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RESPONSE TO COLORS DIVERSIFY DURING THE EXECUTION PHASE OF MOVEMENT

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ABSTRACT

Whether the reason is general application or inherited genetic traits, the color red is always the most attractive one for many of us. The aim of this study was to investigate effects of this intense color on motor task performance. Eleven college students (6 female and 5 male) ranging in age from 20 to 23 years old participated in this study. Three primary colors in a standard color wheel (red, yellow, blue) were used for encoloring visual stimuli, target objects and backgrounds of target objects. A simple visual-search and reaching-grasping task was expected from the participants by using three different measurement setups which were prepared in the sense of cognitive difficulty. Results indicate that stimulus color has a significant effect on reaction time. Independent of setup complexity, when the stimulus color was red, reaction times were significantly shorter in all trials. These results gave rise another contribution to the argument that stands for emotional conditioning existence, resulting from color-emotional association and corresponding behavioral change in connection with thalamo-amygdala pathway.

Key Words: red, emotion, threat, amygdala, short-route, response, movement, performance.

INTRODUCTION

Among the others, eyes are the most trusted sense organs for humans in daily life and correspondingly majority of information about external world is provided on the basis of visual perception (Bornstein 1985). Under the evolutionary pressure of developing better color vision, sense of sight came a long way from dichromatic to trichromatic color vision (King, 2005). In virtue of this more sophisticated visual ability, perceiving and being able to distinguish millions of colors became possible. Color vision gave a chance our ancestors to develop necessary skills for pulling through life-sustaining situations in the wild (Kleiner, 2004). Even though modern people doesn't encounter bright warning colors of a coral snake or a poison dart frog, emotional associations with these colors doesn't change much by urbanizing lifestyle. Still most of us recognize the potential danger from the labels or signs which consist of similar colors arising from universal language of nature. It is thought that life-long association danger with particular colors creates conditional perception affecting memory structure and consequent response pathway resulting diversification in both cognitive and motor skill performances (Elliot et al., 2007; Feltman & Elliot, 2011; Fetterman et al., 2011; Young et al., 2013).

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LITERATURE REVIEW

Formation of a new memory starts with sensation of an internal or external stimulus. Human beings have a multitude of senses and capable of sensing various kinds of stimuli (e.g., light, sound, acceleration) by specialized receptors (Mohs, 2007). These receptors are typically located in sense organs such as eye that contains rods and cones which are sensitive to light. The role of receptors in sensation is transducing received physical properties of a stimulus (light) into electrical signals. These electrical signals stimulate transmitting neurons which carry received information from related receptors to the brain (Goldstein, 2009). Particular signals are conveyed specific regions in the brain, for instance a visual stimulus activates the primary visual cortex (responsible part for processing visual information) located in occipital lobe (Mishkin et al., 1983). However, it is not possible to infer from these electrical signals without associate them to previous knowledge. Therefore intermediary components of the brain (e.g. hippocampus) carry these incoming information to higher cortical centers (cerebral cortex) for association (matching/comparing) process, which results, at the end, perception (Eichenbaum, 2000) Humans also can form or recall memories (collective memories) which they have no direct personal experience (e.g., verbal transfer), which gives a rise to capability of acquire information from other existences (Gedi & Elam, 1996). In both cases perceived information either can be stored as a memory trace in the long-term memory or fade away, depending on its future necessity (Nikolić & Singer, 2007).

Forming a permanent (long-term) memory is not just storing new information within the brain using its plain perceived form. It has to be converted into a new construction via a biological process called encoding (Nikolić & Singer, 2007; Tulving et al., 1996). Humans are capable of encode audial, visual, tactile, and semantic type of information into memory traces. Among the abovementioned encoding types, first three of them are directly related to physical properties of stimulus. However, semantic encoding differs from the others by the means of processing encoding sensory input that has particular meaning or definition. In default of semantic encoding, it is not possible to attribute a meaning to new information (Barba & Goldblum, 1996). For example, we can`t properly retrieve a memory which was aroused from a light wave (visual stimulus) with 700nm wavelength (physical property) without naming it ‘red’ (semantic encoding) while storing.

