Wingler, H. (1925/1998) *Neue gestaltung*. Berlin: Mann.

Mori, M. (1997). *The buddha in the robot*. Tokyo: Charles E Tuttle Co.

Oatley, K., & Yuill, N. (1985). Perception of personal and interpersonal action in a cartoon film. *British journal of social psychology, 24*, 115-124.

Ortony, A., Clore, G. L., & Collins, A. (1980). *The Cognitive Structure of Emotion*. New York, NY: Cambridge University Press.

Pavlova, M., Sokolov, A. A., & Sokolov, A. (2005). Perceived dynamics of static images enables emotional attribution. *Perception, 34*, 1107-1116.

Picard, R. (1997). *Affective Computing*. Cambridge, MA: MIT Press.

Pollick, F. E., Paterson, H. M., Bruderlin, A., & Sanford, A. J. (2001). Perceiving affect from arm movement. *Cognition, 82*(B), 51-61.

Pollock, J. (1950). *Number 18*. Retrieved March 2, 2013, from http://www.guggenheim.org/new-york/collections/collection-online/show-full/piece/?search=Number%2018&page=&f=Title&object=91.4046

Pessoa, L., & Adolphs, R. (2010). Emotion processing and the amygdala: from a 'low road' to 'many roads' of evaluating biological significance. *Nature reviews neuroscience, 11*, 773-782

Ramachandran, V. S., & Hirstein, W. (1999). The Science of Art: A Neurological Theory of Aesthetic Experience. *Journal of consciousness studies, 6*(6-7), 15-51.

Ramachandran, V. S., & Hubbard, E. M. (2001). Synaesthesia, A window into perception, thought and language. *Journal of consciousness studies, 8*(12), 3–34.

Ramachandran, V. S., & Hubbard, E. M. (2003). Hearing colors, tasting shapes. *Scientific American, April*, 52-59.

Reas, C. (2005). *Process 9*. Retrieved March 2, 2013, from http://reas.com/iperimage.php?id=0&section=works&work=p9_s

Reber, R., Schwarz, N., & Winkielman, P. (2004). Processing fluency and aesthetic pleasure: is beauty in the perceiver's processing experience?. *Personality and social psychology review, 8*(4), 364–382.

Rimé, B., Boulanger, B., Laubin, P., Richir, M., & Strookbants, K. (1985). The perception of interpersonal emotions originated by patterns of movement. *Motivation and emotion, 9*(3), 241-260.

Roether, C. L., Omlor, L., & Giese, M. A. (2009). Features in the recognition of emotions from dynamic bodily expression. In Masson, G. S., & Ilg, U. J. (Eds.), *Dynamics of visual motion processing: neuronal, behavioral, and computational approaches* (pp 313-340). New York, NY: Springer Verlag.

Rose, R., Scheutz, M., & Schermerhorn, P. (2008). Empirical investigations into the believability of robot affect. In *Proceedings of the AAAI spring symposium.*

Rothko, M. (1961). *Number 207 (red over dark blue on dark gray).* Retrieved March 2, 2013, from http://content.cdlib.org/ark:/13030/ft9v19p1ts/

Russel, J. A. (2003). Core affect and the psychological construction of emotion. *Psychological review, 110*(1), 145-172.

Saerbeck, M., & Bartneck, C. (2010). Attribution of affect to robot motion. In *Proceedings of the 5th ACM/IEEE international conference on human-robot interaction (HRI2010).*

Saerbeck, M., Schut, T., Bartneck, C., & Janse, M. D. (2010). Expressive robots in education – varying the degree of social supportive behavior of a robotic tutor. In *Proceedings of the 28th ACM conference on human factors in computing systems (CHI2010)* (pp 1613-1622).

Sawada, M., Suda, K., & Ishii, M. (2003). Expression of emotions in dance: relation between arm movement characteristics and emotion. *Perceptual and motor skills, 97*, 697-708.

