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Contextual Control of Perceptual Behavior

A thesis submitted in partial fulfillment of the requirements for the degree of Masters of Arts in Behavior Analysis

by

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Abstract

This paper offers an experimental analysis of changes in perception. In doing so, the relative flexibility of a person's perception of color as a product of interacting with other colors will be demonstrated through a matching procedure in a training and testing methodology. The analysis focuses on how setting factors (i.e. color stimuli immediately preceding a test color stimulus) come to affect a person's behavior with respect to the test stimulus. We argue that what is present for a participant in interaction with a stimulus is a history of past interactions with other stimuli. Data obtained from the pilot investigation demonstrated extensive differentiation in responding during testing conditions as compared to training in four of five participants. Questions regarding the way in which pilot participants followed the instructions were raised and as a result a subsequent investigation was conducted to incorporate more explicit instructions and controls for the appearance of colors. Results from this investigation show response differentiation to a lesser extent then in the pilot, however, data obtained more closely resemble the subtle phenomena of perception.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

The Perception of Color

The ability to perceive color provides for a richer experience of the surrounding world than is enabled when this ability is lacking. The perception of color is important for both the identification and state of objects, as well as for the appreciation of the special structure of scenes (Webster, 1996). Anatomically speaking, the eye is a coordinated system comprised of eight components (cornea, lens, pupil, iris, retina, the rods and cone cells, fovea, and optic nerve). Kalat's (2002) outlines the process of vision as follows: Light travels through the pupil, which can open by means of surrounding muscles contracting or extending as lighting conditions change. The light is focused onto the eye's retina as it passes thought the rigid cornea and the more flexible lens. As light reaches the color receptors (rod and cone cells) of the retina, these receptors are stimulated by the various light waves. Light, or rather a form of electromagnetic radiation, changes in wavelength and the human eye is sensitive to these wavelengths within the range of 360 to 480 nanometers (Kalat, 2002). The cone cells, which primarily direct those light waves associated with color vision, perceptual detail, and bright light differ from the more prevalent rod cells, which are active in low light situations (Kalat, 2002, p. 109–112). In conjunction with physiological research pertaining to how the eye comes to "see" color, many different cognitive mechanisms have been proposed to explain color perception from a psychological perspective. Given the breadth of study concerned with perceptual activity, I will focus on color constancy, color adaptation, and color priming/masking preparations as they relate to an explanation of perceptual change.

Psychological Approaches to Color Perception

Color constancy

Color constancy is the perceptual construction that describes the ability to discern an object's "true" color regardless of variations in lighting (Enns, 2004). Color constancy is said to solve the problem of object invariance, or the idea that known objects won't change their physical characteristics based simply on changes in lighting conditions. An object's "true" or intrinsic color is of particular importance to organismic survival. Enns notes, "For understanding color vision, it is important to know that some surfaces absorb most wavelengths of light and reflect only a small range of wavelengths" (2004 p.82). This description describes how objects come to look a certain way (in relation to color). For example, objects that look white are those whose surfaces reflect the entirety of the wavelength spectrum, while objects that vary in color absorb only certain wavelengths while reflecting others. Color constancy allows for the psychological study of perceptual changes by providing an account of the unchanging color of an object due to surface light absorbance. This means that if changes in perception are observed, the changes can be attributed to the organism's interaction with that stimulus and not with the as a stimulus as a physical object alone. Color adaptation provides a physiological account of changes in perception due to extended interaction with a stimulus.

Color adaptation

While color constancy describes the notion that one can detect a stimulus object's color regardless of lighting conditions, color adaptation describes how the appearance of a color can change due to cone cell adaptation. Webster and MacLin (1999) note that visual perception is highly adaptive and, as such, the perception of an object is affected by the "observer's state of adaptation" (p. 647). Visual adaptation is how visual perception changes as a function of length of stimulus presentation. Webster (1996) delineates two forms of adaptation: light and contrast.

Light adaptation describes how the visual system changes in different lighting conditions. For example, as the eye is exposed to longer and longer periods of time in dim light, the more one can perceive the environment. However, it is important to note that vision in low light has a threshold limit (Webster, 1996).

Contrast adaptation is said to be depictive of adjustment to the structure or pattern of a stimulus (Webster, 1996). The difference between this phenomenon and masking or priming procedures is that the stimulus changes the responsiveness of the system "without producing its own response during the test"; while in the masking or priming procedures the participant's sensitivity to the test stimulus is altered as a product of the interaction with the mask or prime stimulus (Webster, 1996, p.604). The change in the responsiveness is observed experimentally when an adapting stimulus is shown for several minutes followed by a brief presentation of a test stimulus. Measurement during this procedure is of the perceptual differences to the test stimulus. For example, when a skier wears yellow tinted ski goggles for a long period of time, the eye is being presented with an adapting stimulus. When the skier takes off the goggles and is immediately presented with the white snow (the test stimulus) the skier reports seeing blue snow. This effect is attributed to the color receptor cells in the eye no longer being physiologically capable of absorbing the color photons on that part of the light wave spectrum. Webster

(1996) describes this effect as the eye's receptor cells loosing their sensitivity, or in other words, their having habituated to the stimulus presentation.

Demonstrating these changes in perception, Wesner and Shevell (1992) had participants alter the appearance of a presented colored light as an adapting field with or without an additional outer ring of color. In one condition, the participant were first "dark adapted" for seven minutes, meaning that the rod receptors in the eye were allowed to adapt to the darkened room as was described earlier in Webster (1996). Once dark adaptation had occurred, the adapting field, comprised of either a greenish or reddish color, was presented for five minutes followed by a white "test" light that the participant altered to match the surrounding adapting field's color. In an additional condition, the same general scenario was presented with the addition of a ring of contrasting color that surrounded the adapting field. Results indicated that the participant's ability to match the test light to the surrounding adapted to color was significantly altered when the additional contrasting color ring was present.

Wesner and Shevell (1994) replicated this study using shorter wavelengths (i.e. violet and blue tones) of light making up the adapting field and outer ring. Results indicated that throughout the color spectrum, shifts in the perception of color could be altered through the physiological process of adaptation.

Jenness and Shevell's (1995) extended the previous two studies' methodology to include a single adapting field that had the capability of being mixed with 5% of randomly scattered lit dots. The advantage in this preparation is that the additional stimulus elements no longer need to be segregated from the adapting field, allowing for what the experimenters call the "contextual elements" (i.e. the dots) to not be confined to one specific distance away from the test stimulus or adapting field. In other words, the authors are asking the same question as was asked in the previous two studies, however using a single adapting field rather than the additional outer rings. Participants in this preparation still adapted to the field for 5 minutes and manipulated the test light as in the previous two studies. As before, the study resulted in significant shifts in matching performance when the dots appeared on the adapting field.

The three above mentioned studies provide further evidence that colors that have been adapted to can create large shifts in the appearance of other stimuli. The adaptation phenomena is principally a physiological one, in that changes in perception are attributed to changes in what the eye can physically see. This effect is attributed to the length of exposure to visual stimuli. However, psychology has a rich history of shorter exposure times, to which we shall now turn.

Priming and Masking

The priming phenomenon is experimentally distinguished from adaptation by the length of exposure to the test's preceding stimulus. In the case of priming, the duration of preceding stimuli range from 30 to 80 milliseconds (Enns, 2004, p. 361). Consistent disparity is observed compared to adaptation experiments wherein stimuli are presented for minutes (Webster, 1996; Wesner & Shevell 1992 & 1994; Jenness & Shevell, 1995). Priming procedures operate under the assumption that a person's response to a test stimulus will change as a result of the priming stimulus' brief presentation. For example, observing the difference in responding to a line drawing after it had been preceded by a brief exposure to a similar picture, as compared to responding to that line drawing after presented in isolation (Solso, 2001). Ikeda and Morotomi (2002) used a priming procedure to investigate changes in participant reports of a color stimulus presented directly to the eye. The sequence of stimuli presentation is as follows: first the participant is exposed to a brief priming blue or red stimulus (200 ms) followed by the test stimulus which consists of presenting one eye with red and the other with blue. Results indicated that the prime had a suppression effect on responses to the test stimulus. In other words, when the priming stimulus was blue, the participant reported seeing more red; conversely when the priming stimulus was red the participant reported that the test appeared more blue. These results were said to contradict earlier work in this area. The authors attribute the contradiction to the use of binocular inputs rather then the monocular methodologies used in the past.

Masking is differentiated from priming by the insertion of an additional stimulus following the priming stimulus. In what Enns' (2004) describes as the procedure of *masked priming*, the priming stimulus is followed by the mask stimulus, which is an unrelated word or picture, for example. The purpose of this preparation is to "mask" any influence of the primed stimulus on the participant's response to the test stimulus (Ennis, 2004, p.370). Schlaghecken et al. (2007) describe the procedure as one in which both the priming stimulus and subsequent masking stimulus are presented at timing lengths that remain "near or below the threshold of conscious perception" (p. 1177). This notion of below threshold influence from a stimulus led Schlaghecken et al. (2007) to conducted an experiment using a masked priming preparation. Their study had participants exposed to a non-colored directional prime followed by a mask stimulus of non-directional qualities and then to a colored directional test stimulus. The participants responded by pressing one of two keys depending on the color of the test stimulus with response times being the relevant measure of behavior. Not only did response times decrease when the prime and test stimulus matched in direction, the experimenters found that this relationship between color and key pressed did not need to be explicitly taught.

To this point the discussion has been concerned with approaches to changes in color perception as they pertain to both traditional cognitive psychological approaches and physiological subject matter. Work in the area of changes in perception has been given little attention by behavior analysts. Reed (1988) commented on this point by saying “perception had always been an insoluble problem for behaviorists, who therefore rarely spoke of it” (p. 4-5). However correct this statement is about the rarity with which the field of behavior analysis investigates this subject matter, it isn’t to say that perception and subsequently changes in it have not been addressed in this field.

Skinner’s Behavior Analytic Approaches to Perception

A possible contributing factor to the lack of experimental work done on changes in perception could come from how the prominent Behaviorist, B.F. Skinner, used terminology unlike that of more traditional perception researchers. One example of this comes from priming. As discussed above, priming is seen as an experimental preparation used to demonstrate differences in response latencies to test stimuli. Skinner (1968) discusses priming as a stimulus which evokes behavior for which reinforcement is made more likely than had behavior not been preceded by the stimulus. An example of this is described in the context of imitation. For Skinner, the model that one is to imitate is said to “prime” the imitative behavior of the observer. This colloquial usage differs considerably from the more methodological usage described earlier.

More generally, though Skinner's analysis suggests that what a person sees depends on the person's history of reinforcement for seeing, as well as on his/her genetic predispositions (1974, p.72). Skinner notes "people see different things when they have been exposed to different contingencies of reinforcement" (1974, p.88). That stimuli are seen a certain way based on the prior consequences of seeing and current environmental factors is what had been termed "conditioned seeing" (1953, p.267). Skinner's mention of an experiment where a participant comes to see a conventional symbol, such as a playing card, as a different color given a brief exposures to that symbol printed in an unconventional color (1953 p. 267) highlights the flexibility of color perception.

Skinner's approach is centered on stimulus control or the process by behavior is evoked by stimuli in the presence of which similar behavior has been reinforced. This analysis has yielded much in the way of an experimental analysis of naturally occurring behavior but may limit the investigation of perceptual behavior. Perception is difficult to observe directly. As we have seen from the physiological and cognitive psychological literature, perception is extrapolated from physiological measures or is explained through elaborate mental processes. Behavior analytic work is typically not interested in the perceptual interaction per se, assuming its occurrence while measuring more overt behavior.

Nonetheless, a number of behaviorally oriented experiments on perceptual activity have been conducted. Blough (1975) demonstrated pigeons' ability to discriminate among varying degrees of light wavelength saturation. A series of experiments were conducted where the organism was presented with a white light presented through a response key. The organism would peck the key in conditions where reinforcement was available for differing light saturation levels. Results indicated that the three birds demonstrated discrimination of varying degrees of light saturation (studies II and III), which means lights of different wavelengths have different saturation levels for pigeons. McFadden & Wild (1986) illustrated how pigeons showed discrimination of the depth of objects due to the their binocular visual system. This finding was observed using a discrimination procedure where the bird would be presented with a series of stimuli configurations with programmed consequences relating to each one. The stimuli configurations in experiment one were those of depth and non-depth, experiment two attempted to mitigate any binocular cues by covering one of the bird's eyes and providing the same stimuli, while in experiment three the angle of stimulus presentation was changed. Generally speaking, these experiments demonstrated how discriminated responding of both two and three dimensional stimuli as well as depth can occur with pigeons. Chimpanzees have been used to experimentally demonstrate variations in visual search performance (Tomonaga, 1995). In this study, three experimentally sophisticated chimpanzees were taught a visual search task using a multiple alternative match to sample procedure. Results from this study demonstrated that for 2 of the 3 participants, the matching behavior could be attributed to perceptual isolation of the target stimulus as a controlling variable. Tomonga notes that the variability, or "flexibility" as the author puts it, observed in the data indicates that attention needs to be paid to both the history of reinforcement as well as other controlling relations affecting current behavior.

These studies have led to a more complete picture of various species' visual systems. They have not provided much in the way of an account of human perception, however. Some research with human subjects has been conducted. For example, Reeve &

Fields (2001), investigated humans' discrimination of visual stimuli. This procedure utilized an apparatus that varied in the percentage of filled pixels on a computer screen. The authors found that perceptual classes could be established through single stimulus exemplar training and forced choice generalization test. The training procedure had participants engage in a conditional discrimination task where by when a sample stimulus of one fill value was presented one of two symbols was selected. When the other sample stimulus was presented, which had a different fill value the other symbol was selected. Following the training a generalization gradient was established by presenting stimuli of 19 differing fill values and having the participant select one of the two symbols used in the training for each of the stimuli presented. The forced choice generalization test consisted of systematically reducing sample stimuli from 19 to 5 in twelve phases. By doing so, the author's claim that perceptual classes were established as a result of discriminative responding to stimuli. These findings contrast with traditional methods, which established perceptual classes through direct discrimination training (Reeve & Fields, 2001).

Fields et al. (2002) extended the previous work to demonstrate similarities between perceptual classes and other classes of behavior such as equivalence and generalized equivalence classes. The authors developed a *cross-class* probe methodology to establish whether or not stimuli would fulfill the necessary criteria to be considered members of a perceptual class. The *cross-class* probe method consisted of two procedures. The first, a serial testing procedure where six randomized bocks of 48 trials of stimuli from one group were arranged on a continuum and presented as samples, a second stimulus arranged similarly comprised the comparisons. A concurrent testing procedure where a block of 144 trails were first comprised of the first group of stimuli compared to the second, followed by a second block of trials were the comparison stimuli from the last acted as the sample. Through this test methodology, the research demonstrated the emergence of linked perceptual classes, which led to the conclusion that these classes share functional properties of equivalence classes. These studies have contributed not only to our understanding of equivalence but also to the notion that perception is another behavioral phenomena to be studied.

