Affective Objects

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Abstract

This paper will attempt to define a new area of research: affective communication through the use of *affective objects*. An *affective object* may be defined as any physical object which has the ability to sense emotional data from a person, map that information to an abstract form of expression and communicate that information expressively, either back to the subject herself or to another person. This paper will also propose a theory of how to utilize existing knowledge (i.e. how humans interpret the expressive qualities of modalities such as color, sound, and light) to inform the invention process.

1 Introduction

Communication technologies have traditionally emphasized the pragmatic. Telephony, videoconferencing and online dialoguing exemplify current options for transmitting information among conversational participants. The primary role of these systems is to send the intended communication in a format that resembles in-person communication as closely as possible. Upgrades and enhancements to these systems tend to focus on improving the existing algorithm (i.e., the latest-model videoconferencing set-ups have higher bandwidth and larger screens than earlier models).

Researchers have begun to explore alternative options for conversational mediation and augmentation [12, 24]. Particularly in the area of emotion communication, traditional methodologies are recognized to be deficient. It is becoming increasingly apparent that alternative methods of augmentation must be added in order to expand the "emotional bandwidth" in a mediated dialogue. For example, online chat systems and bulletin boards are proliferating with options for adding icons and other graphical representations to augment communicative content. Attempts have also been made to incorporate the use of physical objects in communication [16]. These new systems tend to map the emotion in conversation to some kind of nonverbal expression.

The form this mapping can take varies widely. Some builders follow the model of facial expressions and develop features that allow the user to add “smileys” or other facial information to text-based messages. Some give the user the ability to change the color of the text itself. Some have explored the use of physical objects, such as Brave et al's [9] InTouch system, which uses a dual-site rolling-pin device to communicate some aspects of touch. This research is important because it provides new options in emotion communication, but it is badly in need of a coherent theory for how to think about building objects that communicate emotion. Such a theory would require not only knowlege of the emotional response system, but should guide mappings in a way that is structural rather than arbitrary. The fields of sensory physiology and artistic technique are rich with guidelines to direct the builder of emotion-mediating technology in deriving mappings for the expressive qualities of a device.

2 Rationale

Initially, one might question the necessity of exploring novel forms of emotional communication. After all, human evolution has already made us exquisitely sensitive to the emotional nuances of language and nonverbal behavior. Not only do children begin to acquire language at a very early age, but they also gain the ability to interpret nonverbal cues. In fact, it is becoming apparent that children develop these capabilities even earlier than originally thought, and that the limitation for research is not their age, but in devising instruments to accurately assess the nonverbal abilities of very young children [5]. Birdwhistell [3] even suggests that over 80% of human communication is encoded in facial expression and body movements. This research might be interpreted as suggesting very little need for technologies to include alternate forms of nonverbal expression.

Thus, it is somewhat radical and counterintuitive to imagine building devices with emotion-expressing capability, because we don't really *need* them. This kind of thinking is similar to our ancestors deciding that they really didn't need to use the new technology of fire to cook food because eating raw food was perfectly nutritious. It is, and we could all survive on raw food adequately, but the now-available varieties of cooking provide variety, enjoyment, and entertainment, as well as a form of creative expression. To say that researchers should focus on building communication technologies that duplicate the human's innate mechanisms is inherently limiting. A leap of faith is necessary in order to view technology as contributing to the evolution of natural communication into augmented communication.

The ability to digitize and store information is the key factor that makes this leap possible. Digitization makes it easy to gather data from one kind of signal and almost instantaneously turn it into something else. Synesthesia, a rare but non-life-threatening neurological condition, is a good metaphor for this rechannelling of information. The synesthete has a neurological makeup that is different from non-synesthetes in that the part of the brain that processes sensory information does not interpret the boundaries that separate one kind of sense from another [11]. For example, most of us just hear sounds when we listen to music. A sound-vision synasthete might hear the musical tones, and simultaneously see colors, or shapes or some other kind of visual experience. The associations that any given synasthete has are always idiosyncratic -- two individuals may both associate colors with sounds, but they will probably not associate the same sounds with the same colors. This has inspired many synesthetes who are also artists to produce works that let the public "see" what they see. One famous example of this was Scriabin, whose master orchestral work "Prometheus" was originally written for both orchestra and a "light organ", which projected colors onto the auditorium wall at appropriate times during the music.

For years, artists have attempted, through various methodologies, to produce "synesthetic art". Recently, an entire volume of the art and technology journal *Leonardo* was devoted to this very topic [20]. Building these kinds of sensory translation systems was very difficult before the advent of digital technologies. The "Prometheus" light organ, for example, required a contraption made of pulleys, wires, candles, and transparent colored films connected to an augmented organ that projected the appropriate colors at the right times. With digital technology, the stream of numbers used to create a musical sample can be easily reprocessed in a graphical algorithm to produce colors. This ease and flow in the use of digital samples is what can make possible the augmentation of human communication. Instead of sensing information (through video, audio, haptic, or other means) and translating it verbatim, we can instead use the synesthete as a model, and process the signal into a different format.

3 A Model

Elam's [13] analysis of what happened in the art world with regard to painting in the mid-1800s may provide insight into how a sea change can influence the trajectory of a field of thought. Before photography was invented by Daguerre in 1830, much of the driving force behind painting styles was the development of techniques for realistic rendering of what the painter saw. Schools trained the artist in such techniques as perspective drawing, with the goal being the maximization of realism. The development of painting over several hundred years prior to the 20th century shows the increasing ability of artists to accuractly represent the real world. The idea of painting anything less representational was probably outside the ability of many individuals to imagine. When photography emerged, it broke an important barrier. It was now possible for someone to snap a photograph and make an exact copy of reality on the two-dimensional surface. A remarkable thing then happened to painting:

> *"…the invention of photography changed the way that artists approached their work. Photography diminished the need and desire for art to simulate reality in the visual recording of people, events and objects, and because photography was able to capture reality so well artists could not compete. Accordingly, the concept of recording reality shifted to interpreting reality. This new idea of translating the subject matter in art welcomed innovation and abstraction." [13]*

No longer constricted by the need to make paintings realistic, movements grew up that freed painters to start working abstractly and symbolically. While some artists continued striving toward perfect linear representation, others saw this as a chance to reconceive the direction of their work. Some of the first artists to do this included Picasso, Kandinsky and Miro. They inspired movements such as Cubism and Abstract Expressionism[35]. The art world entered an era of creativity and variety that was previously unimaginable, which in turn influenced the thinking of the world around it.