So far, two main memory classifications (explicit and implicit) were identified under long-term memory (Erdelyi, 2012). The memories that we can verbalize are stored as explicit (declarative) memory, which goes into sub-divisions as episodic and semantic memories. Episodic memories are comprised of personal experiences at a specific time and place (where/when). Semantic memories, on the other hand, refer to general knowledge of the world (what). The other type of long-term memory called procedural memory, serves to retrieve the execution of the integrated procedures (how) involved in both cognitive and motor skills (Squire & Zola-Morgan, 1991; Tulving, 1972). Despite the diversity in memory, it must be borne in mind that, these various subsystems works interactively when performing a skill, whether it can be cognitive, motor or perceptual.

As well as form, storage place of a memory changes according to its future area of usage. The walnut shape organ, thalamus, perched on top of the brainstem is responsible nearly relaying all sensory information (with the exception of the olfactory system) to the cerebral cortex (Sherman & Guillery, 2002). Almost all received information meets with the thalamus first before reaching the cortex and every sensory system connected to thalamus includes a thalamic nucleus that receives sensory signals and conveys them to the associated primary cortical area (Jankowski et al., 2013). For the visual system, stimulus coming from the retina passes through the lateral geniculate nucleus and pulvinar nucleus of the thalamus, which in turn reaches primary visual cortex (PVC) (Sherman & Guillery, 2006). Then perceived information is sent from PVC to either parietal lobe via the dorsal stream which stores incoming information for skilled motor behavior or temporal lobe via ventral stream which provides the detailed representation of the visual world required for cognitive operations (Goodale et al., 1994; Mishkin et al., 1983).

Whenever a voluntarily action needed, visual memories are consciously retrieved from aforementioned lesions to complete a motor skill program. However if the thalamus receives information reflecting a strong emotional feeling or indicating a treat, response pathway alternates. The information is first sent out directly from thalamus to the amygdala which is an organ responsible for controlling emotional behavior (Morris et al., 1998; Paré et al., 2004; Whalen et al., 1998). In many studies this pathway defined as the thalamo-amygdala pathway (the 'short route' or 'short cut'). This avoidance/defense system is thought to responsible for detecting threat stimulus, trigger autonomic activity required to support action, and select and prepare motor programs related to fight or flight responses (Garrido et al., 2012; Liddell et al., 2005; Morris et al., 1999; Öhman, 2005; Vuilleumier, 2005). The short route conveys fast, but only a crude perception of the situation. As a result, responses arise from the thalamo-amygdala pathway are often consist of rough movements. Because, these movements are not a result of cortical pathway which gives a fine-tuning to the motor skills, and most of the time they seem as overreaction (e.g., sudden backward jumping). On the other hand, the short route is regarded as a primitive mechanism of defense and reactions coming from this route are much faster than the long route (thalamo-cortico-amygdala pathway). These reactions frequently protect us from potential dangers providing extra time before the mind can form a complete representation of the stimulus via cortical pathway.