Kantor's Interbehavioral Approach to Perception

Another approach to the explanation of changes in perception is to attribute these changes to the functional properties of a stimulus having been transferred from another stimulus. In the present case, historical perceptual functions of a stimulus are brought to bear on the current perceptual activity of an organism. As Hayes (1992) points out, one of the difficulties with traditional behavior analytic conceptualizations of past behaviors is the need to actualize the past in the present. The traditional solution to this problem has been that the organism's history of reinforcement changes the organism such as to enable it to respond in new ways on future occasions (Skinner, 1974, p 236-237). Hayes' (1992) theoretical contribution to this issue centers on the notion that the psychological history of the individual organism is directly apparent in the interactions occurring in the present. Hayes (1992) mentions that much of this line of thinking can be drawn from Kantor's Interbehavioral perspective on psychological interactions.

Kantor's Interbehavioral perspective focuses on the bidirectional relationship that stimulus and response functions share (Kantor, 1975 p. 33). Smith (2006) outlines the interdependencies between stimuli and responses along with the Interbehavioral field construct. Smith stresses the importance of not focusing on any one aspect of the Interbehavioral field when analyzing psychological events because it is "the full complement of interdependencies [that] is always the ongoing actuality" (2006, p. 88). In investigating these events it becomes necessary to abstract features from the event as a whole, however, recognizing that these features are interdependent with one another (Delprato & Smith, 2009). This is due to a field notion of psychological events addressing all of the contributing factors in any one behavioral segment. By acknowledging that abstraction of features of the Interbehavioral field is necessary for scientific investigation, Kantor's remark that "all knowing or perceiving obviously begins by confrontations of the individual with things and events which he thereby learns to identify, discriminate, name, as reactions in later confrontations" (1975 p.446) outlines the importance of the perceptual component in any event. It is the initial perceptual contact with the world that enables subsequent behavior to occur.

As addressed earlier, not only is the organism in contact with the object in a perceptional event but also the setting in which this object is found. Kantor offers an interesting example of the importance of contextual factors on perceptual activity: "At one time A stimulates B to perceive him as a person who is calmly greeted and to whom B extends his hand for a conventional clasp. Upon another occasion B slaps A vigorously on the back. What B does depends upon who else is present"(1975, p.183). This example, demonstrates the role of the context or setting in determining the actualization of stimulus - response functions. This is to say, how a person responds to stimuli depends on the setting in which these stimuli are encountered. An experimental example provided by

Tonneau et al. (2006) describes a Pavlovian preparation where observing a stimulus sequence can have an impact on test performance.

In Tonneau et al. (2006) second experiment, participants were first presented with four boxes two on top of the other. The two left boxes were open to reveal the same colored ball in each while the adjacent two boxes were closed. Following this, the same four boxes were presented with the two left boxes open with the same colored ball, however, now the right boxes were open with the top row having different colored balls and the lower row having the same colored balls. A third stimulus set was presented with four boxes, the two on the left being open with the same colored ball but differing from those colors presented in the previous trials and the two adjacent boxes being closed with either a slash across the front of the box (the upper) or an asterisk on the lower. The next trial was a test trial where participants were presented with two colors (one corresponding to the seen color in the left boxes of the last stimulus set and one novel color) and either a slash mark or an asterisk. It was the participant's task to identify which color was behind the box when either the slash or asterisk was presented. The researchers found that participants could correctly identify the correct stimulus in the absence of programmed reinforcement. These results together with Hayes' conceptualization of historical interactions being present in current responding, not only is the contextual setting comprised of things in the environment but also the historical functions these stimuli bring to bear on the response function of the organism interacting with them. The notion of flexibility is echoed in Kantor's treatment of perceptional changes. Although the stimulus object may not change in its composition from occasion to occasion, how that stimulus comes to stimulate the organism's responding may be very different (1975, p. 179).

These differences in responding may be attributed to any number of variances in the composition of the interbehavioral field. Kantor (1975) notes that one must look at both developmental and operational conditions to examine how changes in conditions come to effect changes in responding. With respect to developmental conditions, if the organism is biologically intact, then an intact visual system can be assumed. Additionally, if adequate training and or exposure had occurred for the individual, then that individual would be sufficiently equipped psychologically to perceive a verity of events. In terms of the operational conditions, Kantor mentions fatigue, concurrent responses, interest, variations in media, and the interactional setting as relevant considerations. For present purposes, the variations in media and the interactional setting/context are of particular importance. The visual adaptation literature reviewed above has exemplified how variations in media (i.e. light and saturation) can come to change perceptual responses. The interactional setting or context in which one encounters stimuli also has an impact on the perception of things and events.

Gibson's Active Approach to Perception

In line with a natural science approach to perception, Gibson's (1966) account is also important to consider. Psychology has often addressed perception as a passive process whereby the organism reacts to the sensation from the stimulus object. Gibson argues that perception is an active system rather then a set of organs whose purpose is to channel stimuli (Gibson, 1966). For Gibson, the term *perceptual system is* preferred over *perception* due to the former's descriptive utility in addressing this more active conceptualization of perception. Gibson's (1966) comprehensive evaluation of what he calls the five "perceptual systems" proposes an integrative approach to these systems rather than a mutually exclusive one. Within this integrative approach, the perceptual system is active as is exemplified in the statement: "the eyes, ears, nose, mouth, and skin can orient, explore, and investigate" (1966, p. 4). This fits well into Kantor's conceptualization of a psychological event as a multitude of factors interacting simultaneously.

Gibson's (1966) classification of the sensory systems is divided into five systems: the auditory, haptic (touch), taste/smell, and the visual. Each sensory system has its corresponding mode of attention, anatomical organ, organ activity, and sensitivity to stimuli. The visual system relies on looking as its mode of attention (1966, p. 50), photoreceptors (rods and cones) as the receptive units, and the eyes as well as the head and entire body act as the anatomy of the organ. In terms of the activity of the visual system, Gibson denotes that accommodation, papillary adjustment, fixation, and exploration occur. The physiological thresholds of the photoreceptors' sensitivity to differing light conditions only limit the stimuli available for vision. The external information obtained from the stimuli is explained by Gibson (1966) to be "everything that can be specified by the variables of optical structure (information about objects, animals, motions, events, and places)"(1966, p. 50).

Gibson's treatment of color vision is exemplified by the statement: "It would follow that an observer cannot distinguish the colors of objects without having the incidental ability to distinguish the colors of the spectrum. But it does not follow that sensations of 'pure color' are entailed in the seeing of surface color. The sensations are what I call useless dimensions of sensitivity"(1966, p.183). The idea that color is significant only so far as is necessary to discern the qualities of things rather than the "true" color of things speaks to the flexibility or variability in the perception of colors. This flexibility, as we've seen can be attributed to both physiological effects such as adaptation, as well as to psychological effects as in priming, masking, and discrimination procedures.

To capture perceptual flexibility, matching methods have been employed. Jenness & Shevell's (1994), aforementioned adaptation study utilized a matching procedure where participants would adjust a background field. The participant adjusted a background incrementally by pressing either of two computer mouse buttons so that the visual field would become less greenish or reddish. By having only two distinct buttons available for the participant to represent his/her perception, the apparatus limits the fluidity with which the participant can make a response. Webster & MacLin (1999) describe a *Nulling Matching* procedure where in participants were shown a target stimulus followed by a random image and the participant then adjusted this image. The procedure had the participant press a button, which would adjust the display along either the x or the y index. After the participant made a response the next presented image would be representative of that button press. Both of the above outlined matching procedures introduce a useful way of recording a participant's perception of an image, however, both rely on individual button presses rather than a more fluid image display.

In summary, the perceptual behavior of an organism refers to the interactions among organismic and environmental elements. These interdependent elements contribute to the perceptual behavior of an organism through an active system. The present investigation proposes an experimental analysis of perception. In doing so, the relative flexibility of a person's perception of color as a product of interacting with other colors will be demonstrated through a matching procedure. The analysis focuses on how setting factors (i.e. stimuli immediately preceding a test stimulus) come to affect a person's behavior with respect to the test stimulus. For the purposes of this investigation, the argument is that what is present for a participant is the history of a past interaction with another color. For example, as one perceives violet after having just been exposed to blue, the historical "blueness" is actively participating in the present interaction of seeing violet. In short, the proposed study addresses how changes in stimulus presentation come to affect the functional properties of a perceived stimulus.

Pilot Study

Participants

Six undergraduate students participated in the pilot study. Participant recruitment was done through the University of Nevada, Reno's sponsored Sona Systems experiment management website. Participation in the study was contingent on the successful completion of a color blindness test. Upon competition of the experimental session each participant was debriefed and given one hour of research credit, regardless of study completion or performance.

Materials and Setting

The experimental session was conducted in a quiet room equipped with a desktop computer (Dell GX270™), table, and chair. The stimuli were presented on the computer's monitor (Dell™ 19inch LCD, Brightness 88/100, Contrast 70/100, pixilation:

1280x1024) with the participant's responses being made using the computer's keyboard, mouse, and a "dial" manipulatable. The Griffin Technology™ *Power Mate* USB multimedia controller was used as the dial, which can be turned in a 360° fluid movement. Experimental conditions were controlled and data recorded using a Visual Basic.net (2008) program. Additionally, for the color test, three Ishihara color test plates were used. These plates were obtained from the Wikipedia Free Encyclopedia (http://en.wikipedia.org/wiki/Ishihara_color_test).

Design and Procedures

The experimenter greeted the participant and reviewed the relevant consent material before leading the participant to the experimental room. Upon entering the room the participant was seated in front of the computer monitor where the program's instructions were presented.

> *"Welcome and thank you for participating. The experiment you are about to take part in is designed to see how you will behave in different situations. On the computer screen you will be presented with a color. When the gray screen appears your task will be to use the specially designed mouse wheel to match the color you've just seen. Once you see the color you've just seen press the space bar to indicate your choice. If the match is correct you will be shown a sign saying "CORRECT", if an incorrect match is made you will see "INCORRECT" appear on the screen. It is important to understand that the more correct responses made, the sooner the experiment will be finished. Once the experiment is over, precede to the adjacent room for debriefing. If you have any questions before beginning, please ask the experimenter before clicking on the "Start" button. Click on the "Start" button if you are ready to begin."*

If the participants had any questions the experimenter explained relevant procedural details only.

The experiment was completed in one session and lasted no more then 60 minutes. The experiment consisted of a pre-assessment, to determine that the participants could perceive color accurately, and a training and test methodology design.

Dependent and Independent Variables

The introduction of a primary color stimulus presentation before the secondary color presentation in the testing condition represented the independent variable manipulation. Colors presented, dial manipulatable sensitivity (i.e. the relationship between participant's response and its corresponding affect on the color presented on the screen), and stimuli presentation-timing lengths were set to default settings in all conditions.

The dependent measures were response latency (all conditions), response accuracy (*Training* only), and the quantifiable color matching response (in both the *Training* and *Testing* phase). The quantification of participant's response were determined by the red, green, and blue (R-G-B) scale used in the programming of the study. The R-G-B scale referred to the numerical value used in the representation of color by the computer's monitor. Each of the three colors ranges on a scale from 0 to 256. If all three colors were set to 0, black would be present on the screen, conversely if all three were set to 255, white would appear; and with all three set to 128, gray would be presented. By independently manipulating these three scales along this continuum most colors on the light spectrum are available for presentation. For the purposes of the pilot method, relevant color values are describe in the following format R: 128, G: 0, B: 128. In this example, red has been set to 128, green to zero, and blue to 128, this would represent violet on the computer screen.

Pre-assessment: Colorblindness Test

Upon clicking the “Start” button the participant began the color blindness test. The stimuli used for this assessment were a series of Ishihara color plates designed to evaluate color deficiencies in the visual system of the participant. Each plate consisted of a number that is embedded in a pattern of varying colored dots (see Figure 1). Evidence suggests that these stimuli, viewed on a computer, are an effective means of identifying colorblindness (Kuchenbecker, et al. 2007).

The color plates were presented one at a time, with a total of three plates presented. Once the color plate appeared on the screen, the participant used the number pad on a standard computer keyboard to enter the number they perceived to be superimposed on the plate. The participant had to correctly identify each number on the three plates to move to the *Training* phase of the study. Participants who did not identify the numbers correctly were thanked for their participation, granted credit, and excused.

Training

The training condition consisted of presenting a secondary color stimulus that the participant views on the computer screen and subsequently engages in a matching task with respect to that presented color. A secondary color stimulus is defined for the purposes of this investigation as, any color presented that is comprised of two are more color values, which are greater then zero on the R-G-B scale. Three secondary color combinations were presented during this phase. Violet, R: 128, G:0, B: 128. A variation on violet that is slightly more blue (R: 112, G: 0, B: 144), and lastly a variation on violet that has more red (R: 144, G: 0. B: 112).

In the current investigation each movement of the manipulatable results in an immediate change in the color presented on the computer screen during the matching task. The dial manipulatable is designed to move in a fluid 360° motion, with each movement registered by the computer program. This signal can be converted, by the computer program, to represent a set increment of movement up or down the R-G-B color scale used. The increment used for the pilot method was 64, meaning that the computer program would have to have registered 64 separate movements by the dial to go from violet (R:128, G: 0, B: 128) to either red (R: 256, G:0, B: 0) or blue (R: 0, G: 0 , B: 256). By setting the manipulatable at 64 incremental movements from violet the colors presented will advance by two color units with each movement made by the participant. For example, if the participant were to move the manipulatable toward blue (i.e. moving the dial right) from violet (R: 128, G: 0, B: 128) the next color would be R: 126, G:0, B: 130 followed by R:124, G:0, B:132 and so on.

For each trial the secondary color had been presented for 3 seconds followed by a gray screen. The instructions to the participant articulated that when the gray screen appears the matching task had begun. At this point the participant used the manipulatable to change the color on the computers screen to match the previously seen color within a pre-programmed range. The pre-programmed range for the pilot investigation was plus or minus 10 numerical units away from the presented color. Upon begging the matching task the gray screen faded from gray to either blue-violet or red-violet depending on which direction the participant started to turn. The gray hue only persisted for four movements in either direction before it would disappear completely with only red and blue tones remaining for the duration of that matching task. Once the participant moved the manipulatable either left or right, different variations of color along the spectrum of red-to-violet-to-blue would appear. The manipulatable was set such that if the dial turned toward the right greater and greater variations of blue-violet would appear until the manipulatable reached a point where only blue appeared (i.e. the blue 256 value). Subsequently, if the manipulatable turned toward the left greater and greater variations of red - violet would appear until the dial reaches a point where only red appears (i.e. the red 256 value).

As the participant moved the dial from left to right, they indicated that the color on the screen best matched the previously seen color by pressing the space bar. Given a response that fell within the designated range a sign reading “CORRECT” appeared on the screen for a half of a second. In instances where the participant’s match falls outside the designated range a sign that read “INCORRECT” appeared for the same duration. The participant had 15 seconds to indicate their response. In the event the participant didn’t indicated their response in the allotted time the “INCORRECT” sign would appear and the ITI would be imposed before the next trial began. After feedback had been delivered a 5 second inter-trial interval (ITI) was used to separate the trials. A black screen was used to represent the ITI. To move from baseline to testing the participant’s had to successfully match each of the 3 stimuli 3 times for a total of 9 correct trials. Upon successfully reaching the 9 correct trial criteria the participant was exposed to 24 testing trials.