If we were to attempt a graphical interpretation of this phenomenon, it might look like Figure 1. The horizontal line represents perfect rendering, and the curved line represents the trajectory of painting. At the crucial time point in 1830, the previously diagonal slope of the line (demonstrating a gradually increasing profiency of artists at representing the three-dimensional world) begins to diverge from its course. The various bumps and downward trends post-1830 visualize the decreased realism of various schools of abstraction. Note that the curve representing the trajectory of painting in the figure is hypothetical, and the peaks and valleys do not correspond to any particular events in history.

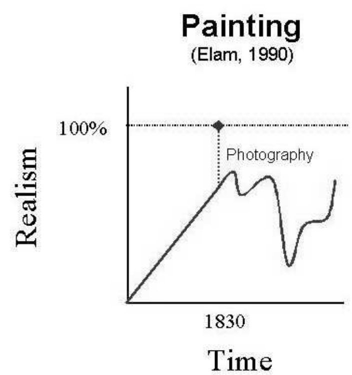


Figure 1: Realism Trajectory of Painting

What can communication technologists learn from this phenomenon as Elam describes it? If we think about what technologists have been doing with communicative devices, it is similar to the pre-1890's painters trying to depict reality on paper or canvas. The primary goal has been to make mediated communication as much like face-to-face exchange as possible. Phones get faster; videoconferencing equipment designers eke out more bandwidth for their systems. All of these efforts are built on the assumption that emulating face-to-face communication should be the ultimate goal of designers.

Instead, perhaps more designers should take a hint from the revolution in thought afforded by photography. In fact, the two situations have much in common. Both the pre-Daguerre painters and many current builders of communications technology suffer from a lack of perspective on their situation. For the painters, their field took a radical turn when 100% realism was attained. Communications technology is much farther from that 100% mark, but rather than waiting for that innovation to occur, we can already begin to explore alternative methods for communication.

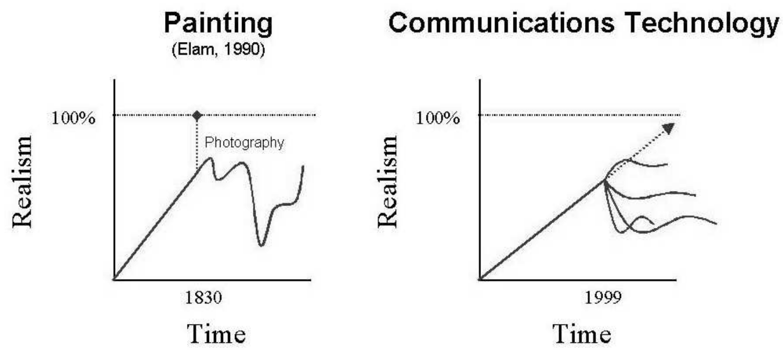


Figure 2: Realism Trajectory of Painting vs. Communications Technology

In the Communications Technology part of Figure 2, we thus see a similar horizontal line, where 100% communication would represent the equivalent of the invention of photography -- perhaps something like full-body holographic communication. The curved line differs, however. Since 100% realism is nowhere near being achieved, it is likely that communications research will continue in its current direction, probably becoming asymptotic sometime before it reaches that perfect mark. But according to the painting example, research concurrently could be diverging into the exploration of innovative and abstract forms of communication; many directions in parallel. Essentially, we can conceive of communications technology as headed in a similar direction as representational painting. However, instead of waiting for the critical event of perfect communication devices, view the technology as ready for divergent, multiple areas of exploration to exist concurrently. We suggest that one possible directions for this new kind of research is *affective objects*.

4 Building the affective object: sensing

The first issue in building an affective object is how to gain access to the affective content. This can be addressed in several ways.

One possible mechanism for sensing is physiological parameters generated by the autonomic nervous system. Caccioppo et al [10], and Bradley, et al [8] give good synopses of the parameters of the autonomic nervous system and how psychophysiological measures such as EMG, blood pressure and galvanic skin response react to different stimuli and behave during emotional episodes. While there is still much debate about emotion specificity to physiological parameters, states such as arousal are relatively robust within a single signal, such as the skin conductivity response. Physiological signals may be unobtrusively gathered by placing sensors into wearable devices, or merging them into objects we are in contact with every day, such as computer mice, keyboards, and furniture.

Another fertile area for emotion signals is the vocal response. Pittam and Scherer [27], and Murray and Arnott [22] describe several parameters that correspond to affect in voice. There many redundant cues that collapse into three important areas, namely: 1. utterance and silence lengths, 2. pitch contours, and 3. loudness. The vocal signal is easily captured by inexpensive microphones.

Facial expression is yet another input mechanism. Ekman [14], among others, describes categorical facial expressions and examines cross-cultural similarities. Cameras, though often controversial with regard to privacy issues, can be used to unobtrusively monitor facial expression and to track lips and eyes.

Lastly, though results are not shown in the literature yet, our laboratory is exploring hypotheses about how people's handling of objects – squeezing, holding, touching, etc. -- will prove to be fruitful information sources about arousal and tension levels.

5 Building the affective object: mapping

Old theories in psychology's history, though now antiquated, can provide insight into the mapping problem. Allport [1] describes two such theories: *physiognomy* and *graphology*. The two theories are somewhat similar – *physiognomy* refers to the study of the totality of someone's movement patterns – gait, posture, mannerisms, etc; *graphology* refers in particular to the study of handwriting analysis. At the time of Allport's writing, the belief was that one could analyze the behavior of a subject in these domains, and be able to discern personality features from their gestures or their writing. Particular movement patterns were hypothesized to correlate with appropriate personality features. For example, if "John" tends to move with quick and light gestures, one might conclude that he is conscientious and efficient. The theorists aligned with this school of thought tried to develop a coherent model of these correlations. Modern psychology no longer approaches the study of personality from this perspective. However, an important lesson may be learned from the mistakes made by the early physiognomic theorists. One of the problems with this research was that the theorists tried to perform subject-independent analysis. They attempted to discover universal cues that would differentiate personality or emotion across many subjects. This approach could not lead to satisfying data sets. However, if the subject's patterns are approached from an intra-individual perspective, it may in fact be be possible to ascribe meaning to fluctuations and changes.

Below is an example of my signature (figure 3). This is the way that I normally sign documents and write letters. Someone that I write notes or letters to regularly becomes accustomed to my handwriting looking like this, over a period of weeks and months.

Figure 3: Normal Signature

Perhaps one day, I write a note, and it looks like Figure 4 instead.

