Violating Expectations of Color Order

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Abstract

An exploration of emotion in color communication is presented in this paper. It begins with an outline of a proposed theory of emotion and a hypothesis of how color may induce emotion. A discussion follows that details what is essential in a color message to predict emotional responses. Experiments are described that might assist in validating the theory put forth in this paper.

1. Introduction

Recent improvements in communication technology have been media oriented. Technology has been used to increase connectivity, processing power, bandwidth, and storage of all media, including cinema, television, telephony, and traditional and electronic publishing; it has also been used to improve message presentation by providing higher fidelity and improved tools for message creators. The evolution of media has proceeded rapidly, leveraging off of equally rapid developments in computer and communications hardware and software foundations.

However, technology-assisted communication is approaching an asymptote in its effectiveness: neither the medium nor the message content carries meaning. Meaning is generated in the mind of the message recipient. Increased medium capacity to model the external, physical world provides the message creator with no additional understanding of the internal world of the message recipient. Face-to-face communication, on the other hand, continues to be effective because of four factors: (1) the message creator's ability to directly manipulate the message to evoke the proper response; (2) the message creator's consistency of expression; (3) the recipient's ability to instantaneously move through levels of abstraction; and (4) instantaneous feedback between the message creator and the recipient. The goal is to make technology-assisted communication as effective as face-to-face communication by assisting the message creator in the task of message expression and interpretation. This can be done by modeling the internal world of the message recipient's mind.

The aspects of this internal world that may offer the greatest promise are those that are relational in their nature, since relational processes provide the basis for adaptation. A class of internal relational processes is called emotions. The definition of the class of emotions includes more than the emotional behavior that one experiences as feeling happy, sad, loving, etc. It also includes the causes and the intermediate processes that lead to emotional behavior. Understanding how specific emotions behaviors are induced is critical to making technology-assisted communication more effective.

Color Evokes Emotion. It is a relational attribute of the mind, not the physical world. The internal and relational characteristics of color have led us to the hypothesis that color media can be used as a form of technology-assisted communication with the potential to maximize its role in the emotion processes.

Direct Manipulation of Emotion

Expression of emotion is either innate, or has been learned to such an extent that it is unconsciously executed. We have access to high-level mechanisms that generate a desired emotion, e.g., if one is angry, one can express anger without conscious thought. One does not consciously access explicit low-level instructions such as "twist eyebrow up and hold it there for 400 ms" to convey a desired emotion. In media communication, the ability to "twist a knob" to have a body of text or an image convey anger or sadness would be analogous to the ability that is currently possible in face-to-face communication. This is the vision of the role of color in technology-assisted communication.

Increased Probability of Consistent Cues

Emotional cues are the physical movements one pay's attention to in order to derive meaning in face-to-face communication. The cues used to form expectations and identify violations of these expectations in face-to-face communication are relatively consistent. For example, sadness tends to manifest itself with slower movements than when one is happy. Other physical cues are aligned with this emotional state: sadness invokes a diminishment of change in other instances of behavior, such as slower speech and a gentler touch. With technology-assisted communication at this time, there are limited means for controlling this rate-of-change of cues. It is usual for all cues to change quickly, and this results in the generation of conflicting cues, and worse, consistently wrong cues that invoke the wrong emotions!

Availability of Instantaneous Movement through Abstraction Levels

Too much or too little detail can impede one's ability to cull meaning from a situation. Abstraction provides a means to group details, where each group can contain its own properties. A group can be referred to without delving into its component properties. The ability to look at an object as a component of another object or a collection of its own objects is critical to effectively supporting the thought process. This process of abstraction is instantaneous in face-to-face communication. Mental focusing is aided through subconscious focusing of the senses. However, this is difficult to achieve in technology-assisted communication since it requires the conscious manipulation of low-level controls to alter sensory focus in support of rapidly changing mental focus.

Availability of Instantaneous Feedback in a Common Context

Communication is fundamentally an interrupt driven process. A message from a creator interrupts a recipient who is possibly pursuing an agenda quite different from the message creator. The current contexts of the creator's and recipient's internal world are likely to be different, leading to different meanings for the same message. Face-to-face communication offers the opportunity for fewer misinterpretations of the message because of access to direct cues, immediate feedback, and a shared environment or context that greatly enhances the possibility of appreciating the other person's context.