Testing

Before the testing phase began the participant was shown an additional instruction screen reading:

> *"Great work! Now you are about to start the next phase of the experiment. In this phase, once the gray screen appears use the wheel to make the current screen match the LAST SEEN color and press the space bar."*

During testing the participant was exposed to the independent variable followed by a secondary color and then allowed to engage in the matching task with respect to the secondary color. The matching task was identical as in the training; however, no programmed consequences were given during the testing phases. Each trial had been separated by a 5 second ITI black screen.

Three trial variations where used in the testing phase: a blue-to-violet trial, red-to-violet, and extended violet trials. The dimensions for the primary colors used were R: 256, G: 0, B: 0 for red, and R: 0, G: 0, B: 256 for blue. The secondary color never changed during the testing condition, each presentation of the secondary color (violet) had dimensions (R: 128, G: 0, B: 128). Primary colors were exposed to the participant for 5 seconds immediately followed by a 3 second presentation of the secondary color. The only exceptions to this were the extended violet trials, where violet was continually presented for 8 seconds. The purpose for this was to expose the participant to the color for the same amount of time as the red-to-violet and blue-to-violet testing trials.

Immediately following the secondary color an identical gray screen as in the training condition had been presented, which indicated to the participant that the matching task had begun. The participants had 15 seconds to indicate their response by pressing the space bar when the color presented on the screen looked to the participant as the secondary color presented had. The 24 testing trials were semi-randomly presented with each stimulus variation be presented eight times. Upon completions of the 24 semi randomly presented trials, the participant was thanked for their time and excused from the experiment.

Pilot Results and Discussion

Five of the six participants completed the study. The computer settings for participant D_02 had been faulty and their data subsequently are not considered in the analysis. Table 1 represents the average response difference away from the presented secondary color for each participant. The table shows that for participants D_01, D_03, D_04, and D_05 considerable differentiation occurred. The results for the four participants suggests that continued interaction between the participant and the independent variable had been occurring during interaction with the violet stimulus.

Figure 2 depicts the individual trial data for participant D_01 where the first four trials corresponded to the training to violet (R: 128, G:0, B: 128). For D_01 matching responses to the training stimulus are redder in appearance than the presented stimulus. Given this, it's assumed that for that individual violet is seen as more red. When in testing however, participant D_01 responds to the extended violet condition with matching responses that correspond to a violet that is slightly bluer in appearance. This suggests that for this participant longer exposure to the violet stimulus allows for better-matched responses to that stimulus. The middle graph on figure 2 shows participant D_01's responses to both the training violet trials as well as the blue-to-violet testing trials. The matching performance in this condition suggests that as the participant is matching to violet they are reporting to see the test stimulus as more blue in appearance as compared to the performance in the training condition. The last graph of figure 3 shows red-to-violet testing trials as they relate to the violet training data. These results do not show the same pattern of responding as the previously described blue-to-violet data. As such, these data suggest that for this participant, during the red-to-violet testing phase can better accurately match to violet then they could when the preceding stimulus was blue.

Participant D_03 data are represented in figure 3. The first graph depicts the participant's matching response in both the violet training and extended violet testing conditions. Slightly more differentiation occurs in the violet testing condition, however aside from the first two testing trials, their response stay very close to the presented violet color. The middle graph represents participant D_03's matching response in the blue-to-violet testing condition as compared to the violet training condition. Much like participant D_01, participant D_03 shows significant response differentiation in this condition. The lower graph represents much of the same as the preceding one, with responses in the red-to-violet testing condition being consistently differentiated then those in the violet training condition.

Figure 4 contain the training and testing condition data for participant D_04. This participant represents similar patterns of responding to participant D_03 in all three of the testing conditions. Matching responses for both the blue-to-violet and red-to-violet testing conditions deviate from the presented violet color. These data suggest that for this particular participant their selections, although by no means close to the presented violet color, do not deviate as significantly as participant D_03. These responses represent a subtler affect from the independent variable's presentation. As is often the case with perceptual activity, subtle effects from the functional properties of stimuli can, and in this case does have a significant effect on behavior. Further evidence of these effects from the independent variables on behavior can be seen in Figure 5. Participant D_05 demonstrates the same behavioral patterns as the previous participants, with response differentiation occurring in both the blue-to-violet and red-to-violet testing conditions.

The final participant, D_06 did not show the same constant behavioral patterns as the past four participants (Figure 6). D_06 responses deviated more in both the violet training and extended violet testing condition then either of the other two testing conditions. Given the irregularity of the response patterns for this participant no definitive conclusion can be made with respect to any influence the independent variable had on responding.

Overall, the results from participant D_01, D_03, D_04, and D_05 support the notion that what is present for a participant in interaction with a stimulus is a history of past interactions with other stimuli. Specifically, when presented with a primary color followed by a secondary violet color, the perception of that secondary color is altered by the pervious interaction with the primary color. The effects shown for participant D_03, D_04, and D_05's behavior in the testing conditions are made even more salient when attention is paid to the extended violet testing condition. Although some variability occurs in the matching responses when the participant is exposed to the violet stimulus for an extended duration these are not to the extent of those responses that occur to the violet stimulus when either the blue or red stimulus had preceded it. Furthermore, even though participant D_01 did not have response patterns in line with participants D_03, D_04, or D_05, this participant's responses do provide evidence of the subtle affects the independent variable can have on matching response.

With these results an argument can be made that the contextual control exerted on the participants responses is the historical interactions brought to bear on current responding in the absence of programmed consequences. The implications of these results as it relates to the altering of trained operant responses in the absence of consequential stimuli are an important one. To further this argument, however, there needs to be evidence that ensures that the participants responses are under the control of both the currently presented stimulus and the historical affects of the previously presented primary color, and not an uncontrolled for variable. To make sure that the participants are not generating their own rules for responding and are in fact making their responses to the "*last seen color*" as the directions state, a further condition to illustrate this is necessary. The necessity of this condition is made in lieu of matching response for both participants D_03 and D_05. These participants responses for both the blue-to-violet and red-to-violet testing conditions reflect matching selections that are very similar in appearance to the primary colors that preceded the secondary violet color. To ensure that these responses were made in accordance with the directions provided a more direct matching-to-sample condition will be added.

Method

This investigation sought to extend the results from the pilot method with the addition of training and testing tutorials, a match-to-sample procedure to ensure that the participants were responding in accordance with the rules laid out by the experimenter, and finally a reprogramming of how colors were presented to control for varying luminance and saturation in the presented color.

Participants

10 undergraduate students participated with recruitment conducted through the University of Nevada, Reno's sponsored Sona Systems experiment management website. Participation in the study was contingent on the successful completion of a color blindness test. The participants were individually debriefed once their respective experimental sessions had ended. Participation in the investigation was worth one research credit, regardless of study completion or performance.

Materials, Setting & Stimuli

The experimental session was conducted in a quiet room equipped with a desktop computer (Dell GX270™), table, and chair. The stimuli were presented on the computer's monitor (Dell™ 19inch LCD, Brightness 88/100, Contrast 70/100, pixilation: 1280x1024) with the participant's responses being made using the computer's keyboard, mouse, and a "dial" manipulatable used in the pilot experiment. The Griffin Technology™ *Power Mate* USB multimedia controller was used as the dial, which can be turned in a 360° fluid movement. Experimental conditions were controlled by and data recording was done using a Visual Basic.net (2008) program. Additionally, for the color test, Ishihara color test plates were again used.

Differing from the pilot investigation was how the presentation of color stimuli were programmed. A change from the red-green-blue (RGB) scale to a hue-saturation-luminance scale was used as it has been shown that the HSL model is better suited for human interaction (Levkowtiz, 1997). Additionally, Gonzalez & Woods (1992) note that when using the RGB model, luminance values for each of the red, green, and blue values will be different. The result is that important properties of an image of color will not appear natural in the RGB model (Gonzalez & Woods, 1992).

The benefit of moving to a HSL color model is the increased control gained by being able to hold two variables (saturation and luminance) constant while still selecting colors of varying hue. Levkowitz (1997) likened it to how a painter prepares a color by first selecting a pure hue, then adding white to get tint, followed by black to achieve a shade, or mix both to get a tone. Levkowitz (1997) notes that "the more white mixed in the color, the less saturated it will be, the more black in it, the darker (less luminance the color will have) it will be" (p.49, parenthetical statement added).

In the HSL color model, hue is selected from values ranging from 1 to 360, while saturation and luminance are values between 0 and 1. For all colors presented in the investigation, both saturation and luminance are held constant at .45. The values were selected due to the appearance of varying hue values across the color spectrum being sufficiently light while at the same time not excessively muting the differing colors.

The quantification of participant's matching response were determined by the HSL color model used in the programming of the study. The colors were first programmed in an HSL model and then covered to RGB for display by the computer. Colors in the HSL model need to be converted to the RGB model for presentation through computer hardware (Levkowitz, 1997). These conversions are made in the computer program and are done in a manner that retains the hue, saturation, and luminance qualities of the HSL model. Matching responses done by the participant were recorded as an RGB value and then converted back to HSL by the computer program. As a result, all color values described are done using hue values ranging from 1 to 360.

Design and Procedures

The same experimenter conducted all sessions. The experimenter greeted the participant and reviewed the relevant consent material before leading the participant to the experimental room. Upon entering the room the participant was seated in front of the computer monitor where the program's instructions were presented. If the participant had any questions the experimenter explained relevant procedural details only.

The experiment was completed in one session and lasted no more then 60 minutes. The experiment consisted of a pre-assessment colorblindness task, to determine that the participants could perceive color accurately: followed by a training tutorial, a training condition, a testing tutorial, a testing condition, and a finial match-to-sample task.

Dependent and Independent Variables

The independent variable consisted of manipulating the presentation of colors during the testing phase. This manipulation resulted in the participant being presented with a primary color (either blue or red) before presenting the secondary violet test color. This differs from training, as there were no primary colors presented during that condition. The dependent measure was the participant's matching response to the presented color.

Pre-assessment: Colorblindness Test

The stimuli used for this assessment were three Ishihara color plates designed to evaluate color deficiencies on the visual spectrum. This was achieved by superimposing a number is embedded in a pattern of colored dots (see Figure 1). Upon being seated in front of the computer the first color plate was presented on the screen. The three-color plates were presented one at a time. Once the color plate appeared on the screen, the participant used number pad on a standard computer keyboard to enter the number they perceived to be superimposed on the plate. To move to the training tutorial the participant had to correctly identify each number on the three plates presented. Participants who did not identify the numbers correctly were thanked for their participation and excused. Upon entering the three correct numbers for each plate the follow instructions would appear:

> *"Welcome and thank you for participating. The experiment you are about to take part in is designed to see how you will behave in different situations. On the computer screen you will be presented with a color. When the gray screen appears your task will be to use the specially designed mouse wheel to match the color you've just seen. Once you see the color you've just seen press the space bar to indicate your choice. If the match is correct you will be shown a sign saying "CORRECT", if an incorrect match is made you will see "INCORRECT" appear on the screen. Before the experiment begins there will be several practice trials. It is important to understand that the more correct responses made, the sooner the experiment will be finished. Once the experiment is over, precede to the adjacent room for debriefing.*
> *If you have any questions before beginning, please ask the experimenter now. Otherwise click anywhere on this message to begin.*

By clicking anywhere on the screen, the training tutorial was initiated.

Training Tutorial

The purpose of the tutorial was to provide the participant an opportunity to engage in no less than two correct mock training trials. These trials consisted of presenting a colored screen for three seconds followed by the participant having to match to the previously seen color within a designated range. Colors presented during the tutorial were not those contacted during either training or testing conditions of the investigation. The hue values used in the training tutorial ranged from teal (hue:60), to green (hue: 120), to yellow (hue:180). The first screen was green (hue: 120) with a text label reading "Practice" in the lower center of the screen. This label remained on all subsequence screens during the tutorial. Additionally, "Screen 1" was written in the center of the screen. Following the three second green screen a gray screen appeared with text in the center of the screen reading "Match to Screen 1". At this point the participant would manipulate the dial, resulting in immediate changes of color on the screen. Each movement of the dial resulted in a change in color of two hue values either toward 180 or 60 depending on the direction of the movement.

Just as in the pilot investigation, the gray would dissipate from the screen after four movements of the dial in any direction resulting in only hue values ranging from 60 to 180. When the screen registered hue values plus/minus 10 from the presented green color (i.e. a range from 110 to 130) text would appear in the middle of screen reading: " That's it! Hit the Space Bar". By pressing the space bar while this text was present, text reading "Correct" appeared in the center of the screen. If the participant had not pressed the space bar within the specified range, text reading "Incorrect" appeared on the screen. After either case a five second intertrial interval (I.T.I) of a black screen was presented before the next trial would begin. The participant was given fifteen seconds to make a response. If the participant did not make a response within fifteen seconds, text reading: "You waited too long to make a response", and another tutorial trial would begin after the ITI. Two correct tutorial trials needed to be completed before the training condition began.

Training

The training condition consisted of a three second presentation of a secondary test color. Three secondary test colors were used as stimuli this phase. Violet, (hue: 300); a variation of violet that was bluer (hue: 287); and a variation of violet that was redder (hue: 313). The manipulatable was set to move two hue values with each registered movement of the dial, thus resulting in 30 movements from violet to either red or blue.

After the test color was presented for 3 seconds, the participant used the manipulatable to change the color on the computers screen to match the previously seen color within a pre-programmed range. The range was any value plus/minus ten hue values from the presented color. Unlike the tutorial, no text is present on the screen during stimuli presentation with the exception of feedback after the participant had indicated their response. Once the test color had been presented for 3 seconds a gray screen appeared. The gray screen faded from gray to either hues of violet to blue or violet to red depending on which direction the participant turned the dial. The gray hue persisted only for 4 incremental movements in either direction before it disappear completely with only violet, red and blue hues remaining. Once the participant moved the manipulatable either left or right, different variations of color along the spectrum of red-to-violet-to-blue appeared. The manipulatable was programmed such that if the dial turned toward the right, greater and greater variations of violet-blue appeared until the manipulatable reached a point where only blue appeared (hue: 240). Subsequently, if the manipulatable was turned toward the left greater and greater variations of violet-red appeared until the dial reaches a point where only red appeared (hue: 360).

After moving the dial left to right, the participant indicated that the color on the screen best matched the previously seen test color by pressing the space bar. Just as in the pilot study, if the response fell within the designated range text reading "CORRECT" appeared on the screen. When the response was outside that range text that reads "INCORRECT" appeared. The participant had 15 seconds to indicate their response. After feedback had been delivered a five second black screen ITI was used to separate each trial. In the event that the participant didn't complete the matching task in the allotted time, the ITI still appeared followed by the next trial. To move from training to the testing tutorial the same criterion is used as in the pilot study of 3 correct trials for each of the 3 color variations presented. As a result nine correct trials would have had to be recorded for hue values: 300, 313, and 287.