Figure 4: Altered Signature

The recipient (if it is someone who receives frequent correspondence from me) already knows something about the state I was in when I wrote it – namely, that something was different from the state I'm normally in when I write. The reader may have a few guesses. Perhaps I was in a hurry. Perhaps I have an injury and it was hard to write. Perhaps I was writing in a vehicle. Whatever it was, there was something different, and it might prompt the reader to ask me about it, even if the question was simply, "Your handwriting looks unusual. Why does it look different?" The same phenomenon would apply to my gait. If I were to walk slower, or in a different manner than usual, I might be asked if I am tired or depressed, or if I sprained my ankle. This ability to discern slight differences in a pattern is a hard-wired response in our brains. The human brain is prewired to pick out patterns and deviations from the environment [30]. Thus, a first principle for understanding how to design an object to be expressive might read as follows*: if we give an object any expressive ability, people will, over time, be able to naturally perceive differences*.

According to the theory I have just described, it follows that I should essentially be able to map the affective signal to just about anything, and because the brain is predisposed to perceiving changes, the communication of affect changes should be effective. This is likely true. However, as a second principle, we shall hypothesize that the easiest way to make mappings is if they are intuitive. For this reason, it is crucial to delve into the literature to explore both the ways that artists communicate emotion through different media, as well as to study psychological experiments that investigate how subjects respond to varying abstract stimuli. These areas can be remarkably parallel, and should concurrently inform the design process.

To aid the process of looking at this hypothesis, an "Abstract Expressive Space" can be constructed. Based on the dimensional model of emotion used by Schlossberg [31], and Lang, et al, [17], where the horizontal axis represents valence (positivity or negativity) and the vertical axis represents arousal (intensity), one can analyze many different expressive modalities, including body movement, sound, fabric texture, and others, in order to map them onto this model.

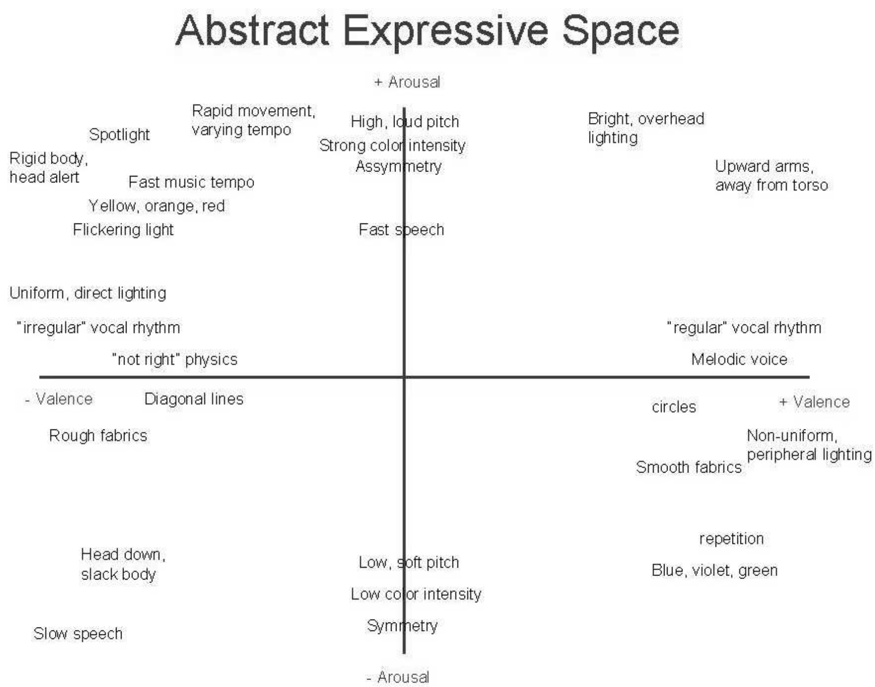


Figure 5: Abstract Expressive Space

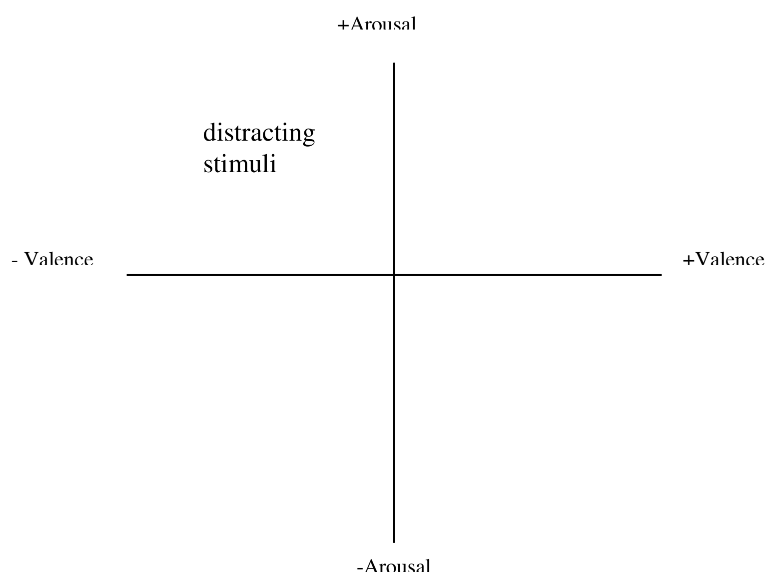
There are several important points to note about this figure. One is the richness of sources that helped to create the configuration of labels. Both experimental psychology and artistic technique references were consulted as sources of information [2,4,6,7,13,17,18,22,23,24,26,27,28,33,34]. Second is the apparent paucity of examples in the central area of the figure. This can be explained by the fact that while it was possible to infer from the sources which quadrant a given quality belonged to, the texts rarely indicated relative position within the quadrant. Additionally, the authors tended to highlight polar opposites (i.e, the strongest examples of any given modality) as descriptive examples. For example, when Boyce [7] describes lighting conditions, he contrasts the valence of flickering light vs. uniform/peripheral light, but makes little mention of the arousal dimension (of course, he was not trying to place light qualities on a two-dimensional model). It is thus up to the model-maker to make best-guesses as to where the modality being described fits into the multi-dimensional space.

Lastly, it is important to realize that there are some expressive modalities that do not lend themselves to being characterized in such a way. For example, while it is straightforward to place musical variables such as high vs. low pitch into the figure, it is not possible to put more complicated musical structure into such a constrained model. According to any analysis of emotion in music (for example, Juslin [18], Meyer [21], and Rowe [27]), the relative comparisons made are complex enough to prohibit their being broken down in such a graphical, two-dimensional manner. This suggests that while the model may be useful in guiding a theory of nonverbal expression in many simple domains, it may yet be too simplified for expressive devices that use a complex modality such as musical themes or songs.