Besides, controlling emotional behavior, the amygdala can also store memories about them. A behavioral paradigm called emotional conditioning mostly takes place in the amygdala (Davis, 1992; Fanselow & Gale, 2003; LeDoux, 2003). Emotional conditioning is a learned behavior and involves the pairing of a neutral stimulus with an aversive unconditioned stimulus. The neutral stimulus initially elicits no emotional reaction, but after repeated pairings with the unconditioned stimulus, the neutral stimulus becomes a conditioned stimulus. Human memory arrangement in the amygdala is in tendency of linking treat-like perceptual information to a fight-or-flight emotional response (Phelps, 2006). Animals, objects, sound or many other neutral stimuli can turn into treat-like conditional stimulus; even it seems there is no semantic relation with unconditioned stimulus (Jacobs & Nadel, 1985). However there are some contexts that carry similar meanings for most of us. One of the best examples for the argument is the emotional associations of colors. When psychological properties of colors are taken into account, almost all primary colors represent one or two emotions. Evidently researches showed that the color 'red' is perceived as the most danger indicative and tread-like stimuli among the others (Elliot et al., 2007; Elliot et al., 2009; Tanaka & Tokuno, 2011) . As a matter of fact, most of the signs or objects that have a potential meaning of danger have chosen to be colored as red and it is also a natural indicator of danger which represents poisonousness, anger and dominancy among the animal world (King, 2005; Soriano & Valenzuela, 2009). When humans repeatedly encounter situations where red is accompanied by particular dangerous experiences and/or concepts, they form specific conditional associations (Elliot et al., 2007). Considering the aforementioned characteristics of thalamo-amygdala pathway, it has been hypothesized that perceiving a neutral visual stimulus colored red as a danger indicative stimulus is possible and the corresponding response can be given by the way of short-route. Yet, quite a few well controlled studies investigated the effects of emotional associations of color on motor skill performance. Therefore the aim of this study was to examine reaction and movement times using three different colors as stimuli in three visual search task environment.

METHOD

Eleven college students (6 women and 5 men) from Middle East Technical University ranging in age from 20 to 23 years old (M_{age} = 21.83, SD = 1.16), voluntarily participated in this experiment. All Participants were right handed and have no visual or musculoskeletal health problem that can affect visual search and reaching-grasping tasks.

Three primary colors in a standard color wheel (red, yellow, blue) were used in this study for encoloring visual stimuli, target objects and backgrounds of target objects. For the experimental setup a $24cm^2$ square board consisting 36 pieces of $4cm^2$ squares was designed. The board was divided into four fields equally and each 9 squares included 3-red, 3-yellow and 3-blue squares, ensuring equal distribution of the objects. Standard map pins used as target objects and they were placed exact mid-point of the each squares. RGB values of the displayed visual stimuli and the backgrounds on the board were; Red = 131, 59, 47, Yellow = 165, 183, 15 and Blue = 19, 52, 103 and target objects' were; Red = 131, 54, 51, Yellow = 165, 183, 15 and Blue = 20, 61, 127. A printout represents "hand-stop area" was placed closed to bottom-right corner of the board and average distances of the objects towards to hand-stop area didn't statistically differ in terms of their colors. Total 36 colored rectangle images (700*400px) were given in a random order via 1280*1024px, 17' LCD (Lenovo™) as visual stimulus, at every 5th seconds. Each stimulus was displayed for one second and after stimulus disappears a large hand illustration appears for 4 seconds reminding participants return their hand back to hand-stop area. All stimuli were given by a virtual instrument (VI) created in LabVIEW 2010 environment.

A simple visual-search and reaching-grasping task was expected from the participants. They asked to pick any corresponding colored object from the board as fast as possible and drop it in a jar, which was placed top-right corner of the board, before returning their hands to the hand-stop area. Dropping objects into the narrow-mouth jar was used as an independent cognitive task to eliminate the short-term visual memory, which was occupying participants cognitively, while causing the board became out of sight after each stimulus.

Three different measurement setups were prepared in sense of cognitive difficulty which was determined by target distribution. In the first setup objects were placed on same colored backgrounds. Due to the object background similarity, this setup was the most difficult in terms of visual search. Secondly, objects were placed on different colored backgrounds (red on blue, yellow on red, blue on yellow), which created the highest object visibility. In turn this setup was the easiest. Finally objects were distributed on different colored backgrounds equally (e.g., for the red objects; 4 on blue, 4 on yellow and 4 on red) and the difficulty of this setup was between 1st and 2nd (see Figure 1 for measurement setups). Setups was implemented in random order with one week intervals to prevent learning effect.