Testing Tutorial

The purpose of the tutorial was to provide the participant an opportunity to engage in no less then two mock testing trials. After completing the training phase the participant was presented with the following instructions on a white background:

> *"Great work! Now you are about to start the next phase of the experiment. In this phase, once the gray screen appears use the wheel to make the current screen match the LAST SEEN color and press the space bar. There will be a few practice trials before the next phase begins." Click anywhere on the screen to begin.*

After using the mouse to click on the screen the screen changed to a yellow screen (hue: 60) for five seconds with text in the center of the screen reading: "OK lets practice"; immediately below which was text reading: "Screen 1". At the bottom of the screen the word "Practice" was present and continued to be present on all screens during the tutorial. After the five seconds of yellow, the screen had turned to green (hue: 120) for three seconds with text in the center of the screen reading: “Screen 2”. After the three second presentation of green the screen would turn gray with text reading: “Match to screen 2”. The gray screen was again programmed to dissipate incrementally with each movement made by the dial until no gray was apparent on the screen after four movements in either direction. The participant moved the dial from left to right with hue values ranging from 60 to 180. No indication was given to the participant as to when a screen color was one that matched the second screen. This was done to mimic the testing trial format where not programmed consequences were presented. It was the participant’s task to indicate their final movement by pressing the space bar. To ensure that matched responses were only made to colors other then those at either end of the hue value range, a criterion was set where values ranging from 170 to 180 and 60 to 70 were not considered “correct”. In the event that a participant made an incorrect matching response, another tutorial trial was presented. A minimum of two tutorial trials was presented, each one separated by an ITI consisting of a five second black screen. For each trial, the participant was given fifteen seconds to make a response. If the participant did not make a response within fifteen seconds, text reading: “You waited too long to make a response”, and another tutorial trial would begin after the ITI.

Testing

During testing, participants were exposed to the independent variable of either a blue or red color stimulus for five seconds. Following the presentation of the IV the test color was presented for three seconds and then the participant engaged in the matching task with respect to the test color. The matching task was identical to the one used in training; however, no programmed consequences were given during the testing phase. Each trial was separated by a 5 second ITI consisting of a second black screen.

Three trial variations were used in the testing condition. A blue-to-violet trial consisted of a blue screen presented for five seconds, followed by the violet test color for three seconds. Red-to-violet trials had red presented for five seconds followed by a three second presentation of the test color. Additionally, an extended violet trial variation was used where the violet test color was presented for eight seconds. The three trial variations were semi-randomly presented for 24 trials (eight trials per variation). The dimensions for the primary colors used were hue: 360 for red, and hue: 240 for blue. The test color never changed during the testing condition, each presentation of the test color (violet) has dimensions: hue: 300.

Immediately following the test color, a gray screen was presented, which indicated to the participant that the matching task had begun. The dial was again programmed to change the screen color by two hue units along the spectrum of red to violet to blue. Participants had 15 seconds to indicate their response by pressing the space bar. If no response was made in the allotted time the ITI black screen appeared for five seconds followed by the next testing trial. No programmed consequences were provided during this condition. Upon completion of the 24 trials, the participant engaged in the match-to-sample procedure.

Match-to-Sample

To further ensure that participants had followed instructions a three trial match-to-sample procedure was used. After completing the 24 testing trials the participant was presented with the following instructions:

> *"Congratulations you have now reached the last condition of the experiment. For this condition the same colors will again be presented as in the last condition. After the color sequence is presented, 3 colors squares will appear. Using the computer's mouse you will "click" on the color square that represents the LAST SEEN color."*

During this phase one trial of each of the three testing conditions trial variations were presented in the same manner as in the testing phase. That is to say, that a primary color was presented for 5 seconds followed by a 3 second presentation of the violet test color. The only exception to this would have been a trial where violet is presented for 8 seconds.

In each trial, once the colors had been presented the participant was exposed to three colored boxes. One box with a blue hue (hue: 240), the other red (hue: 360), and lastly a violet (hue: 300) box. The participant then used the computer's mouse to select a colored box by pressing the right mouse button when the cursor was placed over the box.

Data Analysis

Participants' matching responses were used to determine the way in which the participant perceived a presented color. For example, matching responses made in training were used in determination an average response to the violet hue. These data were then used in the analysis of the testing data by providing a point of comparison for matches made to the violet test color during testing.

Results

Tutorial Data

Performance during training tutorial trials is presented in Table 2. The table shows each of the 10 participant's tutorial trials to completion in training and testing as well as the mean response differentiation. Mean differentiation refers to calculating how far the matching responses differed from the presented color. In the case of training, the presented color was hue: 120. For these trials each matching response was then recorded to determine the numerical distance away from hue: 120. For example, Participant E_01's first response was hue: 126 followed by a response of hue: 128. These responses resulted in a total difference from hue: 120 of 14 hue units from the presented color. This number was then divided by two (i.e. the number of tutorial trials) resulting in an average response differentiation for training tutorial trials of 7 hue units (See Table 2). During the tutorial participants took no more than three trials to complete with one participant (E_07) requiring an additional trial due to no responding in the allotted 15 seconds. Average response differentiation ranged from 5 hue units (E_08) away from the presented color to 13 units (E_03 & E_06).

Training Data

Training data for the ten participants are shown in Table 3. All participants met the requirements of at least three correct trials for each of the three variations presented. Eight of the ten participants did require more then three trial presentation of the violet color to meet these requirements. Average response differentiation, which is calculated in the same manner as the tutorial trials, shows that for seven of the ten participant's responding occurred within a plus/minus ten hue units from violet (hue value: 300).

Additionally, standard deviations (SD) scores are provided for each participant's performance to give a measure of the variability around the average differentiation. These scores were calculated by taking the square root of the summed raw scores divided by the number of trials, subtracted by the squared average differentiation.

Participant E_01 completed testing in three trials with average response differentiation of two hue units from the violet test color. The standard deviation of 2.3 from the average indicate that the participant's responding remained consistent for the three trials. Participant E_02 required six trials to complete the training to the violet test color, with a mean response differentiation of 13.3. The standard deviation score of 10.6 indicate that for participant E_02's matching performance was variable around the average response to violet. Participant E_03 completed training in five trials. The average differentiation was 9.2 hue units from the test color, which denote responses on average were within the plus/minus ten units from the test color. SD score of 5.4 show variability around responding for participant E_03. Participant E_04 completed training in three trials. Mean response differentiation of 1.3 and SD score of 2.3 indicate accurate matching performance to the test color. For participant E_05, who completed training in five trials, both average differentiation (27.3) and SD score (31.7) shows inaccurate and variable responding to the test color. Participant E_06 finished violet training in four trials. Mean response differentiation (6.5) demonstrate performance that stayed within the plus/minus ten hue units from violet, however SD score of 5.7 indicate that variability was observed in average responding. These data correlated with the necessity for participant E_06 requiring more than three training trials to move to testing. Participant E_07 finished training to the violet test color in four trials. Average response differentiation (2.5) and variability around the differentiation (SD = 2.5) indicate consistent and accurate performance in training. Closer inspection of the data for participant E_07, show that the forth training trial was a by product of the semi-random trial presentation method used, where in this case an extra trial had been presented to the participant. Participant E_08 completed training in four trials. Average responding away from the test color of 9 hue units with a SD score of 11.4 indicates that responding was less accurate to the test color. Participant E_09's average response differentiation to the test color resulted in a mean score of 14.5 for the four training trials. A SD score of 11.7 show considerable variability around the average response differentiation. The finial participant (E_11) completed training in five trials. Average response differentiation of 12 hue units with a SD score of 13.2 demonstrate variable and somewhat inaccurate matching responses to the violet test color.

Testing Tutorial

Performance during the testing tutorial is provided in Table 2. Data are provided for the number of testing tutorial trials needed to complete the tutorial. Only one participant required more than the two tutorial trials. Participant E_02 responded outside the correct criteria during their second trial and as a result a third tutorial trial was presented. Average response differentiation in testing tutorial trials are additionally shown in Table 2. These data were calculated in the same manner as were the training tutorial. For example, Participant E_01 completed the testing tutorial in two trials, with the first response being hue: 126 followed by the second response of hue: 114. This resulted in a total of 12 hue units from the presented hue: 120 color. Dividing this number by two results in a mean testing tutorial differentiation of 6 hue units. Average differentiation ranged from 2 (E_08) hue units from the presented hue: 120 to 27.3 (E_02) units from the presented hue: 120.

Test Performance

In the analysis of testing performance the average response differentiation and average violet hue value was used. These data are shown in Table 4 & 5 respectively. These data determine the location of the ordinate intersect (i.e. average response to violet test color) and show the average differentiation as bars both above and below the ordinate intersect (i.e. differentiation envelopes). Calculating the average response to the violet test color is done by summing all responses to the violet test color during the extended violet trials in testing and dividing by the number of trials. This number is then used in determining the ordinate intersect for participants testing figures. The purpose of changing the ordinate intersect is to represent the average seen color. In so doing, a better indication of how that specific participant matched to violet is shown, and comparisons across the other testing conditions are made to reflect the individual differences across participants. Table 5 provides the hue value for each participant.

The differentiation envelopes are calculated using the same method in determining mean response differentiation in the tutorial and training conditions. This value is then used to create a visual envelope above and below the average violet hue used as the ordinate intersect. Table 4 provides the values used to create the differentiation envelopes for each participant's test performance figure. By using the differentiation in the violet testing condition as an indication for the differentiation envelopes, determinations can be made as to how proceeding primary color come to effect the violet color.

Three categories of responding were observed in the testing performance of the ten participants: supplemented, contrasted, & undifferentiated. Supplemented performance is shown when responses to the violet color during testing moved in the direction of the primary color that had preceded the violet test stimulus. This pattern is seen for participants E_02 (Figure 8), E_05 (Figure 11), and E_08 (Figure 14). Contrasted performance was shown when responding to violet in the testing condition moved away from the violet color in the direction of the opposite primary color that had preceded the test color. This pattern is seen in participants E_01 (Figure 7), E_03 (Figure 9), E_04 (Figure 10), and E_06 (Figure 12). Undifferentiated responding was shown if the participant's responses failed to show a consistent direction of change during a testing condition. This was observed in participants E_01 (Figure 7), E_03 (Figure 9), E_04 (Figure 10), E_06 (Figure 12), E_07 (Figure 13), E_09 (Figure 15), and E_11 (Figure 16).

Participant E_01's testing data are shown in Figure 7. Comparing across testing conditions, where the ordinate intersect line is set at 296 representing the average responding to violet, shows undifferentiated responding in the violet testing condition with the majority of responses having values less than 300. The blue-to-violet testing condition represents an example of contrasted performance. In this testing condition all but one response exceeds the differentiation envelopes in the direction of red. Undifferentiated performance is observed in the red-to-violet testing conditions.

Participant E_02's testing data are shown in Figure 8. Testing condition performance was highly supplemented in both the blue-to-violet and red-to-violet trials. This exaggerated performance in testing conditions, questions the extent to which the participant was following the instructions. Similar responding was exhibited in testing performance for participants E_05 (Figure 11) and E_08 (Figure 14). All three participants had five or more data points in a testing condition exceeding 70% of the hue values from the presented color and a primary color. If five or more responses were shown to exceed 42 hue units from violet, their data were excluded. As a result, these data indicated that the participants were not following instructions despite passing tutorial and training conditions.

Figure 9 represents testing performance across conditions for participant E_03. The ordinate intersect is set at hue value 301, which indicate average matching to violet during violet testing as consistent with the presented hue value of 300. The consistency with which participant E_03 responded to violet are again demonstrated with the relatively small differentiation envelopes of 3.4 above and below the intersect line. Slight contrast performances are seen in the blue-to-violet testing condition with all responses moving from the ordinate intersect in the direction of red, and three responses exceeding the differentiation envelop. Undifferentiated responding is observed in the red-to-violet testing condition.

Participant E_04's testing data are shown in Figure 10. Performance in the violet testing condition was consistent with the presented hue value of 300, as indicated by the average hue value of 299 as the ordinate intersect. Differentiation envelopes were set at a value of 3 to demonstrate the lack of variability in this participant's responding in the violet testing condition. A slight contrast effect was demonstrated in the red-to-violet testing condition. Four of the seven responses exceeded the differentiation envelop in the direction of blue. Responses in the blue-to-violet testing condition are observed to be undifferentiated with responses remaining close to the average hue value.

Participant E_06's testing data in Figure 12 show a contrast effect in the blue-to-violet condition. Contrast was demonstrated by the majority of responses exceeding the average violet hue value obtained in the violet testing condition in the direction of red. Responses during the red-to-violet testing condition are shown to be slightly contrasting with the majority of responses in the direction of blue, with three of the eight responses (trials 1, 6, and 8) demonstrating significant contrast effects. Participants E_07 (Figure 13), E_09 (Figure 15), and E_11 (Figure 16) demonstrate examples of undifferentiated responding across testing conditions. Table 6 displays the average response differentiation for all 10 participants.

Discussion

The present study was aimed at demonstrating the extent to which the perception of a color could be impacted by prior exposure to a contrasting color within the same spectrum. Across 10 participants, 20 tests of this phenomenon were made. The results indicated that perception of the test color was impacted by the preceding color in 5 tests. Contrast patterns were observed in all of the 5 tests. Of the remaining 15 tests, the results were either inconsistent or showed performances that were assumed to show a lack of instruction following.

The purpose adding the match-to-sample procedure was to assess participants' instruction following. Exaggerated supplemental performance in testing was indication of a failure to follow these instructions. Figure 17 summarizes the match-to-sample data for the 10 participants. Six of the ten participants correctly responded to all three of the match to sample trials, while the remaining four correctly responded to two of the three trials. One of the three participants (E_05) with exaggerated supplemented performance in testing answered all three M-T-S trials correctly, while the other two (E_02, and E_08) selected an incorrect sample on one trial. Alternatively, Participant E_03, who also selected an incorrect sample on one M-T-S trial, demonstrated contrast effects during the blue-to-violet testing condition. The finial participant who missed one M-T-S trial (E_04) showed undifferentiated responding across testing conditions. Given this variety of response patterns, the M-T-S procedure did not provide conclusive evidence that a participant followed instructions.

Similarly, the training and testing tutorials were introduced to assume that the participants were following instructions. The tutorials data (Table 2) provides similar variety between tutorial and testing performance. For example, participant E_01 who demonstrated consistent contrast effects in the blue to violet testing conditions completed both tutorials in two trials with consistent average response differentiation between both training and testing tutorials. Conversely, participant E_08 data indicated that the instructions were not followed during testing conditions, completed both tutorials in two trials and had lower average response differentiation in tutorials as compared to E_01. Additionally, undifferentiated responding in testing was not predicted by tutorial performance. For example, participant E_09, whose tutorial performance is the same for both training and testing demonstrated considerable, undifferentiated responding in both the blue-to-violet and red-to-violet testing conditions. These comparisons demonstrate that individual participant's performance varied from tutorial to testing conditions. As a result, the impact the tutorial had on clarifying instructions to the participant is unclear. Further investigations will need to establish the utility of tutorials of this kind to afford adequate instruction following.