The construction of such a figure, as mentioned, is an exercise in interpretation. Again, the authors of the sources which provided examples for the figure were not thinking along the same dimensions as I was, so it is necessary to *interpret* their remarks about the emotionality of expressive modalities in order to place them in a logical place on the figure. This process involved several different methods of interpretation, depending on how the original source conceptualized the specific modality. The next section details the process of extracting such principles from various references.

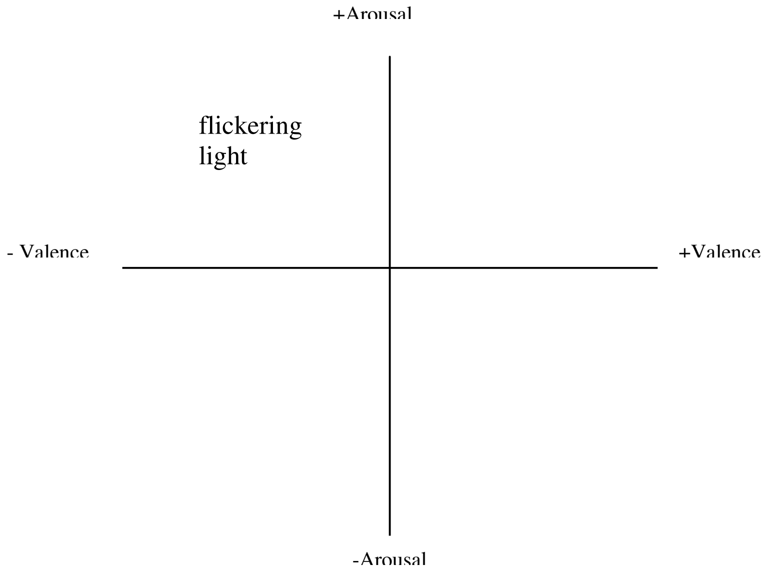
5.1 Lighting Effects

Boyce's [7] reference on human factors in lighting, especially lighting of the work environment, is written as a guide for ergonomics professionals attempting to create optimal work conditions. One of the themes that he repeats often in the book is the concept of distraction, especially the idea that "any event that deviates from the status quo atmosphere is distracting and may inhibit performance." Additionally, he suggests that the relationship is positively correlated – the greater the change in the environment the more distracting it is likely to be. From this, we can infer that the best way to create a calming environment is to avoid distraction. Since we know Boyce is referring to the kind of distraction that connotes negative arousal, this suggests a relationship between distracting stimuli and a position in the upper left quadrant of the Abstract Expression Space.



However, this is not quite concrete enough for the goal of the original figure – what we are aiming for is specific recommendations in the lighting domain, and while this information about distraction is valuable, it would be better to have a more precise recommendation.

Boyce later gives a good example of a concrete recommendation in his discussion of flickering light. Flickering light is distracting, and distracting is often negative. This can be further qualified by looking at the nature of the flicker. If the flicker is constant and unchanging over a period of time, its effectiveness as a distractor decreases over time due to habituation. If the flicker is variable, however, the distraction level remains stable and studies show that subjects' performance decreases over time in the presence of the uneven flickering light. This is probably why the constant flashing light in a discotheque is tolerable, or even exciting to many, but an irregular flicker in one's desk lamp while trying to work is annoying.



This now looks like the recommendation from the original full figure above. We could classify this even further to suggest that uneven flickering light is even more negative and arousing over time. This component is somewhat difficult to show in a two-dimensional figure, but if at some point we added a third dimension to explore time's effect on the modality, we would be able to show the difference between the two modes of flickering light.

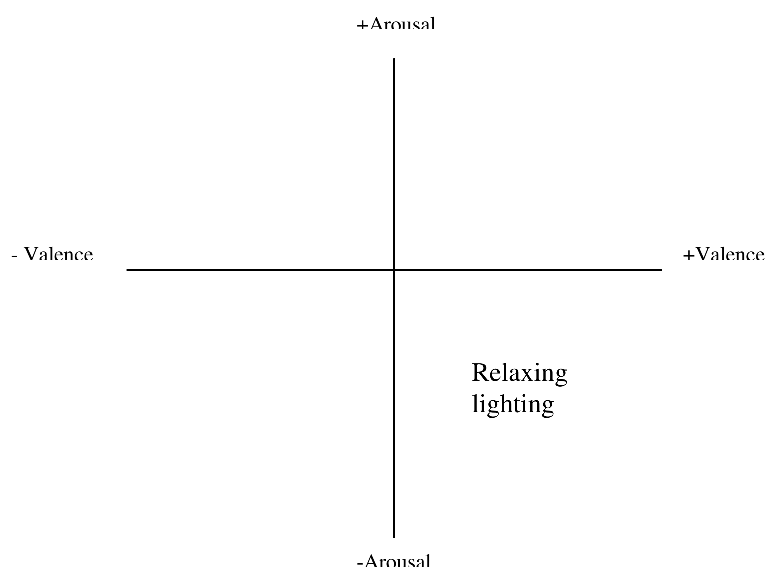
It is important to remember that this is a broad generalization of what people find to be distracting, and also an asssumption that distraction is negative. There are instances when distraction can be pleasant, or at least desired, such as the "MTV" style of film editing where scene cuts occur every second or less. This kind of distraction can be energizing to some, with a positive valence. The projection onto the figure would then look very different, with the distracting stimulus appearing in the upper right quadrant rather than the upper left. Distraction is thus almost always high in arousal, but the valence will vary depending on personal and situational variables. The reader is asked to consider the *method of projection* onto the figure rather than simply accepting these few concrete examples as absolutes.