Shaver, P., Schwartz, J., Kirson, D., & O'Connor, C. (1987). Emotion knowledge: further exploration of a prototype approach. *Journal of personal and social psychology, 52*(6), 1061-1086.

Scheeff, M., Pinto, J., Rahardja, K., Snibbe, S., & Tow, R. (2000) Experiences with sparky, a social robot. In *Proceedings of the 2000 workshop on interactive robotics and entertainment* (pp 143–150).

Scherer, K. R., Schorr, A., & Johnstone, T. (Eds.) (2001). *Appraisal processes in emotion: theory, methods, research.* New York, NY: Oxford University Press.

Scholl, B., & Tremoulet, P. (2000). Perceptual causality and animacy. *Trends in cognitive sciences, 4*, 299-309.

Schubert, T. W. (2005). Your highness: Vertical positions as perceptual symbols of power. *Journal of Personality and Social Psychology, 89*, 1-21.

Silvia, P., & Barona, C. (2009). Do people prefer curved objects? Angularity, expertise, and aesthetic preference. *Empirical studies of the arts, 27*(1), 25-42.

Snowden, R., Thompson, P., & Troscianko, T. (2006). *Basic vision.* New York, NY: Oxford University Press.

Takayama, L., Dooley, D., & Ju, W. (2011). Expressing thought: improving robot readability with animation principles. In *Proceedings of the 6th international conference on Human-robot interaction (HRI 2011).*

Takeuchia, Y., & Hada, T. (2006). Human prosocial response to emotive facial expression of interactive agent. In *The 15th IEEE international symposium on robot and human interactive communication (ROMAN 2006)* (pp 680-685).

Thomas, F., & Johnston, O. (1995). *The illusion of life: Disney animation.* New York, NY: Hyperion books.

van Breemen, A., Xue, Y., & Meerbeek, B. (2005). iCat: an animated user-interface robot with personality. In *Proceedings of the fourth international joint conference on autonomous agents and multiagent systems* (pp 143-144).

van Breemen, A. J. M. (2004). Bringing robots to life: applying principles of animation to robots. In *Proceedings of the CHI 2004 workshop on shaping human-robot interaction.*

van Campen, C. (1997). Early abstract art and experimental gestalt psychology. *Leonardo, 30*(2), 133-136.

van Doesburg, T. (1924/1969). *Principles of neo-plastic art.* New York, NY New York Graphic Society.

Vessel, E. A., & Rubin, N. (2010). Beauty and the beholder: highly individual taste for abstract, but not real-world images. *Journal for vision, 10*(2), 1-14.

Vinayagamoorthy, V., Steed, A., & Slater, M. (2005). Building characters: lessons drawn from virtual environments. In *Toward social mechanisms of android science: a cogsci 2005 workshop* (pp 119-126).

Visch, V. T., & Goudbeek, M. B. (2009). Emotion attribution to basic parametric static and dynamic stimuli. In *IEEE proceedings of affective computing* (pp 346-351).

Whitelaw, M. (2007). More is more: multiplicity and generative art. *The teeming void.* Retrieved June 7, 2010, from http://teemingvoid.blogspot.com/2007/10/more-is-more-multiplicity-and.html

Wistort, R., & Breazeal, C. (2009). TOFU: a socially expressive robot character for child interaction. In *Proceedings of the 8th International Conference on Interaction Design and Children (IDC 2009).*

Wolfe, J. M., Kluender, K. R., & Levi, D. M. (2005). *Sensation and perception*. Sunderland, MA: Sinauer Associates Inc.

Zeki, S., & Lamb, M. (1994). The neurology of kinetic art. *Brain, 117*, 607-636.

Zhao, L. (2001). *Synthesis and acquisition of Laban movement analysis qualitative parameters for communicative gestures*. Unpublished doctoral dissertation, University of Pennsylvania, Pennsylvania.

Zimmer, R. (2003). Abstraction in art with implications for perception. *Philosophical transactions of the royal society of London: biological sciences, 358*, 1285-1291.