Performance in the violet testing condition show some interesting patterns. The average violet hue selected (Table 5) for participants whose responses were shown to be undifferentiated in both the blue-to-violet and red-to-violet remained closer to the test color than those participants who demonstrated contrast effects. All participants showing undifferentiated performance in both blue-to-violet and red-to-violet testing conditions had average responding to the test color (hue: 300) no more then two hue units away.

In contrast, participants E_01 and E_06, demonstrated differentiated responding in the blue-to-violet testing condition and responded on average of four hue units from the test stimulus. These data indicate that the violet test color appeared bluer. These data are similar to results reported by Ikeda & Morotomi (2002). In their study, when using a priming procedure of a 200ms single color stimulus presentation, "suppression" of the primed color stimulus was shown. Had there been more participants demonstrating the consistent contrast effect as shown in E_01, E_03, E_04, and E_06 a greater link between short stimuli presentation priming studies and those looking at the substitutive aspects of perceptual stimuli could be established.

The present investigation was an attempt to demonstrate how setting factors (i.e. stimuli immediately preceding a test stimulus) affect a person's matching behavior with respect to a test stimulus. In other words, the study attempted to show how the functional properties of perceived stimuli interact in the perception of subsequently presented stimuli. Functional transformation has been used as a term describing how the functional properties of stimuli come to affect subsequent responding to other stimuli.

The current investigation shares features with Tonneau et al. (2006), which showed how observing stimuli continuously in time can come to affect later equivalence responding. These effects are evident in the contrasting performance of participants E_01, E_03, E_04 and E_06. A critical point of departure from the Tonneau et al. (2006) study however, is that the current investigation allows for considerable response variability. The matching procedure used in the current study allowed participants to make equivalent matches as well as ones that may deviate along a continuum. By allowing for responding to occur along a continuum, the likelihood of undifferentiated responding is increased as shown by participants' responses in at least one testing condition.

Perception is a subtle behavior that occurs before or in conjunction with more overt behavior. The current investigation offers a method for capturing these subtleties. The variability in participant responding speaks to the flexibility of perceptual responses. Four of the seven participants who were presumed to have followed the instructions showed a contrast effect. This effect has been demonstrated at the physiological level under adaptation conditions (Webster, 1996) however; at the psychological level these findings are new. Furthermore, the timing lengths used in the current investigation do not align with the experimental preparations associated with adaptation where very long timings are used.

Priming is often seen as a supplemental process whereby proceeding stimuli facilitate subsequent responding. The current findings of contrast effects differ from the priming notion. More importantly, all instances of supplemental responding found in the current investigation were obtained from participants who were determined to have not followed instructions. The literature on the priming phenomena is vast and ever changing and if results like those found by Ikeda & Morotomi (2002) are found consistently, there may be changes to the conceptualization of the supplemental effect that primed stimuli have. Until then, however, the current findings do not support the conclusion of primed supplementation.

Further research should look into the capacity with which participant generated rules impede the investigation of perceptual phenomena. It may be the case the rules influence the way in which a person perceives stimuli, or simply that the perception of stimuli occur and subsequent rules are generated which affect performance thereafter. To this, methods could be developed that would decrease the formation of rules. For example, requiring participants to engage in other tasks while being exposed to visual stimuli may reduce the generation of rules. Along with more extensive tutorials as discussed earlier, eye-tracking technologies may be used to ensure that participants contact the presented stimuli. For example, a tone could be presented upon a participant's turning their eyes from the screen and remain on until eye contact was resumed.

In closing, the current investigation sought to capture the subtleties of perceptual interactions, and in so doing, demonstrated the variability with which subsequent responding occurs. Setting factors were not shown to impact perceptual behavior in a consistent manner across participant. Further research is needed to address these subtle phenomenons.

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TABLES

Table 1

Average Response Differentiations from Presented Color				
Participant	**Violet Training**	**Violet Testing**	**Blue & Violet Testing**	**Red & Violet Testing**
D_01	-8	3.75	6.9	2.75
D_03	3.33	-1.75	92.22	-121.75
D_04	0	0	70.22	-89.5
D_05	-6.67	1.14	107.11	-113.5
D_06	-6.8	-6.76	-2	0.75

Table 2

Tutorial Performance Data				
Participant	Number of Training Trials to Completion (Lower Limit = 2)	Average Training Response Differentiation	Number of Testing Trials to Completion (Lower Limit = 2)	Averange Testing Response Differentiation
E_01	2	7	2	6
E_02	2	9	3	27.3
E_03	3	13	2	12
E_04	3	9	2	16
E_05	2	9	2	8
E_06	3	13	2	6
E_07	3*	9	2	19
E_08	2	5	2	2
E_09	2	6	2	6
E_11	3	9	2	11
* For one trial the participant failed to make a response in 15 seconds				

Table 3

Average Response Differentiations and Standard Deviations in Violet Training			
Participant	Training Trials to Completion	Response Differentiation	Standard Deviation
E_01	3	2	2.3
E_02	6	13.3	10.6
E_03	5	9.2	5.4
E_04	3	1.3	2.3
E_05	5	27.2	31.7
E_06	4	6.5	5.7
E_07	4	2.5	2.5
E_08	4	9	11.4
E_09	4	14.5	11.7
E_11	5	12	13.2

Table 4

Average Response Differentiation In Violet Testing	
Participant	**Average Difference**
E_01	8.8
E_02	6
E_03	3.4
E_04	3
E_05	5.75
E_06	6.25
E_07	5.1
E_08	22
E_09	10
E_11	3.4

Table 5

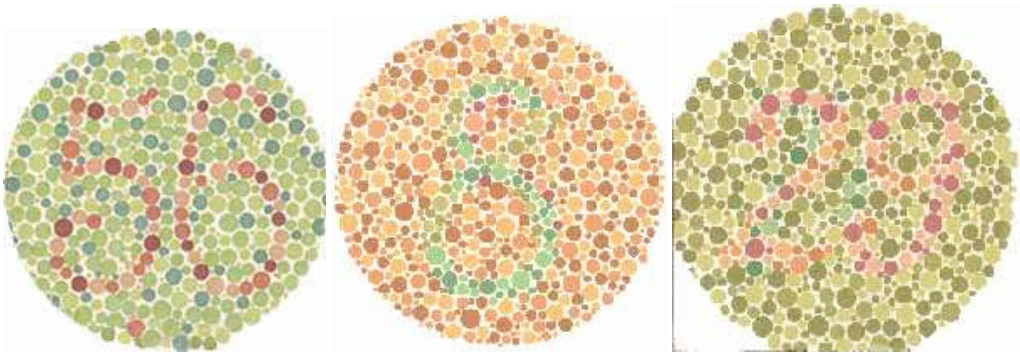
Average Violet Hue in Testing	
Participant	**Hue Value**
E_01	296
E_02	305
E_03	301
E_04	299
E_05	304
E_06	296
E_07	300
E_08	297
E_09	298
E_11	300

Table 6

Average Response Differentiations in Testing Trial Variations			
Participant	**Violet Response Differentiation**	**Blue to Violet Response Differentiation**	**Red to Violet Response Differentiation**
E_01	8.8	12.5	6.3
E_02	6.0	40.3	42.0
E_03	3.4	5.1	4.8
E_04	3.0	2.6	5.4
E_05	5.8	35.3	17.5
E_06	6.3	8.3	10.0
E_07	5.1	4.9	9.3
E_08	22.0	46.3	40.3
E_09	10.0	10.3	8.0
E_11	3.4	5.1	8.3

FIGURES

Figure 1



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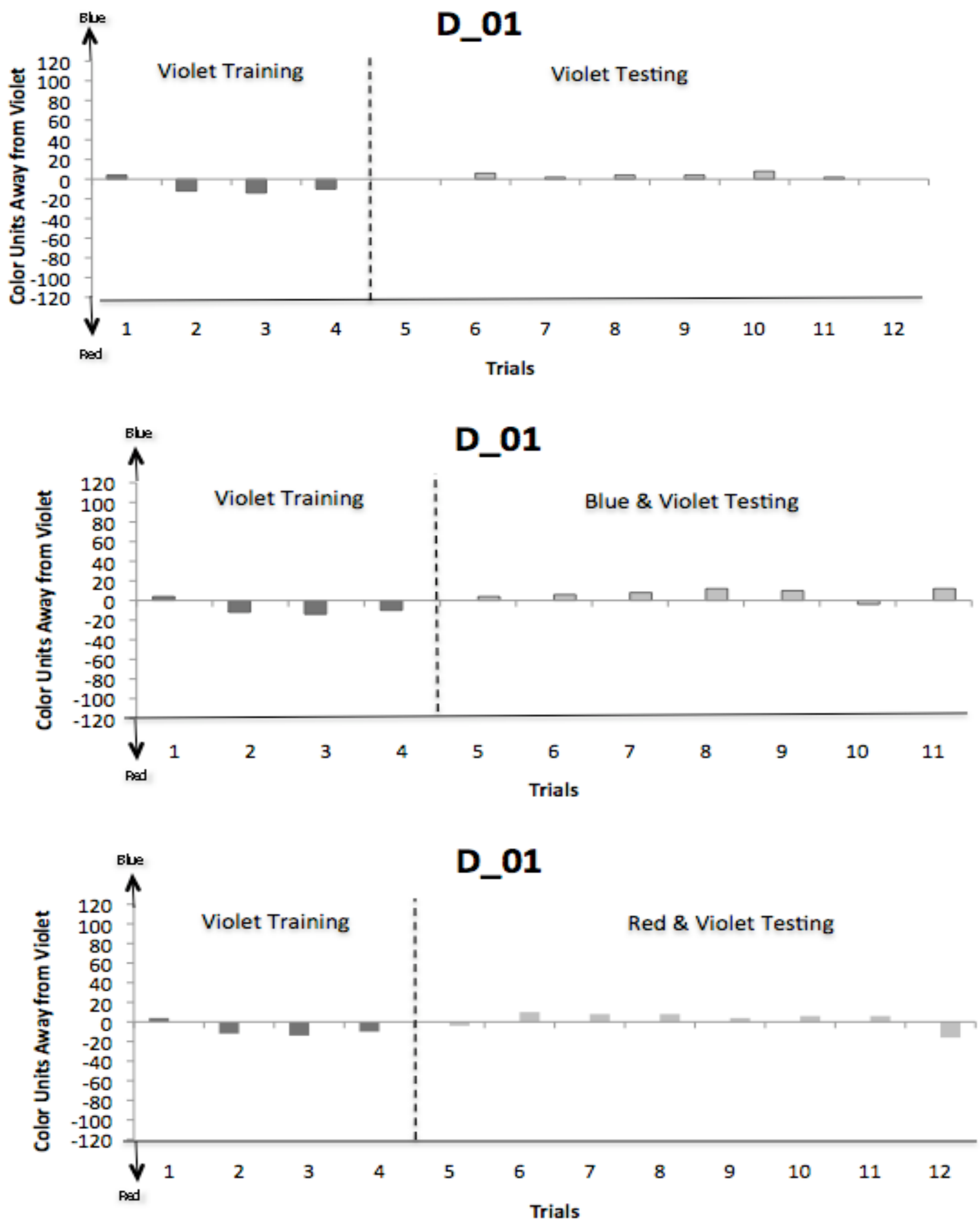

D_01
Blue
Red
Color Units Away from Violet
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
Violet Training
Violet Testing
1
2
3
4
5
6
7
8
9
10
11
12
Trials
D_01
Blue
Red
Color Units Away from Violet
Violet Training
Blue & Violet Testing
1
2
3
4
5
6
7
8
9
10
11
Trials
D_01
Blue
Red
Color Units Away from Violet
Violet Training
Red & Violet Testing
1
2
3
4
5
6
7
8
9
10
11
12
Trials

Figure 3

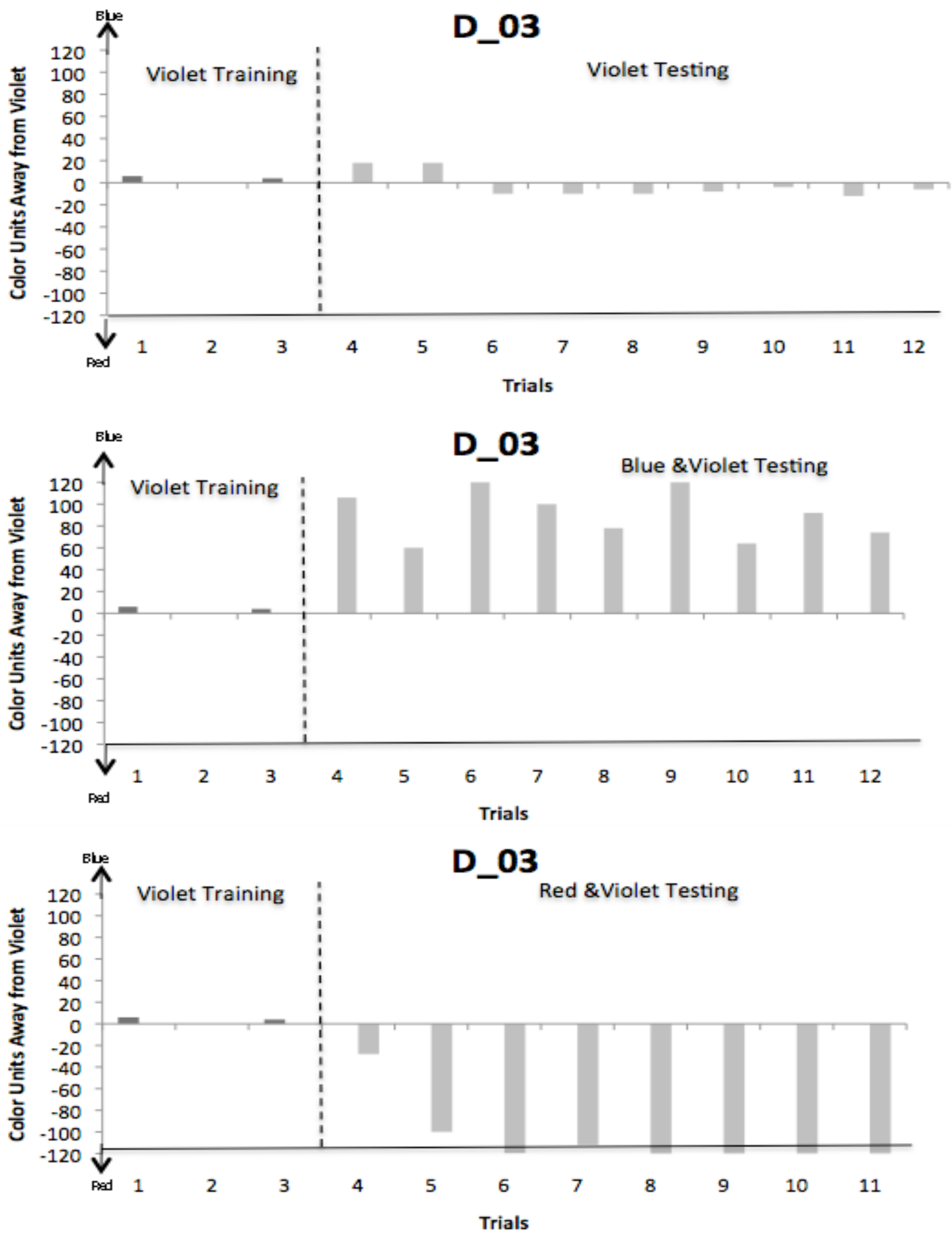

D_03
Violet Training
Violet Testing
Blue
Red
Color Units Away from Violet
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
1
2
3
4
5
6
7
8
9
10
11
12
Trials
D_03
Violet Training
Blue &Violet Testing
Blue
Red
Color Units Away from Violet
Trials
D_03
Violet Training
Red &Violet Testing
Blue
Red
Color Units Away from Violet
Trials