Boyce also includes a table [p. 319] that details the summary of his findings on room lighting cues and subject's impressions of quality:

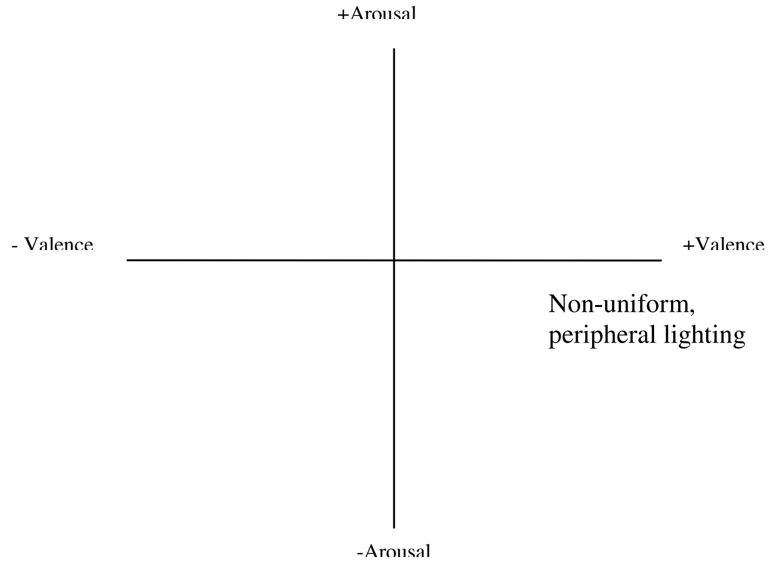
Table 6.2: Lighting cues for subjective impressions

Subjective impression	Lighting Cues
Impression of perceptual clarity	Bright, uniform lighting; Some peripheral emphasis, such as with Reflectance walls or wall lighting
Impression of spaciousness	Uniform, peripheral (wall) lighting; Brightness is a reinforcing factor, but not a decisive one
Impression of relaxation	Non-uniform lighting; Peripheral (wall) emphasis, rather than overhead lighting
Impression of privacy	Non uniform lighting; tendency toward low light intensities in the immediate locale of the user, with higher brightnesses remote from the user; peripheral (wall) emphasis is a reinforcing factor, but not a decisive one
Impression of pleasantness	Non-uniform lighting; peripheral (wall) emphasis

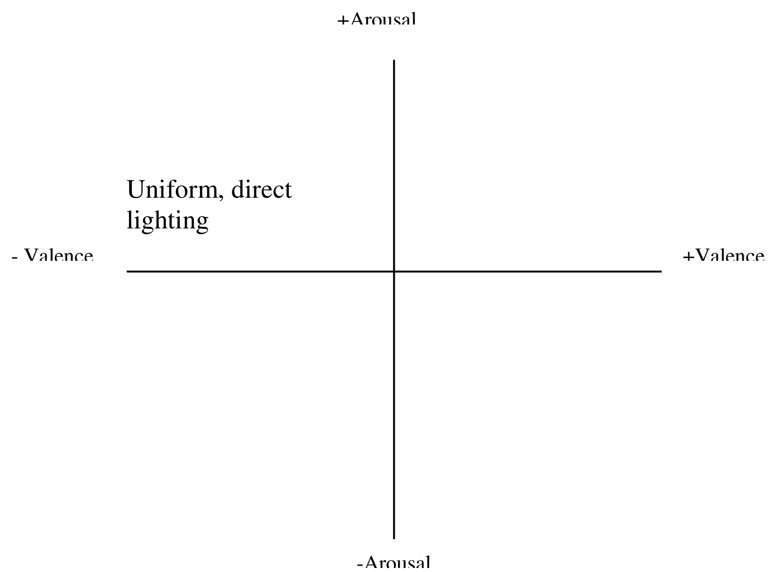
Nothing from this table fits directly into a mapping of arousal or valence, but he does explore qualities such as pleasantness, relaxation, spaciousness and clarity, so we can generalize basic ideas of positivity, negativity and arousal. His category Relaxation is a prototypical example. We know that the semantic label of relaxation tends to connote a position in the lower right corner of the figure:



What kinds of cues does Boyce report belong to this category? He describes non-uniform lighting and peripheral focus, rather than overhead light. Looking at the table, there is significant overlap with the category “pleasantness”, which we can interpret as a semantic label that is slightly more arousing, and slightly more positive than “relaxing”. This might cause us, when we place the concrete recommendations into the figure, to push them slightly to the right and up:



Theoretically, we should also be able to predict that the converse of these recommendations will sit in the corresponding and opposite space in the figure (upper left quadrant).



It should be mentioned at this point that I realize I am interpreting semantic labels quite freely (i.e., "relaxing", "pleasant", "distracting"), with regard to their valence and arousal connotations. In a more controlled format it would obviously be appropriate to assess cognitive labeling of these words – the interpretations by the author will have to suffice for the purposes of this document.

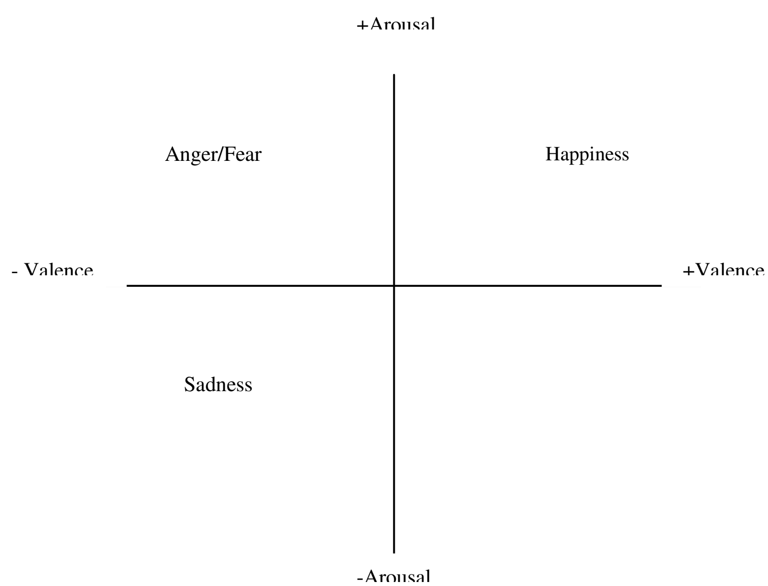
Here again, individual variation will play an important role. For example the use of a spotlight on an individual will almost always be arousing, but the valence of the affect experienced by the person will vary depending on their individual biases and personality. A very extroverted person may love the limelight, and be very positively aroused by standing under a spotlight. A shy person may feel extremely uncomfortable. The guidelines will necessarily be altered by the specific variables in a given situation.