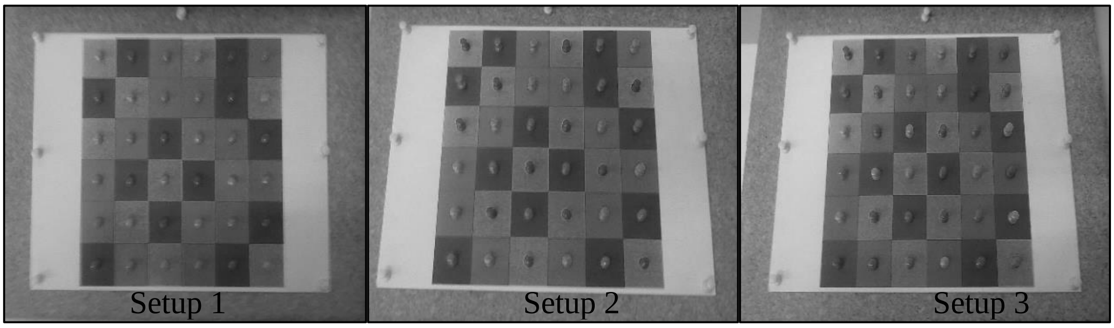

Figure 1. Measurement Setups

Hand trajectory after stimulus was monitored by a dome camera (Point Gray-Dragonfly Express) adjusted for 60fps recording. Reaction (RT) and movement times (MT) were measured using via accelerometer integrated into Delsys Trigno wireless system at 148.1Hz sampling rate. The time period between stimulus and first hand movement measured as RT and the difference between the first movement and touching the target object measured as MT (see Figure 2). Stimulus and sampling synchronization were regulated by the same VI.

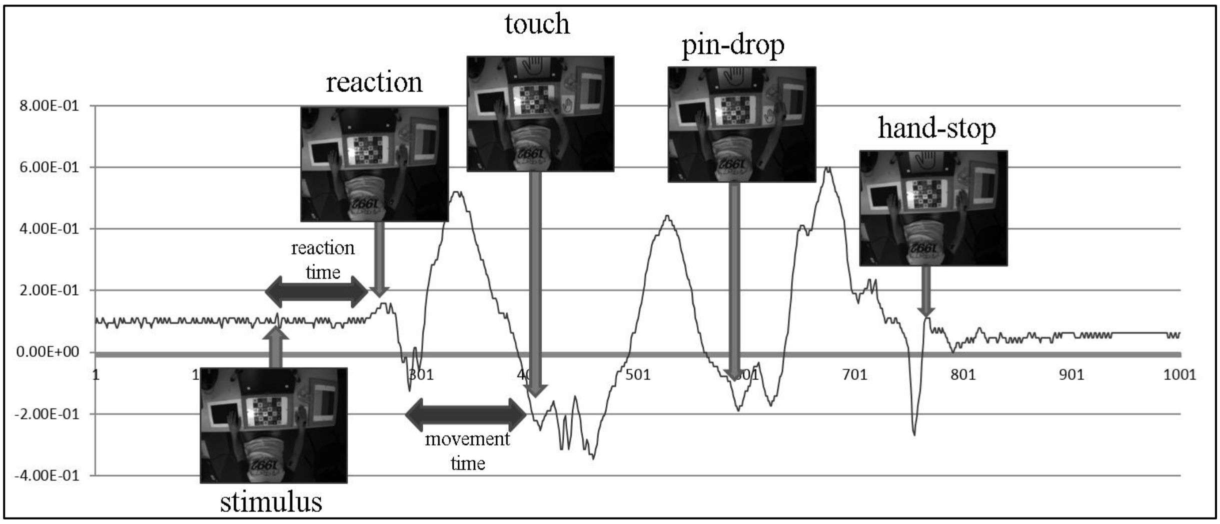

Figure 2. Movement trajectory and interval cut-points over acceleration graph.