By modeling the emotion process, technology-assisted communication applications can be built that address at least the first two factors mentioned above: direct manipulation and consistent cues. Message creators will be able to more directly express, and possibly induce emotion, as well as detect it, without using the prerequisite low-level skills that are currently necessary. Also, creation of more consistent and aligned cues will be possible.

This paper is an initiation of that effort. It begins with an exploration of emotion in color communication since color communication, of all communication, is perhaps the most dependent upon its emotion inducing characteristics as opposed to its more rational component.

Emotion in Color Communication

The importance of emotion in color communication is especially evident in two problems. One problem is concerned with the difficulty of reproducing a color message in different media. It is difficult to induce a person to generate colors outside of the given constraints of physical medium, i.e., it can be difficult to present the same color message in different media. It is inadequate to use radiation (a) for selection of alternative stimuli. Appearance metrics (M) also fail, because small appearance differences may result in large differences in emotional response. The criteria for selecting an alternative stimuli requires an emotion metric.

The second problem experienced by all who have attempted to generate a color message is the difficulty in composing a presentation. Having the capability to generate arbitrary combinations of radiation does not help with the task of composing a presentation. The lack of guidance in selecting colors often results in the message creator generating unintended emotional messages. The creator is not directly manipulating an "emotion inducing" control. Instead the creator must know how to manipulate low-level stimuli (marks on paper for example) so that their relationships eventually translate into the desired emotional effect.

The remainder of this paper is organized as follows: (1) a proposed theory of emotion; (2) a hypothesis of how emotion is induced by color; (3) implications about what is essential in a color message to predict an emotional response; (4) questions that must be answered to demonstrate the validity of the proposed theory; and (5) proposed tests that might reveal insight into the theory's validity.

2. A Theory of Emotion

Emotion mechanisms are the domain of the mind and body. Since there are many different emotion mechanisms serving many functions, there are several competing theories of emotion and no one theory currently dominates.

George Mandler[1] characterizes emotion as an interrupt phenomena. Richard Lazarus[2] explains that "emotions organize behavior around the focal demand that generate it, and also disorganizing the ongoing activity that has been interrupted." Emotions can be experienced during shifts of focus-of-attention. They are manifested in change. Mandler supports the view that emotion can serve to aid humans in coping with discrepancies between their model of the world and their perception of the world. His theory is cognitive; there are other models such as sociological, physiological, etc. We postulate that emotion is experienced during an expansion or contraction of physical time or space. For example, a musician, by delaying a note here and there, forces the listener to wait for the expected note. An emotion may invoked because the listener's expectation or perception is altered.

Mandler's theory offers insight into how emotion might be induced in messages and thus insight into methods of testing the viability of the theory. In keeping with his theory, we hypothesize that messages are generated within the mind by imposing an internal context on message data at the time of interpretation. The process of imposing an internal context on message data potentially consists of the following activities: (1) the acquisition of an internal sense-of-order or expectation; (2) a situation that elicits an order; (3) a perception that violates this order; (4) a template for potential action to resolve the discrepancy; (5) a decision to resolve the discrepancy; (6) the resolving action itself; (7) feedback as to how well the action is resolving the discrepancy; and (8) the possibility of an alteration to the internal sense-of-order in step one. This process can be classified as an emotion system. The emotion is defined by the template for action in step five. The emotion is experienced during the resolving action in step six. The feedback in step seven serves to increase or decrease the emotion. If the choice is made to alter one's expectation and not one's perception, then the internal sense-of-order may be altered as in step eight.

Order implies that the emphasis is on the relationships between objects and not the objects themselves. Expectations can not exist without order and hence expectations also are critically dependent upon relationships. Expectations of interest are focused on relationships of objects in one's internal sense-of-order and the perceptions that violate that internal sense-of-order are perceptions of relationships. Each template for resolving discrepancy defines spatial and temporal relationships that might enhance the successful resolution of a discrepancy between an expectation and perception. That is, the *direction* that either the expectation or perception moves relative to the other and the *rate* at which a change of expectation or perception is encouraged to have to resolve the discrepancy. The instructions define potential behavior in relational terms. By choosing to resolve a discrepancy, one makes changes in relationships, possibly in one's expectations (a specific model or sense-of-order of one's world) and/or possibly in one's perceptions. The resolving internal or external movement is defined in terms of direction and rate of change along that direction. The emotions that people talk about and feel are changes in sensations, not the sensations themselves.

