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ATTENTION ORIENTATION IN COLOUR PERCEPTION

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MASTER THESIS JURY APPROVAL FORM

I certify that I have read this thesis and that in my opinion it is fully adequate, in scope and in quality, as a thesis for the Master degree.

(22.11.2019)

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ABSTRACT

ATTENTION ORIENTATION IN COLOUR PERCEPTION

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In search of the “origin of the categories”, dual nature of the “colour” gives us the opportunity to research how categorization and perception relates to each other. Debate on the literature emphasis on whether human perception is shapped biologically by innate determinants or by culture and environment. Colour categorical perception literature has contradicting results of showing pure perceptual effects and also top-down modulations. However “colour” shows same pattern in the attention studies as well. Therefore in this study, attention used as an indicator for determining the cognitive aspects (top down / bottom up) of colour categorical perception. And also checked if attention creates a modulation too. For these reasons, colour category discriminations were run by participants, under attentional shifted conditions, exogenously oriented by cues. Therefore lateralization effects both suggested by perception and attention literature, controlled by equal attentional weighting through trials. Reaction time, accuracy and Inverse Efficiency Scores were reported to better indicate the possible effects. Therefore results suggests a bottom-up aspect of cross-category colour discriminations, a top-down modulation requirement for within-category discriminations, and a possible categorical facilitation role of attention.

Keywords: colour perception, exogenous attention, covert attention, attentional orientation, visual asymmetry, categorical perception, categorical facilitation

ÖZ

RENK ALGISINDA DIKKATIN YÖNELIMI

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2019

Kategorilerin kökenini arayışımızda, renklerin iki durumlu yapısı (algısal ve kategorik), bizlere kategorizasyon ve algının birbiriyle olan etkileşimini inceleme imkanı sunmaktadır. Literatür çalışmaları, insanlarda algının biyolojik ve içten gelen faktörlerle mi yoksa çevresel ve kültürel yollarla mı şekillendiği üzerine genel olarak yoğunlaşmaktadır. Kategorik renk algısı çalışmaları aynı anda hem saf algısal, hem de yukarıdan aşağıya doğru bilişsel etkileşimleri kanıtlayan karışık bulgulara sahiptir. Aynı desen dikkat çalışmaları literatüründe de görülmektedir. Bu amaçla iki literatürdeki bulguları bir araya getirmek adına, "dikkat", kategorik renk algısının bilişsel süreçlerin irdeleyecisi olarak kullanılmıştır. Aynı zamanda da dikkatin kategorik renk algısı üzerine olan etkilerine bakılmıştır. Kategorik renk algısı ayrımları, katılımcıların dikkatini yönlendirmek için verilen işaretler ile birlikte yaptırılmıştır. Dikkat ve renk algısı literatürünün ön gördüğü lateralizasyon efektlerini kontrol etmek amacıyla, dikkat eşit bir şekilde iki görüş alanına da deneyler boyunca yayılmıştır. Reaksiyon süresi, doğru cevap verme hassasiyeti, ve IES skorları, muhtemel efektleri daha iyi anlayabilmek adına rapor edilmiştir. Sonuçlar, iki ayrı kategorideki renk ayrımlarında aşağıdan-yukarıya işleme, kategori içi renk ayrımlarında ise yukarıdan-aşağıya işleme etkileri görmüştür. Aynı zamanda dikkatin "kategorik kolaylaştırma" ya olan etkileri görülmüştür.

Anahtar sözcükler: renk algısı, lokasyona dayalı algı, algının yönelimi, görsel alan asimetrisi, kategorik algı, kategorik kolaylaştırma

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Best Regards!