RESULTS

Each pick was taken into account as an individual case and as a consequence, total 396 (132 red, 132 yellow, 132blue) cases took place for each trial (see Table 1, for measurement scores). In advance of main analysis, the relationship between dependent variables (RT and MT) investigated by Pearson product-moment correlation coefficient. Although correlations between DVs at each trial were very low ($r_{t1} = .02$, $r_{t2} = .02$ and $r_{t3} = -.01$) and non-significant ($p > 0.05$), separate multivariate analysis of variance (MANOVA) tests were conducted to test the hypothesis that there would be one or more mean differences between RT and MT measurement scores depending stimulus color at each trial by the reason of preventing results from inflated Type I error.

Table 1

Mean Scores and Standard Deviations of Reaction and Movement Times as a Function of Stimulus Color

Measure		Reaction time (*n* = 132) *M*	*SD*	Movement Time (*n* = 132) *M*	*SD*
Trial 1	Red	0.44	0.13	0.54	0.10
	Yellow	0.54	0.13	0.56	0.11
	Blue	0.52	0.14	0.54	0.10
Trial 2	Red	0.41	0.13	0.52	0.12
	Yellow	0.48	0.12	0.49	0.10
	Blue	0.49	0.12	0.50	0.10
Trial 3	Red	0.48	0.11	0.51	0.09
	Yellow	0.54	0.12	0.52	0.10
	Blue	0.50	0.14	0.53	0.09

Using Pillai's trace, a statistically significant multivariate effect was obtained for *first trial*, indicating there was a significant effect of stimulus color on RT and MT, $V = .10$, $F(4,768) = 10.67$, $p < 0.001$. A small multivariate effect size ($\eta^2 = .05$) was estimated which implies that 5% of the variance in the dependent variables was accounted for by stimulus color. Following separate ANOVAs revealed a significant stimulus color effect on RT, $F(2,393) = 19.77$, $p < 0.001$, *partial* $\eta^2 = .09$, but a non-significant effect on MT $F(2,393) = 2.44$, $p = 0.09$, *partial* $\eta^2 = .01$. Similar results were found for the other trials. With the purpose of detailed understanding, multivariate and univariate test results of all trials were given below (see Table 2).

Table 2

Results of Multivariate and Univariate Variance Analysis

	MANOVA			ANOVA RT		ANOVA MT	
Measure	*df*	F^a	η^2	F^b	η^2	F^b	η^2
Trial 1	1	10.67*	0.51	19.77*	.91	2.44	.01
Trial 2	1	3.84*	0.39	14.28*	.07	1.76	.01
Trial 3	1	7.9*	0.19	7.08*	.04	0.7	0

^{a}Multivarite *df* = 4, 768. ^{b}Univariate *df* = 2, 393. *$p < 0.05$.

In accordance with Bonferroni-adjusted post hoc tests, when the stimulus color was red, the mean reaction time (*M* = .44, *SD* =.13) significantly shorter in comparison to blue (*M* = .52, *SD* =.14) and yellow (*M* = .54, *SD* =.12), ($p < 0.001$). On the other hand, mean reaction time difference between blue and yellow colors was non-significant ($p = .69$). For the movement times, there were no significant mean differences found, depending on stimulus color in trial 1. In trial 2 and 3 results were analogical to trial 1 (All measurement results and statistical comparisons can be seen in Figure 3).