3. How Emotion May Be Induced by Color

The Theory of emotion outlined above suggests that color messages must have color relationships that fit one's sense-of-order. One color (if it could exist) would not define an order, since like a point (as opposed to a vector), it is lacking direction or orientation. Similarly, too many different colors offer the potential for too many relationships, serving to resonate with too many different senses of order within oneself. Visual cacophony would ensue.

The minimal set of colors that are necessary to define order is two. (One color would work, *if* a second color is imagined but not "seen." However, the resultant order would be ambiguous and unstable.) As colors are added, a point is reached (perhaps 7-11 as many studies have pointed out) where the number of contradictions or discrepancies is too much to manage.

Merely establishing order is not enough to induce an emotional response. The sense-of-order must be violated. The violation may be found in the surrounding environment, or, in some circumstances, it may be imagined. A violation of this sense-of-order is a situation in need of resolution.

According to our theory expectations and violations define the template for any resolving behavior. The emotion experienced is derived from actually resolving the discrepancy by either changing the expectation, or changing one's perception. Many of these sense-of-order templates are learned associations; others may be universal.

4. Color Abstractions

An abstraction of color structure, useful for predicting response, can be built with three levels that represent the sequential processing of data. The three levels are external radiation, internal visual response, and internal sense-of-order (Figure 1).

External Radiation as a Descriptor of the Physical World

External to the human visual system are the data described by physics. Electromagnetic radiation is described by wavelength(s) and magnitude. The data are a point descriptor. That is, it is sufficient to describe radiation as a single point in time and space. The data are "detected," not "seen."

Internal Visual Response to the Physical Data

Color is not a physical world object description, but an internal mind description. It is a descriptor of our visual system's representation of the physical world. The input are physical world data (radiations). The output are perceptual data. Color should not be defined in classical perception terms since these terms are radiation classifiers not perception classifiers; and they are point descriptors, and a single point descriptor can not predict color. Thus CIE, Munsell, Ostwald, RGB, etc. are not color descriptors but radiation descriptors.

A color descriptor must be defined in contextual terms. It may define color in terms of ratios of contrast, using relational Munsell terms: hue of one color relative to another, value of one color relative to another, or chroma relative to another. There must be at least two radiations for a color to exist (a result of adaptation). Since there are at least two radiations, there are always at least two colors.

Perceptual data constitute a contextual descriptor. That is, the perception of color must be defined in terms of the radiation at multiple points in space and at multiple times. The data are relational. There is no one-to-one correspondence between radiation and perception. The perceptual data are generated by physiological processing of the physics data. These data represent attributes of the vision system's representation of the physical world.

Internal Sense-of-Order: Expectation and Violation

A further response to the perceptual data generated from physical data is a higher-level mental activity that acts on the vision system's representation of the physical world. One such response is emotion induced by the interactions of internally generated colors. It is proposed that a necessary, but not defining, condition for an emotional response is the formation of an expectation and the detection of a violation of that expectation. This level of descriptor requires at least three colors: two as the minimum number of colors that can define a sense of expectation and one color to define a violation. The expectations and violations are internal to the viewer.

$$\text{radiation} = F(\lambda)$$
$$\text{appearance} = F(\Delta\text{radiation})$$
$$\text{emotional response} = F(\Delta\text{appearance})$$

Figure 1. Three levels of color abstraction

We are hypothesizing that the course of resolution can be a change in expectation, a change in perception, or a change in both. This change or response is defined in terms of the direction and rate at which an expectation (or perception) shifts relative to a perception (or expectation). This response is measured in terms of colors and has the form of a vector and its spatial and temporal derivatives.

5. Predicting Emotion Response

We are proposing that the recipient of a color message must develop expectations, and that a discrepancy between these expectations and the perception of the physical world create the possibility of an emotional response to color.

Radiation interactions generate what can be described as simultaneous contrasts. Color interactions carefully preserve the internally generated color (accommodating for simultaneous contrast and other radiation interactions) for different border arrangements. Does a person have a different internal sense-of-order (i.e., grouping) for different border interactions among a group of colors? If there is a border interaction, then can the following be determined: the conditions of interaction; the dimensions of interaction; and the order of interaction within a dimension? Answering these questions may reveal whether "response" is defined as a function of perceptual descriptors or some other descriptors.