5.2 Dance

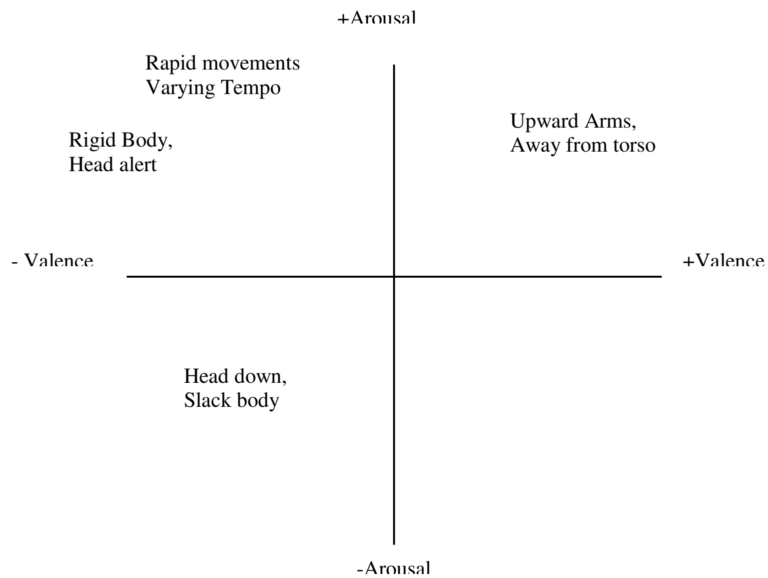
The methods used to place modern dance moves in the figure follow a different format than the ones used in the lighting example. In the relevant reference by Boone and Cunningham [5], the subjects' task is to label dance moves with labels of anger, fear, sadness or happiness. Their results show that with deliberately communicated emotion by dancers, viewers are able to label the dance with the correct emotion more than 90% of the time. They extract six specific body-based cues: frequency of upward arm movement, the duration of time arms were kept close to the body, the amount of muscle tension, the duration of time an individual leaned forward, the number of directional changes in face and torso, and the number of tempo changes an individual made in a given action sequence. These six cues are associated in different combinations with labels of the four emotions, in the following configuration:

Anger	greater number of directional changes in face and torso greater number of tempo changes
Happiness	greater number of upward arm movements greater period of time with arms kept away from the torso
Sadness	longer periods of downward gaze less muscle tension
Fear	rigid body head up and alert

It is relatively easy to place standard emotion labels into our two-dimensional space:



These are intuitive placements, but it is obvious that happiness is high arousal/positive valence, and that both fear and anger are negative arousal/negative valence, etc. Placing the dance moves on the space is now just a matter of replacing the general emotion labels with the specific cues reported in the article. The figure after this projection would look like this:



The one obvious difficulty with the superimposition of the dance moves onto this figure is the fact that anger and fear occupy basically the same space on the arousal/valence axis. The differences between them are more subtle than can be explained by these two dimension (this is in fact a crucial debate in the psychology field regarding cognitive labeling of emotion – for a detailed explanation, the reader is referred to Schacter and Singer [29]).

5.3 Music

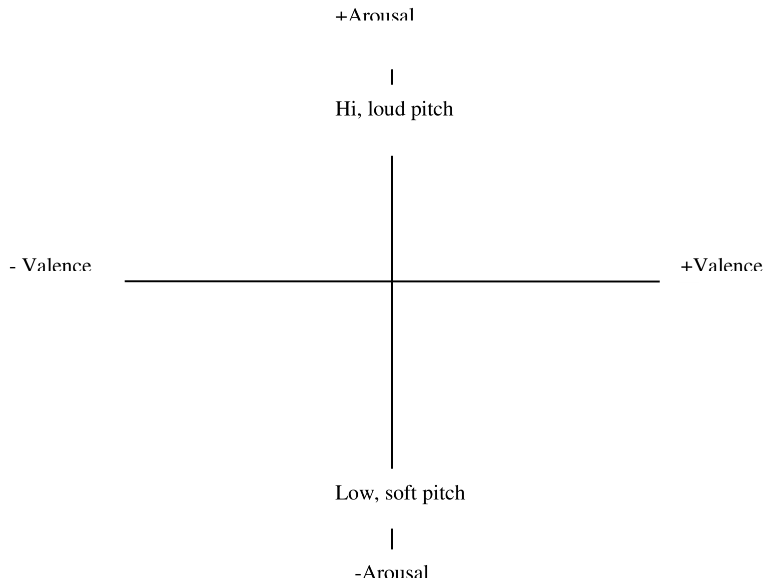
The source used for some of the music mappings required a similar theoretical approach as the dance mappings. Juslin [18] asked musicians to create renditions of the same piece with four different emotional tones: happy, sad, angry and fearful. He then investigated subjects' ability to properly label the pieces with the emotion label matching the performer's intent.

In his discussion section, Juslin reports on the musical cues that were associated across performers with intended emotional expression:

> "The performance analysis showed that (a) anger was associated with high sound level, fast tempo, and legato articulation, (b) sadness was associated with high sound level, fast tempo, and legato articulation, (c) happiness was associated with fast tempo, high sound level, and staccato articulation, and (d) fear was associated with low sound level, staccato articulation, and slow tempo." (p. 412)

Some of these cues are obviously redundant and should not be considered as viable data for the two-dimensions considered together. For example, high sound level and fast tempo are cues for both anger and happiness. However, both anger and happiness are emotions with a high arousal dimension, so the cues could be mapped more simply to a high positive position on the arousal axis. The reader also may notice that fast tempo, in this reference, is associated with sadness. It is generally accepted that speed is associated with increased arousal as a universal phenomenon, so this seems counterintuitive. In fact, Juslin comments on this in the original paper, noting that this one effect is likely specific to guitar music and likely will not apply to other instruments.

Additionally, some of the other cues can be easily mapped to the figure, using the same theoretical premise for mapping emotion labels as in the dance example:

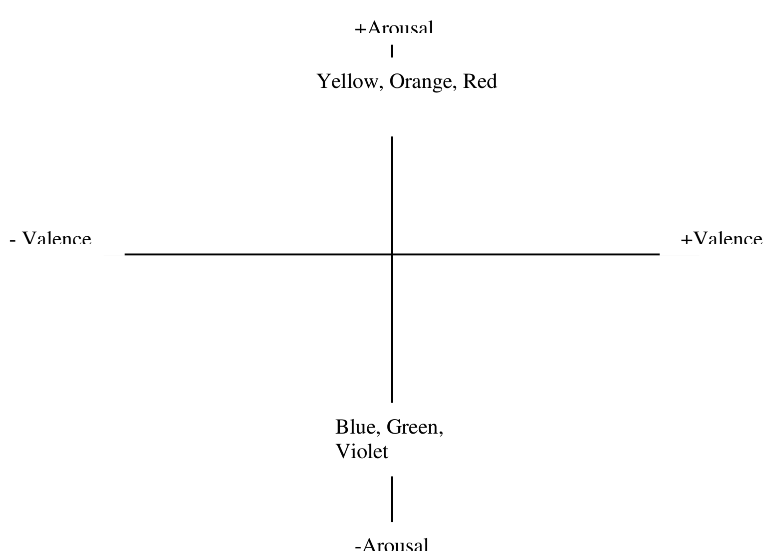


5.4 Color

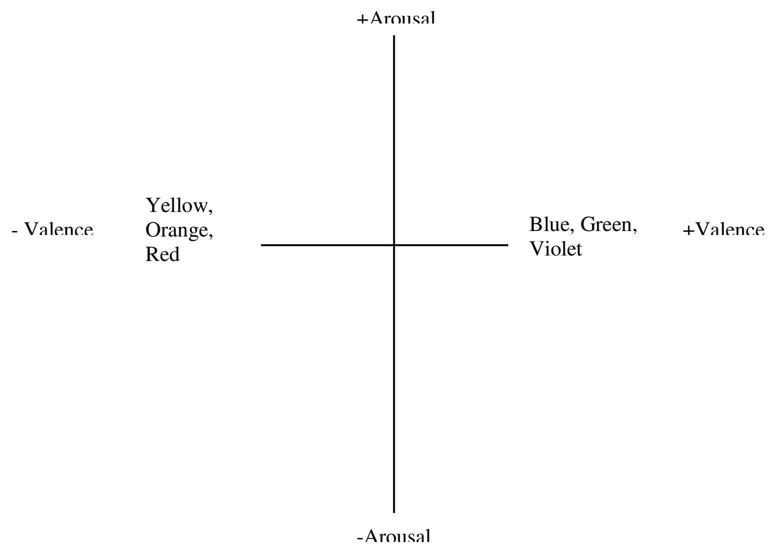
The color examples in the figure are demonstrative of perhaps the easiest way to map a modality onto the two-dimensional space. The source of the mappings comes from Valdez and Mehrabian [34] who literally discuss the arousal dimension with regard to color, in their review of a Jacob and Suess article from 1975. Although the experimenters did not control for brightness and saturation values, their results on subjects' reactions to hue were as follows"

> "Nevertheless, it is noteworthy that higher state-anxiety scores were associated with red and yellow than with blue and green. Because anxiety involves displeasure and high arousal, the latter findings were consistent with results from studies of physiological reactions to color (demonstrating that red and yellow were more arousing than blue and green) and with studies of color preferences (showing that red and yellow were less pleasant than blue and green)." (p. 396)

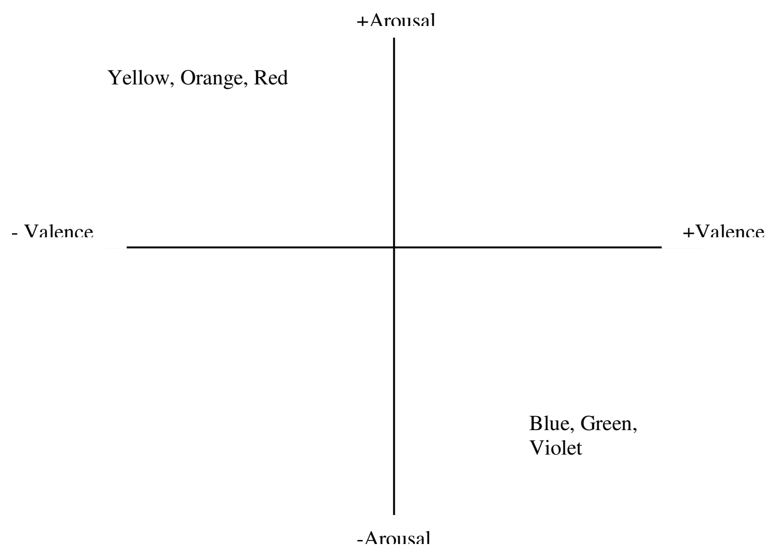
This leads to a prediction later in the paper for Valdez and Mehrabian's own experiment: "Long-wavelength hues are more arousing than short-wavelength hues. This statement is then very easy to map onto the figure:



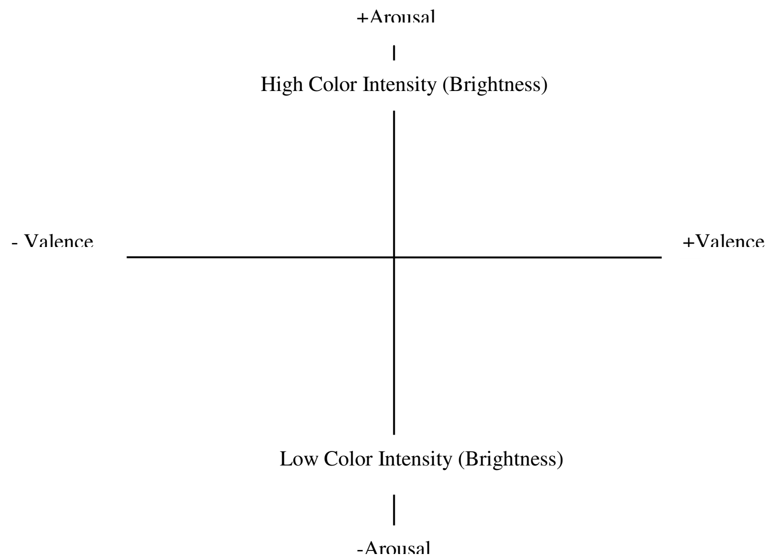
One could do a similar mapping with the reports of pleasantness, where short wavelength hues are reported to be more pleasant (evocative of positive valence reactions) than the long wavelength hues, leading to this figure mapping:



This could lead to a hypothesis that combining the two previous figures would result in the following placements:



Valdez and Mehrabian also explore the effects of gradients on anxiety, and report on Profusec and Rainey's [1987] investigation of rooms painted in pink vs. red. As hypothesized, pink elicited less anxiety than red. This indicates evidence for the viability of gradients being mapped to the arousal dimension. Later in the paper, Valdez and Mehrabian echo this result with their own finding that the brightness level of achromatic color samples varies in the same direction with regard to subjects' self-reported arousal. This maps to the two-dimensional figure as follows:



These examples too are meant as broad guidelines, and not absolutes. For example, an adolescent male trying very hard to assert his masculinity may be very influenced by societal attitudes toward pink as a "female" color. If asked to sit in a pink baby's room, he might feel out of place and quite uncomfortable, thus causing his arousal response to be higher than that predicted by the figure. Likewise, if the color red is my favorite and I surround myself with red objects, I may come to be comforted and soothed by such hues, and respond with low instead of high arousal.