Semih Nazlı

İzmir, 2019

TEXT OF OATH

I declare and honestly confirm that my study, titled "Attention Orientation in Colour Perception" and presented as a Master's Thesis, has been written without applying to any assistance inconsistent with scientific ethics and traditions. I declare, to the best of my knowledge and belief, that all content and ideas drawn directly or indirectly from external sources are indicated in the text and listed in the list of references

Semih Nazlı

Signature

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20 December 2019

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LIST OF ABBREVIATIONS

CP	: Colour Perception
HS	: Human Visual System
LRH	: Linguistic Relativity Hypothesis
2AFC	: 2 Asked Force Choice
CIE	: Commission Internationale de L'Eclairage
B&K	: Berlin and Kay
LGN	: Lateral Geniculate Nucleus
RT	: Reaction Time
MS	: Millisecond
VF	: Visual Field
RVF	: Right Visual Field
LVF	: Left Visual Field
PC	: Proportion of Correct Answers
PE	: Proportion of Errors
IES	: Inverse Efficiency Score

INTRODUCTION

Categorization is the process which wide array of experiences and different things are grouped together, and given response as equivalents (Bruner, Goodnow, & Austin, 1956). The idea of categorization goes way back even to classical period in Greece. Plato managed to group objects, based on their similar properties. And he classified them by narrowing down, with using his Socratic dialogue questions to make a basis. From that time to nowadays, the categorization system changed into many variations. "How categorization is beneficial to humans' classification abilities?" is one of the main variants. From an evolutionary point of view, categorization helps an individual to accumulate large amount of information with least amount of time and effort.

However, the origin of perceptual categories and their influence on how humans perceive the world, still being researched in many studies as a fundamental question. As an example, in an everyday life situation, one must use visual search and categorization together in order to perceive the world. Therefore, complete a basic task such as "finding keys". Visual search can be considered as a common perceptual task in daily life, requiring attention in order to look for a particular object or feature (target) among other object or features (distractors). It is basically an attentional deployment.

Colour categories have been considered as outstanding example in order to investigate this fundamental question. Because there is a clear disparity between colour perception and colour categorization (Brown & Lenneberg, 1954). Even though there are millions of discriminable colours in the three-dimensional attribute space, naming and categorizing of all the colours is almost impossible. Those colours vary continuously in the hue, saturation and lightness (Fairchild, 2013), yet humans do not make metric evolutions. Hence, they name colours, roughly into discrete colour categories. This discrepancy can also be seen in the research methodology. Colour categories have a dual nature that, they could be studies as “perceptual categories” and/or “perceptual attributes”.

Properties of colour perception do not simply reflect a physical feature such as wavelengths. Fundamental theories on human colour vision which are trichromacy, colour opponency and colour constancy, indicated in several studies that, colour vision is not outputting the purely physical properties of the light reaches the eye. So, the end product is a result of perceptual processing (Witzel, 2019). Concept of “colour” is a perceptual attribute instead of a physical attribute can be explained by distal attribution. Distal attribution defined as the ability to attribute proximal sensory stimulation over distinct and exterior objects (Auvray, Hanneton, Lenay, O’Regan, 2005). In terms of colour perception, distal attribution can be adapted to the idea of colour categories becoming perceptual categories while categorizing perceptual attributes (Witzel, 2019).

Although we can argue that colour categories could be understood as fundamental perceptual attribute (colour), it can also be understood as linguistic categories. Colour naming contains linguistic reference. While a colour term (e.g. “green”) refers to a specific colour (e.g. a shade of green) through a category (green), these three different aspects cross each other. They create a semiotic triadic relationship. Colour term works as a “signifier” (linguistic sign), and the colour shade works as the “referent” (significate). Thus, the referent relates colour term to colour (feature) and forms a signified (concept). The concept becomes the meaning of the colour term. Basically, overlapping colour feature and colour terms on together, by using the elements of semiotics (Hébert, 2019; Witzel, 2019).

Dual nature of colour categories creates an opportunity to investigate the association between language and perception. The core idea in this investigation is the Sapir-Whorf Hypothesis. The linguistic relativity hypothesis (LRH), refers that the language a person speaks, greatly shapes their reality (Lucy, 2015). Also, their thoughts, actions and mental processes are resolved according to the language (Whorf, 1940/1956). At first glance, different languages encode and processes colour, varying in different ways. This assumption leads to an ideal way of testing predictions, by using colour in order to indicate LRH. Also, categorical variety due to language effect suggests that, the categorization effect is learnt (Kay & Kempton, 1984). With these reasons, colour categories have been focused heavily by linguistic relativity researches.