Figure 4

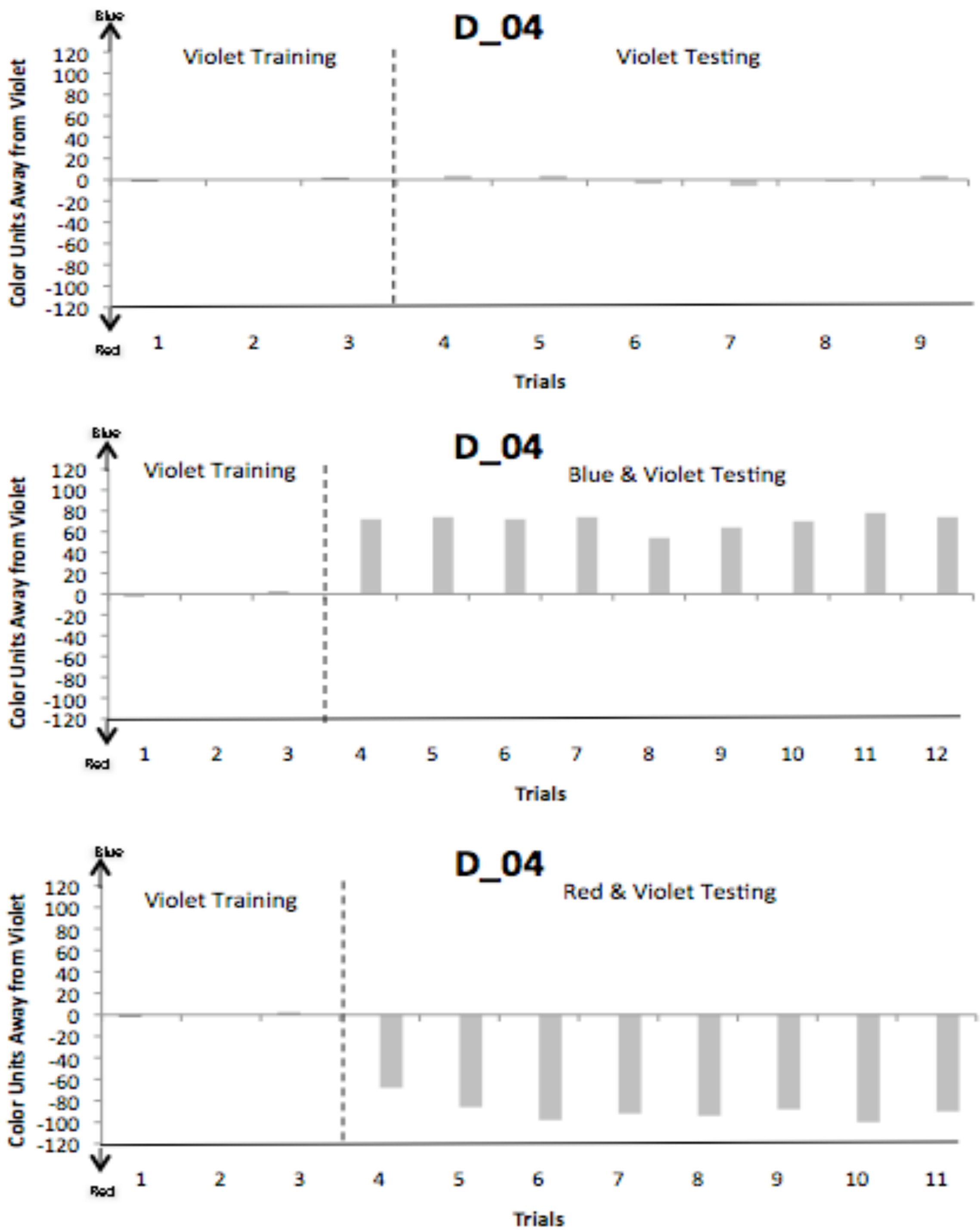
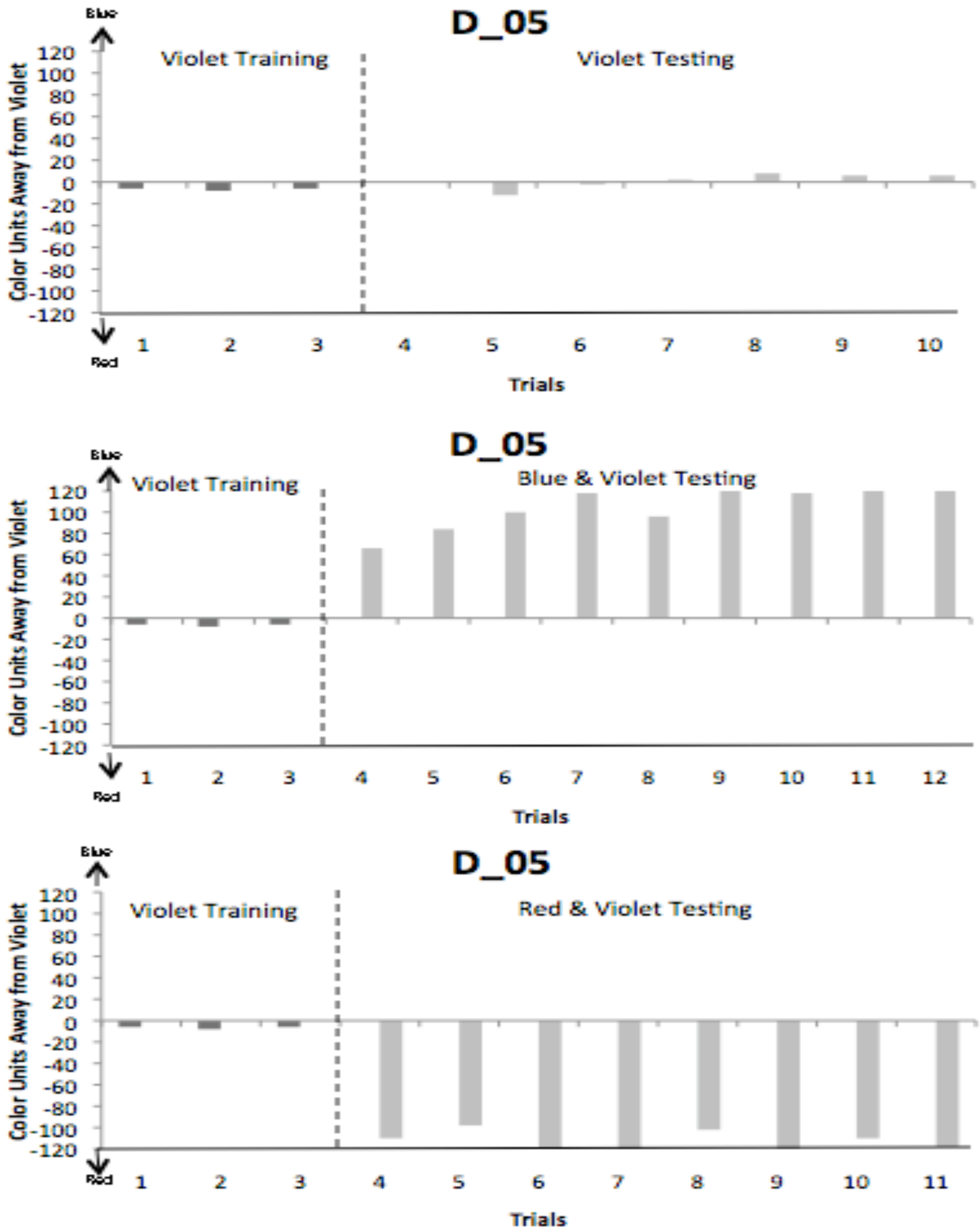

D_04
Violet Training
Violet Testing
Blue
Red
Color Units Away from Violet
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
1
2
3
4
5
6
7
8
9
Trials
D_04
Violet Training
Blue & Violet Testing
Blue
Red
Color Units Away from Violet
1
2
3
4
5
6
7
8
9
10
11
12
Trials
D_04
Violet Training
Red & Violet Testing
Blue
Red
Color Units Away from Violet
1
2
3
4
5
6
7
8
9
10
11
Trials

Figure 5



D_05
Violet Training
Violet Testing
Blue
Red
Color Units Away from Violet
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
1
2
3
4
5
6
7
8
9
10
Trials
D_05
Violet Training
Blue & Violet Testing
Blue
Red
Color Units Away from Violet
1
2
3
4
5
6
7
8
9
10
11
12
Trials
D_05
Violet Training
Red & Violet Testing
Blue
Red
Color Units Away from Violet
1
2
3
4
5
6
7
8
9
10
11
Trials

Figure 6

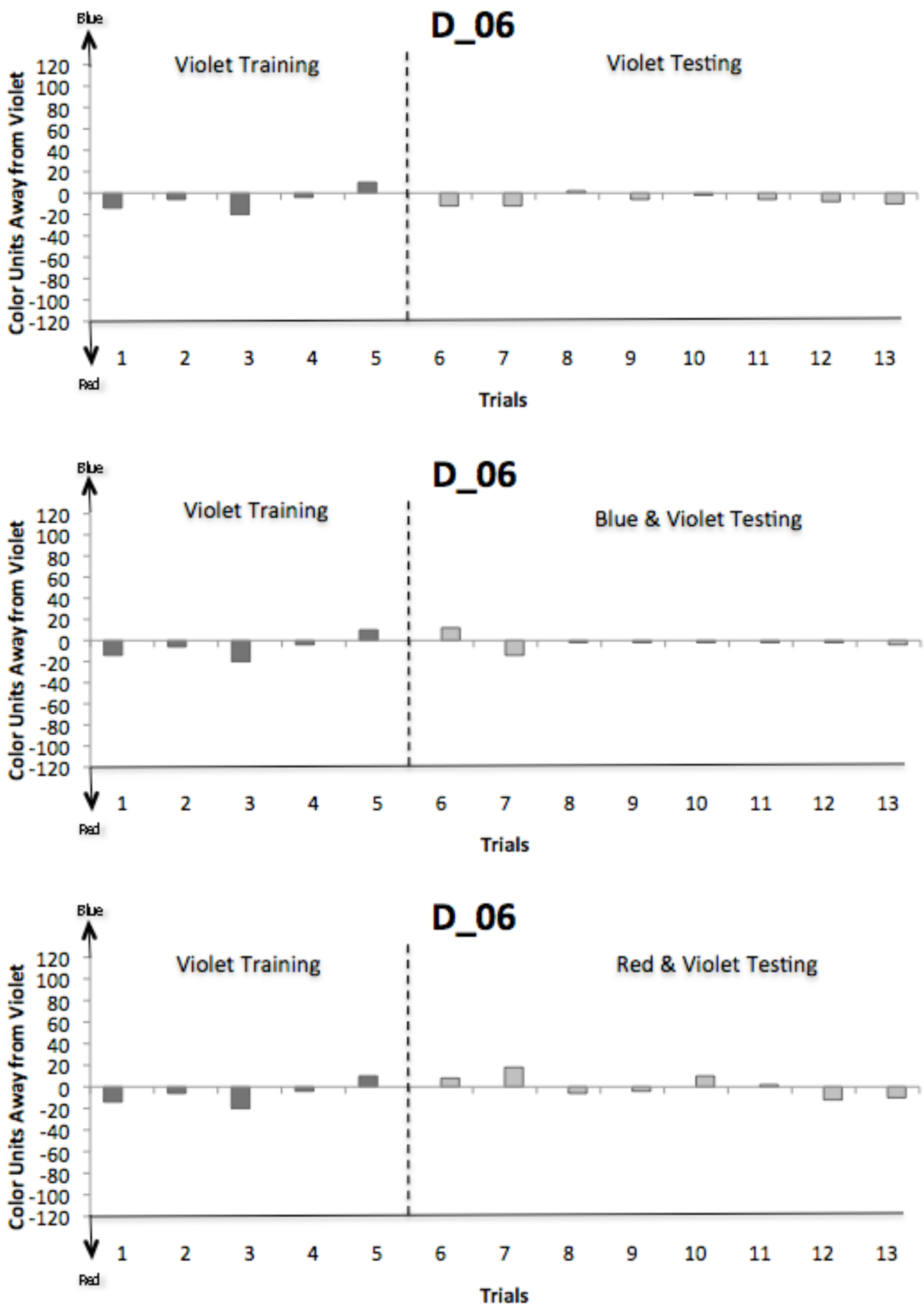

D_06
Violet Training
Violet Testing
Blue & Violet Testing
Red & Violet Testing
Blue
Red
Color Units Away from Violet
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
1
2
3
4
5
6
7
8
9
10
11
12
13
Trials

Figure 7

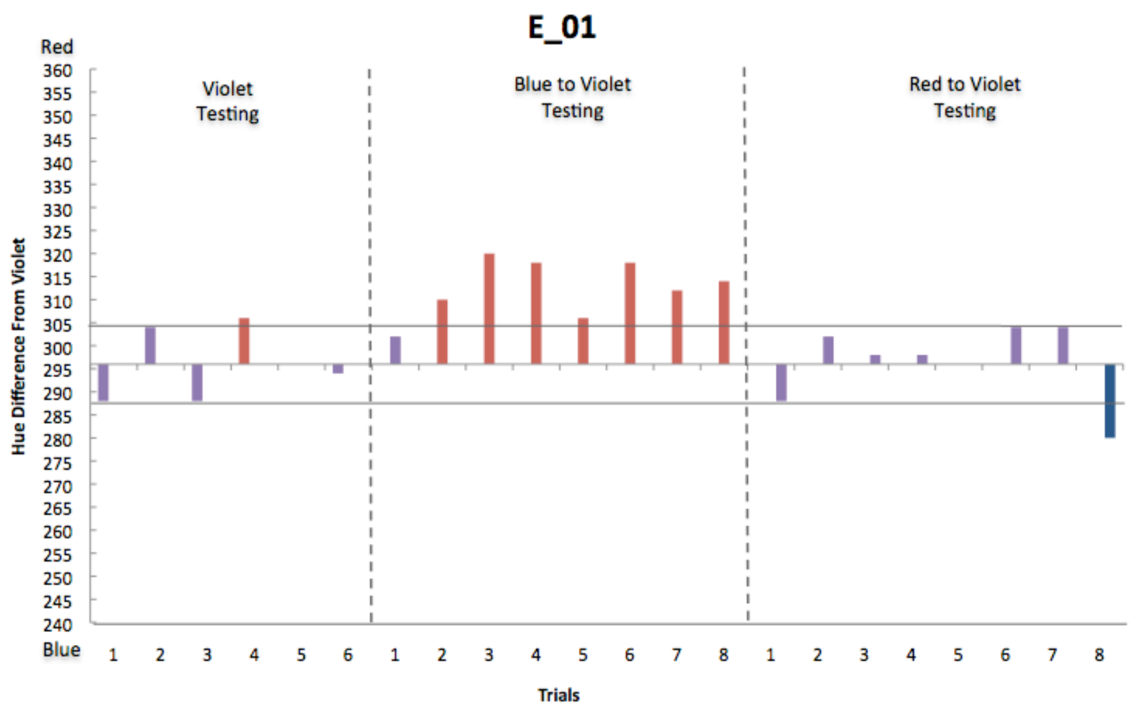

E_01
Red
Blue
Hue Difference From Violet
Violet Testing
Blue to Violet Testing
Red to Violet Testing
360
355
350
345
340
335
330
325
320
315
310
305
300
295
290
285
280
275
270
265
260
255
250
245
240
1 2 3 4 5 6 1 2 3 4 5 6 7 8 1 2 3 4 5 6 7 8
Trials