Assuming that people do react to interactions and that the response is a function of perceptual attributes (i.e., internal color attributes) then what are the various models that people develop to represent their personal sense-of-order of interactions? What are the conditions (size, type, and number of color boundaries that must be traversed between two colors of interest) for the grouping, the dimensions of that grouping, and the order within each dimension? Are these models highly personal (learned) or can they be universally defined across culture, family, and personal experience through a probability distribution?

Given that a sense-of-order exists (be it personal or universal), what is the response of the perception of a discrepancy to a perceptual representation of one's sense-of-order? Can the response be defined by physiological changes? Can this change be characterized by a space/time vector and its derivatives?

The resolution of discrepancy can be internal (an expectation) or external (a movement of some kind). Can internal shifts be revealed through a change in external behavior?

We have designed four experiments to try to answer *some* of these questions. The first experiment is designed to determine if color interactions exist. The second experiment explores the dimensions of color interactions. The third experiment examines order along a single dimension. The final experiment examines what happens when color order is violated.

6. Do Color Interactions Exist?

The goal of the first experiment is to determine if one's response to internally generated colors is based upon the interaction of those colors or merely their presence. If the response is based upon an interaction, then this experiment will reveal the conditions in which the interaction exists.

It is not the purpose of this experiment to label response.

Interaction of colors is analogous to, but not the same as the interaction of external physical world radiation that produces the internally generated sensation, color. This research *assumes* that any interaction will be one of internal appearance attributes.

Experimental Concept

Our stimuli are multiple color patches that share borders. Repositioning the patches generates new borders. A split background containing a split patch, where the splits are co-linear, satisfies the above requirements. By rotating the split patch 180 degrees the experimenter has maintained the color (if simultaneous contrast[3,4] has been accounted for) but has changed the potential interactions (Figure 2). An added benefit of using the split patch configuration is that the split patch maintains a constant interaction between the two halves of the patch. The interactions of each patch with the background is the only opportunity for a change in interaction. (Note that we are not studying large-field effects. The effects of surround are largely independent of the spatial characteristics of the stimuli.[5,6,7]) The goal of this experiment is similar to Lettvin et al.[8]

If a unique set of three patches (Figure 3) is grouped differently depending upon their rotation, then the response to these patches can be said to be due to an interaction (or relative appearance) rather than to an absolute appearance.

Experimental Setup

Before actual color selections for the patches are made, it is important that potential biases be removed from the experiment. There are two major biases: spatial order and

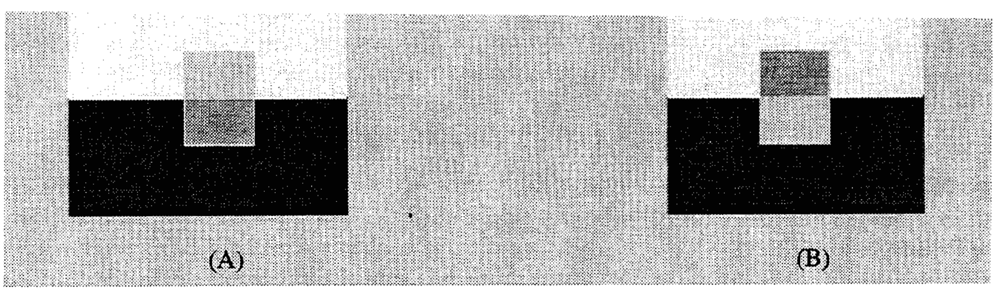

Figure 2. Border interactions—The patches has been rotated 180° from (A) to (B). Even after accounting for simultaneous contrast, the interaction between the stimuli and the background has changed.