6 Selected Examples

In order to illustrate the guidelines such a figure can offer, we will now explore a selected area - color - in more detail.

As well as using hue as an expressive modality, the color's gradient, or saturation level, can be used as well. In his discussion of color mixing, Itten [17] describes the variation in expressive power that is achieved by mixing pure color with either white, black or gray to form gradients. In particular, he states that a wash that contains any amount of color deviating from pure gray immediately becomes expressive. From the perceptual literature, Valdez and Mehrabian [34] found that a significant amount in the variance of subjects' emotional response to color came not from the color's hue, but from the brightness and saturation levels of the color.

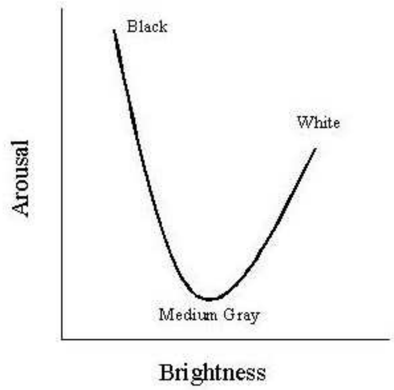


Figure 6: Saturation Level and Self-reported arousal [33]

What can we learn from this? One design principle we might extract from these points is that using gradients of color may be useful for expressing changing emotional parameters, and in fact may even be more useful than using hue as an abstract parameter. The other principle we can extract is that if we do choose to use hue as an expressive modality, that the saturation and value should be kept constant, because these aspects of the color may confound the expression results.

A second example is the use of color contrast. Itten [17] suggests that often it is the relationship *between* colors, rather than a single hue, which contains the most expressive qualities. It is the visualization of one color directly alongside another color that makes available the expressive qualities. Parker [23] additionally suggests that some colors, such as pink or lavender, have a chameleon-like quality, in that they take on mood qualities depending on which hues they are placed alongside. If they are placed with red, they tend to look warmer, and if they're placed alongside blue, they look cool.

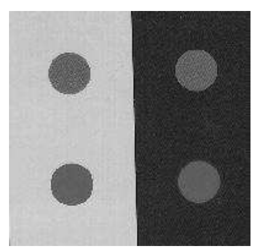


Figure 7: Color Illusion

Sekuler and Blake suggest a very similar concept in their discussion of visual psychophysical illusions [32]. Figure 5 shows the same color in each pair of circles, but against differently hued backgrounds. If you compare the two, the illusion suggests that the pairs of same-color circles are actually different shades, when in fact they are exactly the same. A design principle suggested by this example might be that sometimes the relationship *between* two colors may be a way to present emotional expression through color.

In fact, the relationship between two or more colors is significantly more subtle than that implied by the discussion above. Not only is there interaction between hues, but between saturation and brightness levels of those same hues. *Color harmony* is an important concept for the perception of affect, influencing whether the figure is received as pleasing or discordant. It is difficult to separate the affective qualities of one color versus another since we tend to perceive groups of hues as *gestalts:*

"In reality, though, colors appear as interrelated visual sensations, unpredictable from looking at the colors in isolation. For instance, certain colors, when placed next to each other, can look "exciting," as if vibrating at their boundaries. Other colors can look "subdued" when placed next to each other; still some other colors can look somewhere along a continuum between "subdued" and "energetic." Thus, color experiences have a magnitude associated with them, which can range between *low* magnitude and *high* magnitude. *Experience of color* is the *response* to color relationships, as determined by the magnitude of the interaction between colors." [15]

The study of such interactions informs both the process of color perception as well as the design criteria for using color in art or in practical life. For a detailed discussion of the phenomena of color experience the reader is referred to Feldman [15].

These detailed analyses are two examples of how art and perceptual studies can inform the design of abstract affect communication devices. We further suggest that this kind of extraction of principles can be repeated for any modality, be it sound, tactile feedback, or another form of abstract visual expression.

7 Prototypes

Our laboratory has put these design principles into practice with several example affective objects. Below, we describe two such objects, making use of color principles.

Touch Phone: Through an abstract visualization using screen-based color changes, a standard telephone is able to communicate how it is being held and squeezed. The handset has been modified to include a touch-sensitive surface that conveys the user's physical response over a computer network. The recipient sees a small colored icon on his computer screen that changes in real time according to the way his conversational partner is squeezing the telephone handset. This object explores the abstract modality of hue change as a communication medium. The colors of the Touch Phone icon correspond to the strength of squeezing, mapped to the color spectrum. If the user is in a relatively relaxed state (as expressed by touch), the icon is blue. If the user is extremely tense, the icon will turn red. Neutral states produce green and yellow hues.

The Touch Phone utilizes a standard emotion-color mapping, where colors with longer wavelengths (reds and oranges) represent stress, and the colors with shorter wavelengths (blues and greens) represent physical relaxation. This mapping is based on anecdotal information of the ascription of emotion to color, as well as being supported by sensory psychological findings. [11]

The saturation and brightness values of the graphical object are held constant, as suggested by the design principles described previously, in order to avoid confounding the interpretation of hue.

Figure 8: Using the Touch Phone in three affective states: relaxed, neutral, and tense

The Galvactivator: The galvactivator is a glove-like wearable device that senses the wearer's skin conductivity and maps its values to a bright LED display. Increases in skin conductivity across the palm tend to be good indicators of physiological arousal --- causing the galvactivator display to glow brightly. The galvactivator explores another quality of color theory – that regardless of hue, the brain tends to interpret higher amounts of saturation as correlating with higher intensity. Thus it was logical to map an increase in skin conductivity level to the level of brightness of the LED. According to the findings reported above, saturation of a single color may be a more accurate way of representing arousal or intensity of emotion.

Figure 9: The galvactivator

Initial results suggest that not only is the galvactivator successful at communicating arousal level at an interpersonal level, it is also capable of communicating pooled responses at an audience-wide level [27].

8 Conclusions

Affective objects have the capability to change the way that people communicate. Through their sensing and expressing capabilities, they have the power to mediate and make visible things that are not normally communicated. They have the potential to change and augment what it means to communicate emotion, both reflexively to oneself and inter-individually to a conversational partner. The building of expressive devices that use abstract modalities as communications media should not be arbitrary, but should be guided by psychophysical and artistic principles.

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