Figure 8

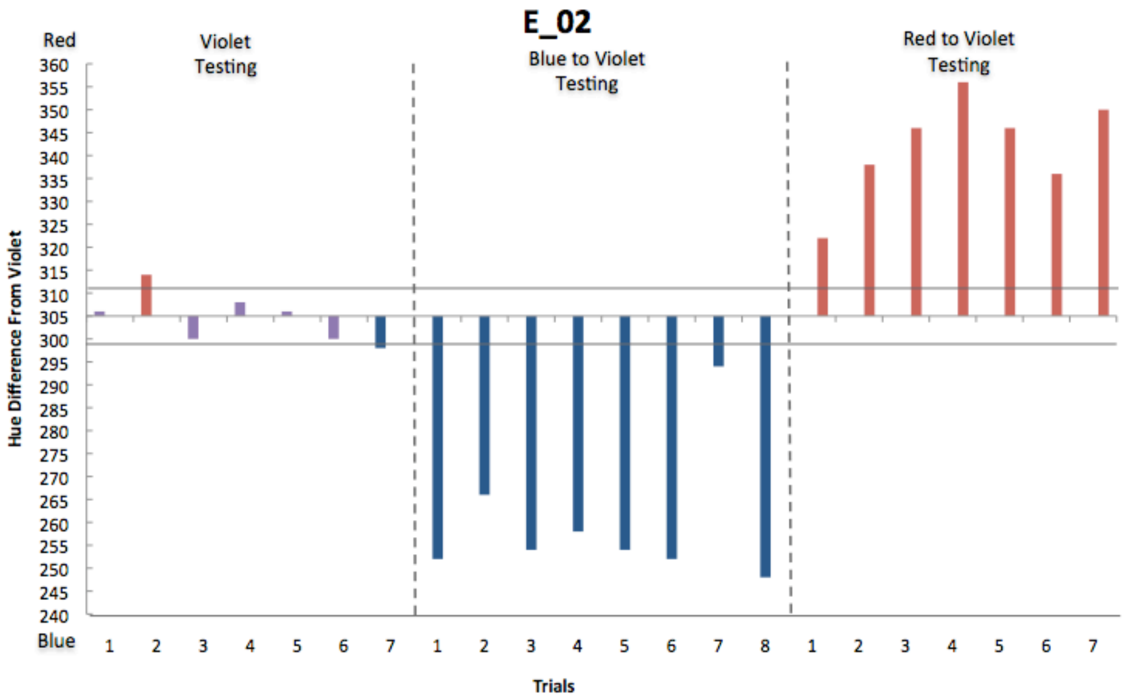

E_02
Red
Violet
Testing
Blue to Violet
Testing
Red to Violet
Testing
360
355
350
345
340
335
330
325
320
315
310
305
300
295
290
285
280
275
270
265
260
255
250
245
240
Blue
Hue Difference From Violet
1 2 3 4 5 6 7 1 2 3 4 5 6 7 8 1 2 3 4 5 6 7
Trials

Figure 9

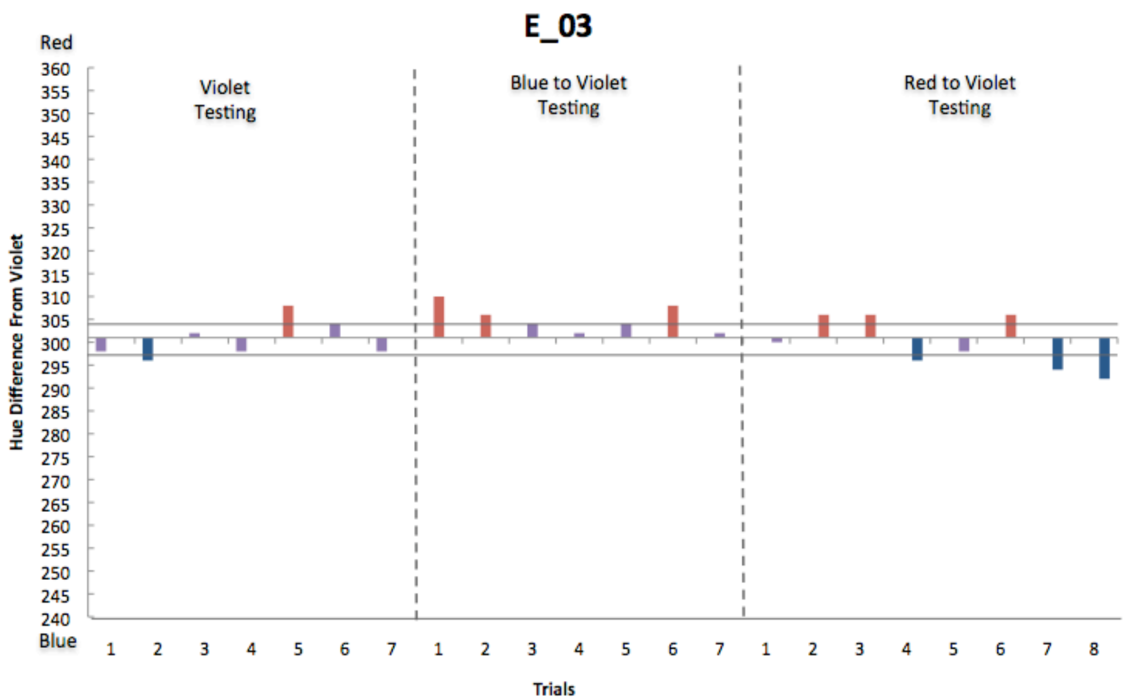

E_03
Red
Blue
Hue Difference From Violet
Violet Testing
Blue to Violet Testing
Red to Violet Testing
Trials

Figure 10

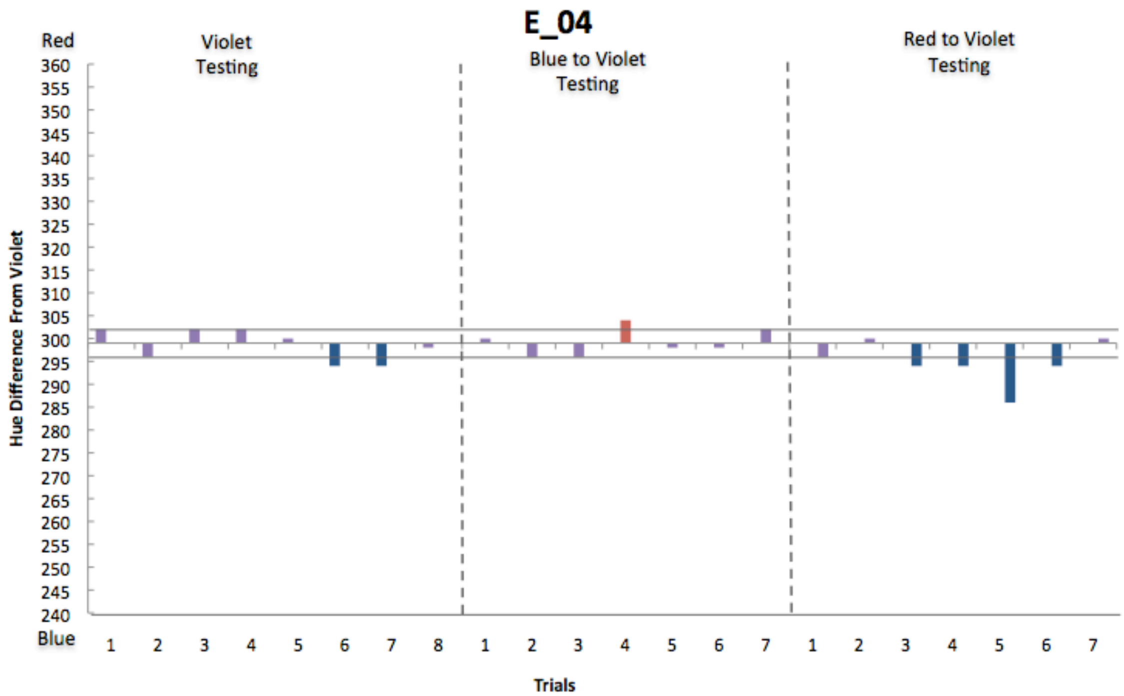
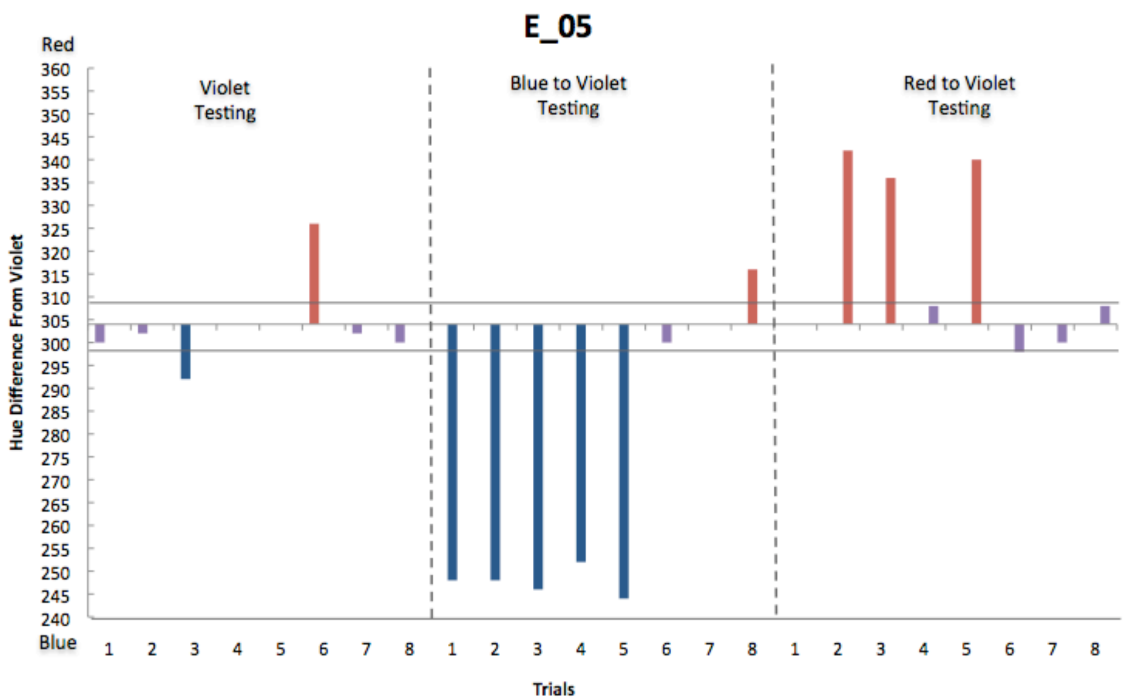

E_04
Red
Violet
Testing
Blue to Violet
Testing
Red to Violet
Testing
360
355
350
345
340
335
330
325
320
315
310
305
300
295
290
285
280
275
270
265
260
255
250
245
240
Blue
Hue Difference From Violet
1 2 3 4 5 6 7 8 1 2 3 4 5 6 7 1 2 3 4 5 6 7
Trials

Figure 11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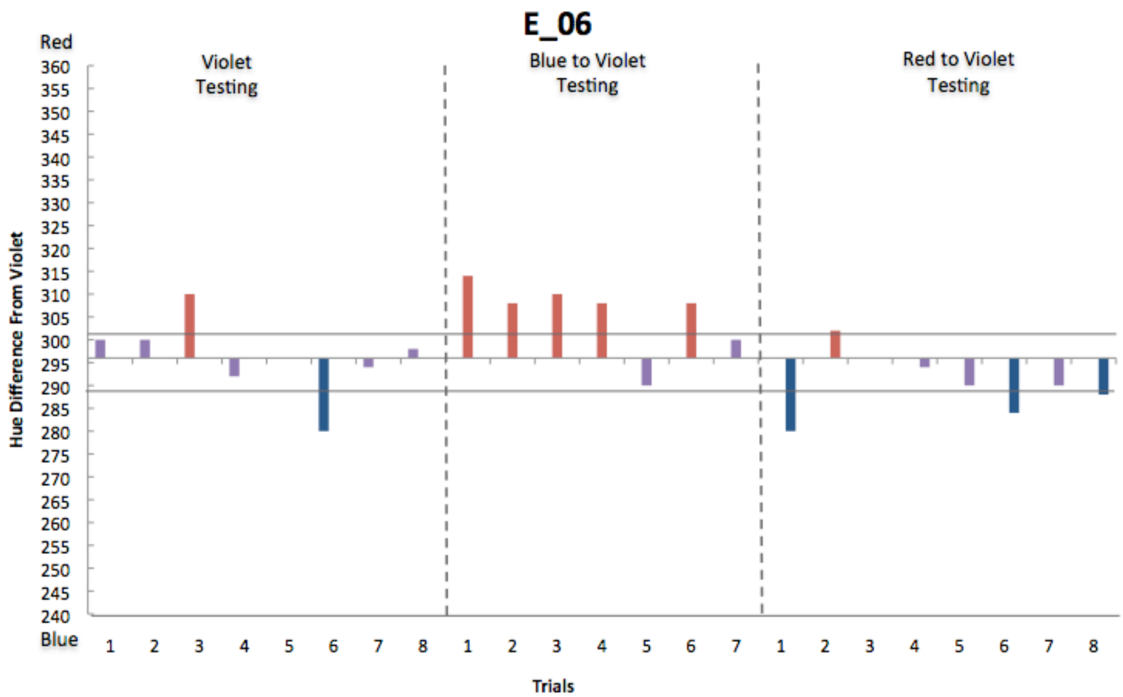
Red
Blue
Hue Difference From Violet
360
355
350
345
340
335
330
325
320
315
310
305
300
295
290
285
280
275
270
265
260
255
250
245
240
Violet Testing
Blue to Violet Testing
Red to Violet Testing
1 2 3 4 5 6 7 8 1 2 3 4 5 6 7 8 1 2 3 4 5 6 7 8
Trials