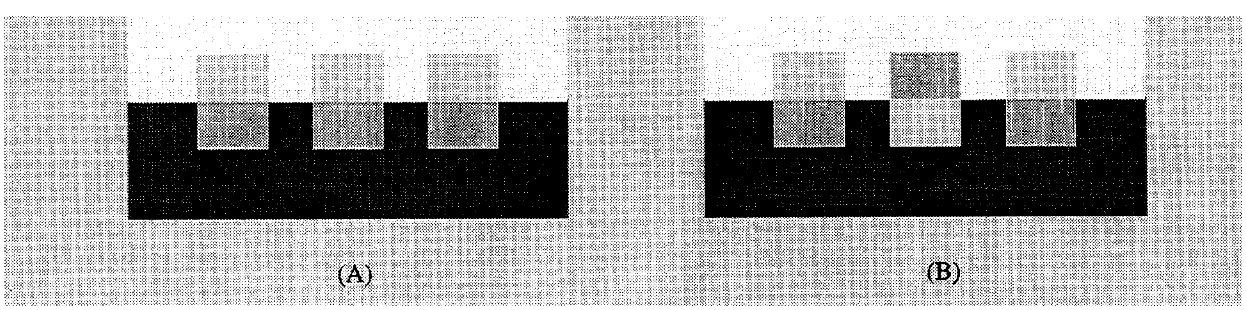

Figure 3. Multiple interactions

presentation order. The experiment requires that the patches be arranged in various orders so that spatial order is removed. Each set of three patches must be presented in every possible unique order. In addition, the presentation of any set of three patches is required to be presented in combinations with other sets, so that presentation order can be removed as a bias.

Each arrangement of patches is composed of eight colors: two background colors, and two colors each for the three split patches . The following parameters are used for selecting the colors: (1) pairs of background colors are chosen whose relative hue angles vary; (2) pairs of colors are chosen for the patches such that the relative change along any dimension between the top and bottom (intra) of a patch is less than the corresponding change between the patches and the background colors; (3) the relative change intra-patch is consistent between patches; and (4) simultaneous contrast is accounted for in the case of patches that change orientation relative to the background. Each arrangement is used twelve times: six (the number of permutations) × two (the number of orientations for the rotated patch).

Experimental Procedure

Subjects are presented with an arrangement of color patches (as in Figure 3A or 3B). They are asked to choose the pair of patches that are most dissimilar from the other pairs. Data analysis is conducted through a combination of techniques developed by Nancy Alvarado[9] for emotion research. They include consensus analysis,[11,12] multidimensional scaling[13] (a version of Minissa with city-block metric[14]), and numerical scaling methods developed by Jameson,[15] which are a variant of Thurstonian Scaling.[16]

Discussion

The colors used in each arrangement do not change except in regard to border interactions. If change in orientation is a factor in the characterization of similarity, then it can be conclude that color interaction exists.

7. Dimensions of Color Interaction

Assuming color interactions exist, we do not know anything about the space they define. The goal of the second experiment is to determine if there is a sense of dimension (or grouping) to color interaction. This experiment has a goal similar to the experiment conducted by Jacobson et al.[18]

Experimental Concept

Stimuli are multiple color patches on a solid background. The relative interactions of each patch with the background are compared.

A color interaction in isolation does not offer the opportunity to determine either the dimensions or the order of interaction, nor does it allow one to make comparisons. Two patches viewed simultaneously allow one to see change, but not accurately assess the magnitude of change. Scale and direction remain ambiguous. Three or more interactions viewed together can be used to disambiguate the relative magnitude and direction of change. This suggests that three patches, where two are perceived to be similar, are necessary to establish a sense of the scale of dissimilarity of the third patch, and to disambiguate the relative direction of change (Figure 4). (Since there is no guarantee that the space defined by color interactions is Euclidean or homogenous, a viable alternative experimental approach is to apply trajectory mapping,[19] a variant of multi-dimensional scaling.)

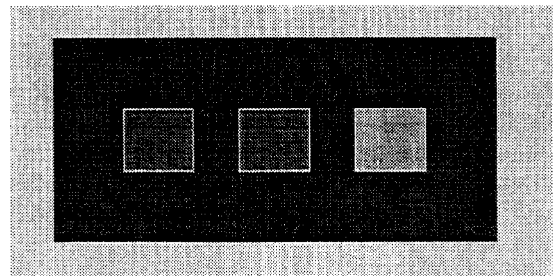

Figure 4. The dimensions of change

Experimental Setup

Again, it is important that potential biases of spatial and presentation order be removed from the experiment.

Each arrangement of patches is composed of four colors: one background color, and one color each for the three solid patches. The following parameters are used for selecting the colors: (1) the background color is chosen to vary in hue, value, and chroma; and (2) colors are chosen for the patches such that the relative inter-patch change is consistent in scale, but not dimension. Each arrangement is used six times (the number of permutations).

Experimental Procedure

Subjects are presented with an arrangement of color patches (as in Figure 4), and are asked to choose the patch that is most dissimilar.

Discussion

Although subjects are not asked to label dimensions, if dimension can be used to characterize similarity, it can be used to order color interactions.

8. Order Along a Dimension

Only two patches are needed to determine order along a single dimension.