Interpretation of colour categories also goes way back to the time of Aristotle and Theophrastus (Lovejoy & Forster, 1913). A ground-breaking discovery on "Basic Colour Terms" ignited the researches. It suggested that, there are only eleven colour categories (foci) exists. Also, it has an evolutionary ordering of seven stages (Berlin & Kay, 1969).

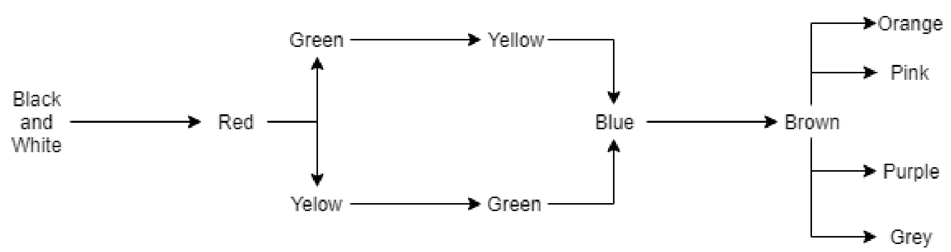

Figure 1. Eleven colour categories for Basic Colour Terms

Follow up studies of Lucy & Schweder (1979), Garro (1986) and Kay & McDaniel (1978) indicated the basic colour terms and language related colour categorization. Further studies on linguistic relativity can be reviewed in Lucy (1997).

As there is the question about how language effects perception by colour categories, it creates another debate called "cognitive penetrability" of perception

(Firestone & Scholl, 2016). Cognition consists of mental activities such as language, memory and learning that are non-perceptual in their nature. Pylyshyn (1999), defines cognitive penetration as cognition shapes ("or penetrates") perception. As a result, Sapir-Whorf Hypothesis and questions about cognitive penetrability, generates a debate of whether human perception is biologically (nature) shaped by innate determinants, or by culture and environment (nurture) (Witzel, 2019).

Categorical Perception (CP) has been widely used as a major approach to establish a link between perception and categorization, in both cognitive and perceptual literature. CP is basically, discrete grouping or segmentation of different hues, from a wide spectrum of stimuli into smaller numbers (Bornstein, 1987). If two stimuli is coming from different categories, and the comparison is equal in distance wise, it is more accurate to discriminate them compared to same category (Harnad, 1987). It is easier to formulate this effect as follows.

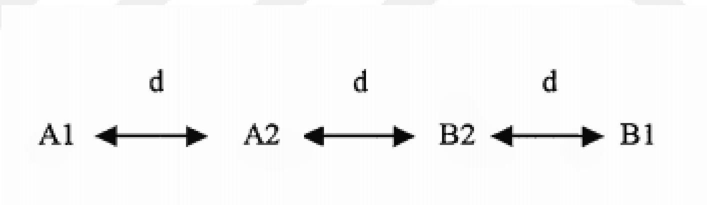

Figure 2. Categorical perception distances

While A, B are different categories, A1 and A2 belongs to A and B1 and B2 belongs to B. Where distance *d* is equal for all above in terms of physical distances (wavelength, stimulus size, etc.) and uniform spaces, discrimination of A2 and B2 will be better than A1-A2 or B2-B1 since A2-B2 pair will be different categories, and A1-A2 and B2-B1 will be same categories.

CP happens, when it is quicker or more precise to discriminate against products that crossing category borders rather than copies of the same category. It is seen when, for instance a green stimulus and a blue stimulus are differentiated more effortlessly than two stimuli of the same category (e.g. two slightly different green tones.).

CP should not be understood and confused as colour categorization. Assigning colours to categories according to colour terms is a different idea than, the colours being perceived in a categorical way (Witzel, 2019). There are several empirical evidences about colour categorical perception that contradicts to each other. On one side, colour vision is modulated by differences in colour categorization across languages (Roberson, Davies & Davidoff, 2000), by language – specific interference tasks (Gilbert, Regier, Kay & Ivry, 2006; Roberson & Davidoff, 2000; Roberson, Pak & Hanley, 2008; Winaver, Witthoft, Frank, Wu & Boroditsky., 2007), and by lateralization of language in the brain (Franklin et al., 2008; Gilbert et al., 2006; Regier & Kay, 2009; Roberson et al., 2008). These studies draws a line to the implication of linguistic colour categorization shapes colour perception.