Figure 12


E_06
Red
Blue
Violet
Testing
Blue to Violet
Testing
Red to Violet
Testing
Hue Difference From Violet
Trials
360
355
350
345
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335
330
325
320
315
310
305
300
295
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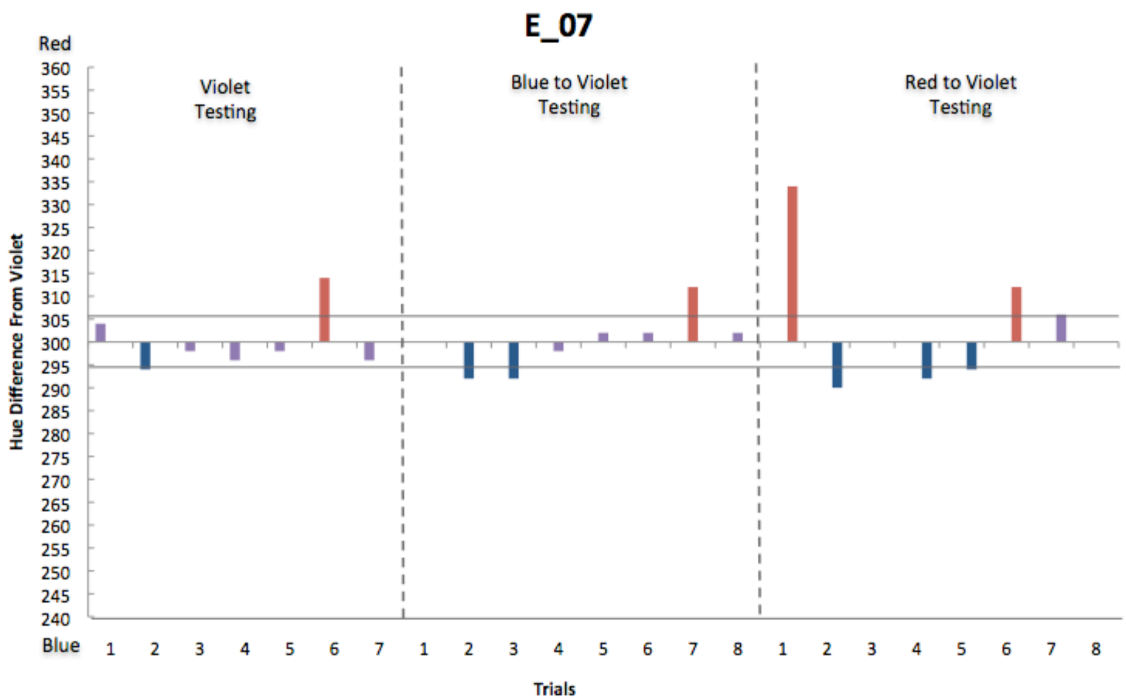
Figure 13


E_07
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Blue
Hue Difference From Violet
Violet Testing
Blue to Violet Testing
Red to Violet Testing
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355
350
345
340
335
330
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320
315
310
305
300
295
290
285
280
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270
265
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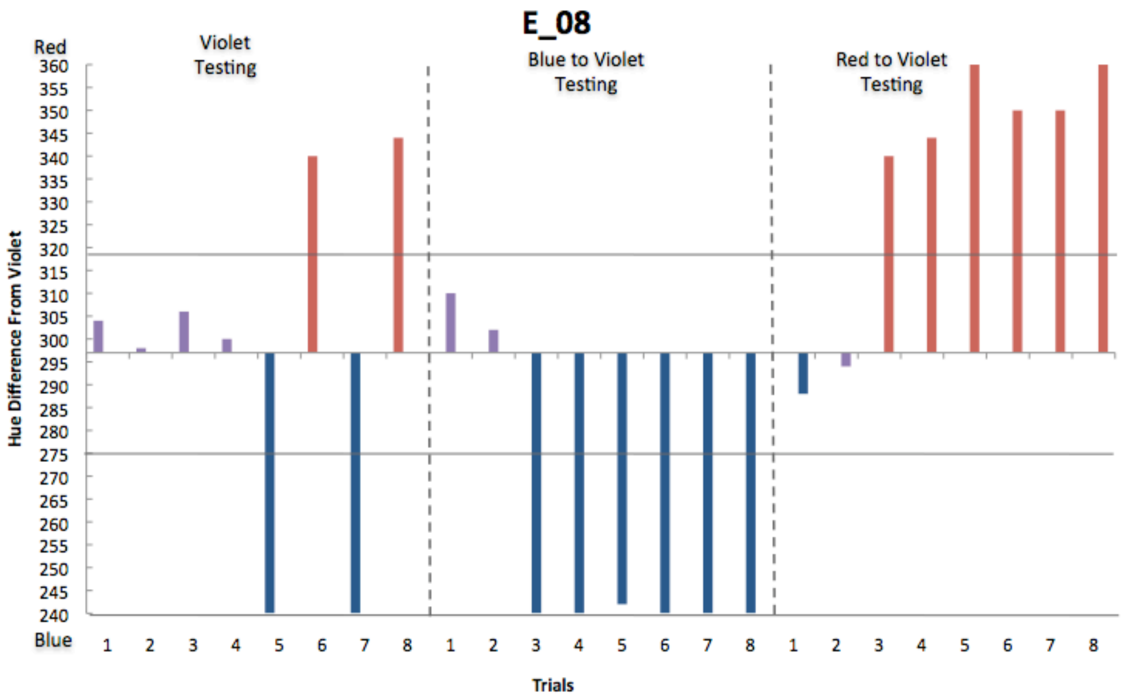
255
250
245
240
1 2 3 4 5 6 7 1 2 3 4 5 6 7 8 1 2 3 4 5 6 7 8
Trials

Figure 14


E_08
Violet Testing
Blue to Violet Testing
Red to Violet Testing
Red
Blue
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355
350
345
340
335
330
325
320
315
310
305
300
295
290
285
280
275
270
265
260
255
250
245
240
Hue Difference From Violet
1 2 3 4 5 6 7 8 1 2 3 4 5 6 7 8 1 2 3 4 5 6 7 8
Trials

Figure 15

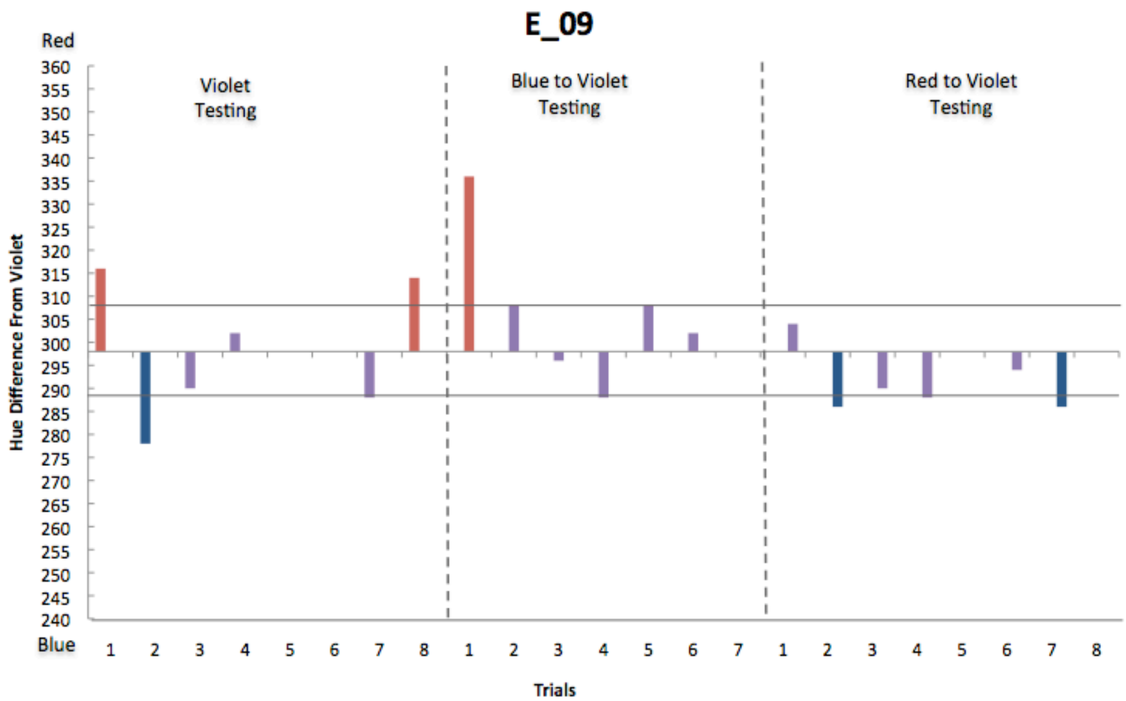

E_09
Red
Blue
Hue Difference From Violet
Violet Testing
Blue to Violet Testing
Red to Violet Testing
Trials
360
355
350
345
340
335
330
325
320
315
310
305
300
295
290
285
280
275
270
265
260
255
250
245
240
1 2 3 4 5 6 7 8 1 2 3 4 5 6 7 1 2 3 4 5 6 7 8

Figure 16

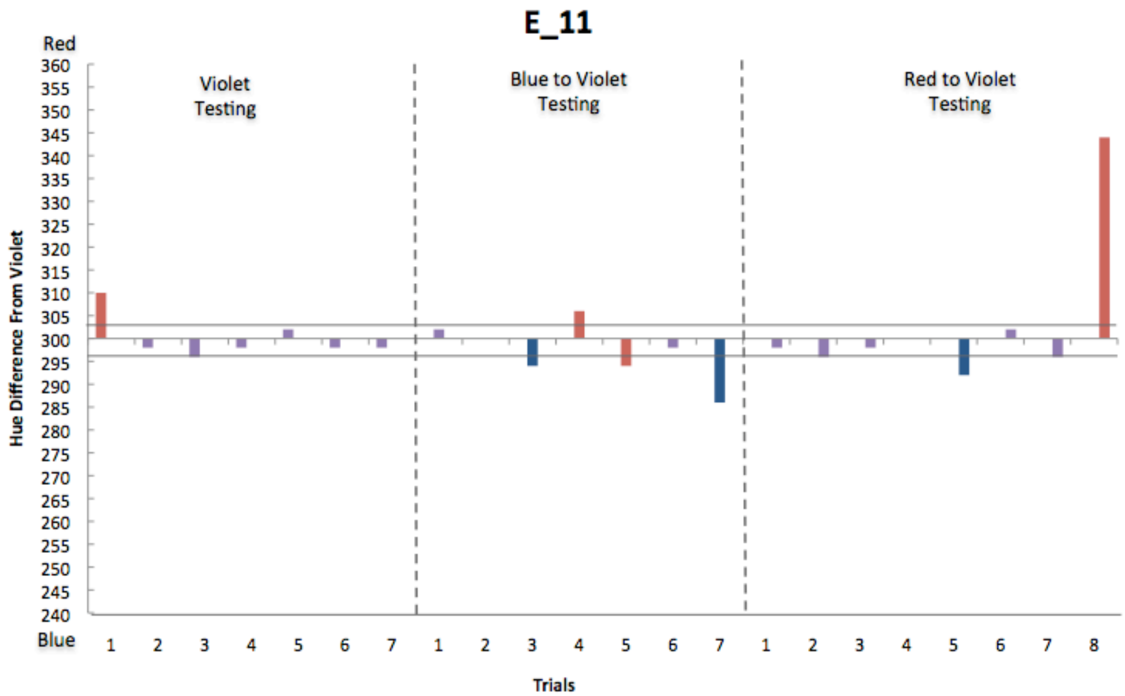
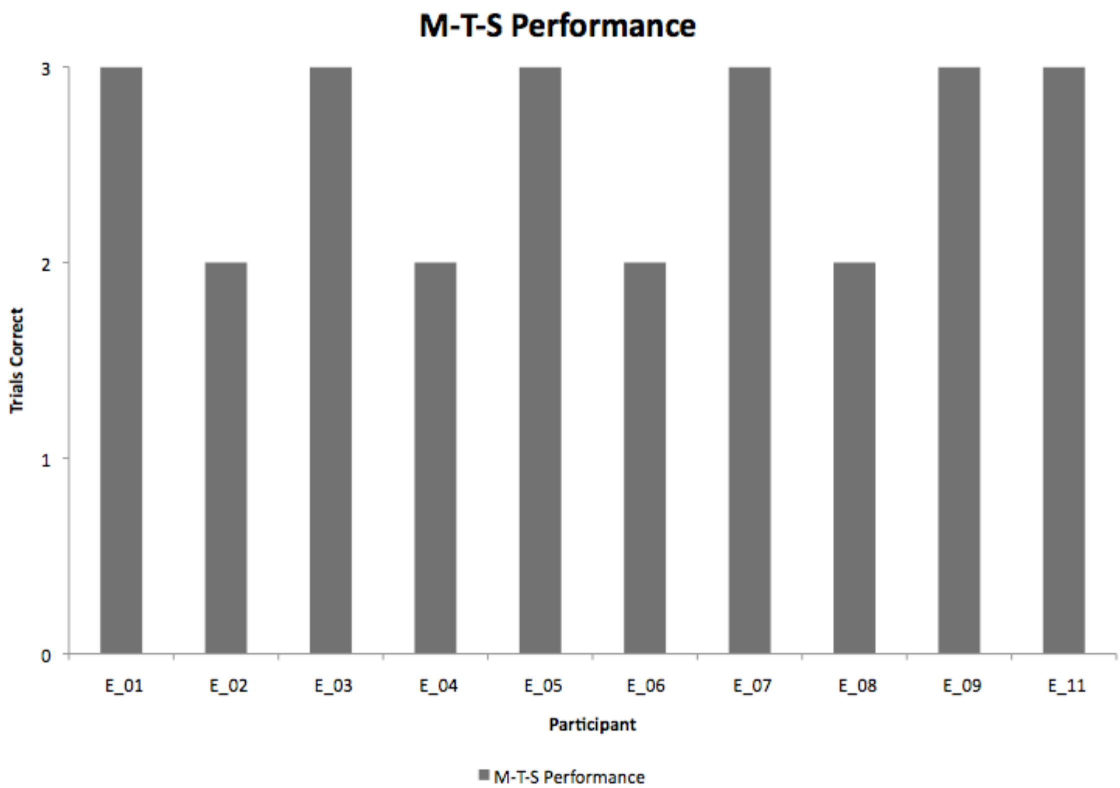

E_11
Red
Blue
Hue Difference From Violet
Violet Testing
Blue to Violet Testing
Red to Violet Testing
360
355
350
345
340
335
330
325
320
315
310
305
300
295
290
285
280
275
270
265
260
255
250
245
240
1 2 3 4 5 6 7 1 2 3 4 5 6 7 1 2 3 4 5 6 7 8
Trials

Figure 17


M-T-S Performance
3
2
1
0
Trials Correct
E_01
E_02
E_03
E_04
E_05
E_06
E_07
E_08
E_09
E_11
Participant
M-T-S Performance