Experimental Concept

We use multiple color patches on a solid background. The relative interactions of each patch with the background are compared.

As before, a color interaction in isolation does not offer the opportunity to determine the order of interaction, nor does it allow one to make comparisons. Two patches viewed simultaneously allow us to assess the order of change along one dimension (Figure 5). This experiment has goals similar to Feldman et. al.'s[19] experiment to define the relative magnitude of response from dyads, but is unlike Feldman's experiment in that an attempt is made to determine order along only one dimension at a time, instead of an order along all dimensions at the same time.

Experimental Setup

As always, it is important that potential biases of spatial and presentation order be removed from the experiment.

Each arrangement of patches is composed of four colors: one background color, and one color each for the two solid patches. The following parameters are used for selecting the colors: (1) the background color is chosen to vary in hue, value, and chroma; and (2) colors are chosen for the patches such that the relative inter-patch change is along only one dimension. Each arrangement is used twice (the number of permutations).

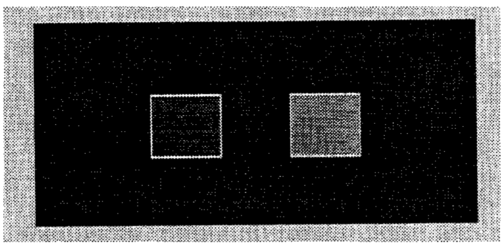

Figure 5. The magnitude of change

Experimental Procedure

Subjects are presented with an arrangement of color patches (as in Figure 5), and are asked to choose the patch that is of greatest magnitude change relative to the background.

Discussion

The characterization of order along each of the dimensions of color interaction provides the framework for establishing expectations and discrepancies of color interaction.

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9. Violating Order

We have hypothesized that emotion can be generated when a situation is encountered in which expectations differ from perceptions. Expectations are derived from a sense-of-order for a given situation at a given time. Emotion characterizes the resolution of any discrepancy between expectations and perceptions. A minimum of three colors are needed in order to create both a sense-of-order and a violation. The concept of requiring a third color to define a response to color interactions is a distinct departure from Feldman et al.

"Emotion" must be identified in order to measure the emotional responses to color. Having previously identified the senses-of-order to the perception of color interactions, the remaining task is to measure responses to a violation of the sense-of-order. The response metrics can be described by: (1) the direction of the resolution (Does one change the expectation or perception; and if so, does the change result in one moving towards or away from the other?); and (2) the rate of change of resolution (the rate at which an expectation or perception can change).

Experimental Concept

We use multiple color patches on a solid background. Two of the patches are chosen to establish a sense-of-order. A third patch is chosen to violate the sense-of-order.

Experimental Setup

As always, it is important that potential biases of spatial and presentation order be removed from the experiment.

Each arrangement of patches is composed of four colors: one background color, and one color each for the three solid patches. The following parameters are used for selecting the colors: (1) the background color is chosen to vary in hue, value, and chroma; and (2) colors are chosen for two of the patches such that an order is determined; and (3) a third color is chosen to violate the order.

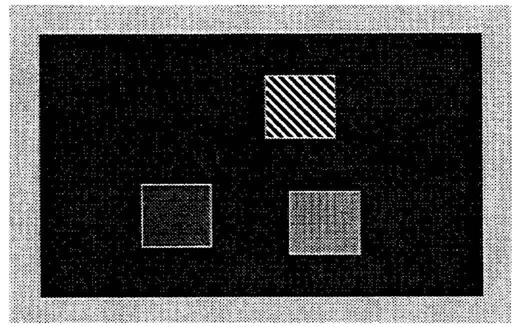

Figure 6. Expectation and violation

Experimental Procedure

Subjects are presented with an arrangement of color patches (as in Figure 6) that approximates a circle. They are asked to choose the patch that is dissimilar, and to remove it from the display by "dragging" it off the screen with a mouse.

Discussion

The intent is to measure a test subject's direction and rate of resolving the expectation/perception discrepancy by monitoring the movement of the patch being discarded relative to the two patches that remain behind, and by measuring the rate of change of that movement.

10. Conclusion

This paper is reporting initial efforts to provide the groundwork necessary to define one's response to color interactions. Thus it provides the theoretical basis for the goal, and it provides possible means of exploring the theory. The details of the experimental procedure, examples of the stimuli, and preliminary results can be found at: HTTP: // walter.www.media.mit.edu/people/walter/color/color order.html.[21]

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