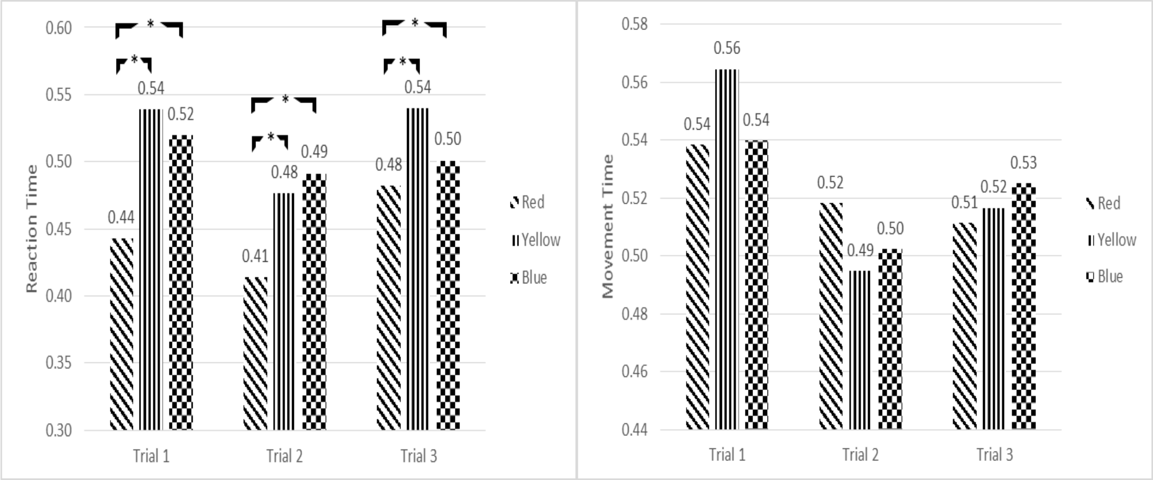

Figure 3. Reaction and movement times of all measurements. * = $p < 0.05$.

DISCUSSION

Referring to correlation coefficients between dependent variables, we found reaction and movement times are independent of each other, as indicated analogous studies; and can be examined individually. As a matter of fact, while participants performing the task, it was observed that they lift their hands (reacted) immediately after the given stimulus and then they began to search the target object visually. Probably there was a momentarily overlap between these two behaviors; however it was not possible to see it with naked eyes. For the measurements, given task was very common reaching and grasping task and stimulus response compatibility was very high. Therefore it was possible that participants didn't consider it necessary to plan hand trajectory, before reacting. However, when dome camera images were examined, it was seen that choice process latened target-driven movement and resulted an increased movement time as much as 1s in some picks due to trajectory change during movement.

In many disciplines, a great deal of study has been published on human responses toward various stimuli. Several of them identified that the perception and related response mostly depends on direct or indirect experiences of the responder. From the emotional aspect, perceptional variation according to stimulus's representation propounded as the main underlying reason for behavioral alteration (see Gross, 2002, for more detailed information how emotions effect behavior). Every perceived visual stimulus carries color information and the link between color and emotional conditioning has been demonstrated by many studies (e.g., Elliot et al., 2007; King, 2005; Soriano & Valenzuela, 2009). Especially some colors have specific influence on psychological function of our brain effecting either cognitive or motor (sometimes both) end-result (Elliot et al., 2007). When the danger indicative usage of red in our daily life taken into account, it is reasonable to think that red objects can be easily perceived as treat-like stimulus and activates human fight or flight responses. Under favor of different setups prepared in various cognitive difficulties, results gave us an opportunity to understand the effects of different stimulus colors on both reaction and movement times. Results clearly indicate that participants reacted faster when the stimulus color was red. There are quite a few studies in the literature on similar topic and some of them share parallel results referring motor performance (Attrill et al., 2008; Elliot et al., 2007; Hill & Barton, 2005). Especially reaction time results of the study could be a supportive evidence for presence of the short-route and the place of color red in this response pathway.

On the other hand, some interesting results occurred for movement time. For blue and yellow objects movement times were parallel with the cognitive difficulty of measurement setups as expected. For red objects, however, movement times were unexpectedly shortened in setup 3. If setup 3 was approached from a different standpoint, ignoring color-background color match, it had the most complicated appearance for the participants. Therefore, it could be only speculated that setup complexity can effects movement speed differently when target object is red. Unfortunately, researching the underlying reasons this interesting result was out of scope of study and it is strongly advised for the next researches.

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