On the other side, several studies claimed that linguistic categories derives from the categorical nature of the colour perception itself. Regier, Kay & Khetarpal (2007) indicated that, colour vision itself is categorical, and colour categories already exist even infancy and before language acquisition (also Bornstein, Kessen & Weiskopf, 1976; Franklin, Clifford, Williamson & Davies. 2005; Franklin & Davies, 2004; Ozturk, Shayan, Liszkowski & Majid, 2013). So, the core problem here is that, while the continuum of colour perception and difference between perception and categorization taken to consideration, why some studies observes the effect of categories on perception, yet others cannot find any.

Different aspects of colour perception allows us to compare measures of colour perception at different levels of perceptual processing. Stages of colour processing starts with physical characteristics of stimulus, carries over to sensory signal from cone excitations and cone-opponency (second stage mechanisms), processed through "higher level" cortex for perception by sensitivity and colour appearance (Munsell chips, CIELAB, etc.) and ends with a colour naming. These whole processes increases the difficulty of relating colour categorization to colour perception. However, when the categorical patterns measured by a low-level information, opens a way of attributing appropriate processing level to proper perceptual reference and measure. But still potentially have higher level of processing aspect (Witzel, 2019).

Important step in the colour processing hierarchy, is basic ability to discriminate colours by comparing sensitivity with sensory signal (Krauskopf & Gegenfurtner, 1992). After using sensitivity and thresholds, signals gets shaped by second stage mechanisms (Brown, Lindsey & Guckes, 2011). This information, as a reference for perception, leading to testing of higher-level category effects. Witzel and Gegenfurtner (2014, 2015, and 2016) argues the effects of attention and subjective evaluation on perception, by defining perception as direct responses to presented stimulus. Therefore, brings up an issue of "categorical facilitation".

As Witzel (2019) indicates whether categorical facilitation is due to observers' attentional focus shift, on linguistic categories, to differentiate the stimuli. Categorical facilitation is however in line with the evidences for the newest Bayesian model, introduced to potentially cause a ground for top-down effects of categories on colour perception (Holmes, Moty 2017; Regier and Xu, 2017). Taking category knowledge as an existence, integration of perceptual information and existed knowledge forms category effects.

In this thesis, topics of colour categorization, colour categorization perception, categorical facilitation and the role of attention in a general picture will be indicated. By focusing on the "colour" as a physical feature, not as a perceptual product at first, this thesis, will try to discuss attention and colour discrimination first. Afterwards, it will argue different mechanisms in cognition, and how they take role in different types of colour discriminations. "How" attention modulates colour categorical perception, will be the main interest. Consequently, relationship between the concepts of attention and colour will be discussed in the following chapters. Some basic concepts also will be indicated as a reminder.

1.1. HUMAN VISUAL SYSTEM

Biological and physiological design of human visual system (HVS), grants a mechanism for passive selection of the visual information. Passive selection actuates in three different steps. The photoreceptor cells are only sensitive and responding to the light in the visible spectrum. In the centre around fovea, the spatial resolution is maximum, therefore indicating a non-uniform sampling of visible light on cell performance. Visual cells are sensitive to spatial frequencies. On the other hand retina and cortical cells respond to contrast, reducing excess information. (Sharhrbabaki, 2015).

Additional to the passive selection of visual information, a mechanism is required to deal with the vast amount information surrounding us. It has been described by Neisser (1967) as a "spotlight" that highlights a portion of visual scene to be processed delicately. The spotlight also described as the term visual attention.

1.2. ATTENTION AND VISUAL SEARCH

A bombardment of stimuli reaches to our senses every moment, yet a small portion of them gets selected for further processing. Visual system requires tools such as the "spotlight", in order to optimally allocate processing resources. Allocation is important and efficient, because cortical computations have high metabolic costs (Lennie, 2003). In order to regulate such big costs of cortical computations, spatial attention mechanisms regulates the process (Pestilli & Carrasco, 2005). Attention, considered as state of arousal, simply a cognitive and behavioural process of allocating the limited cognitive processing resources (Anderson, 2005).

Although the cortical computation regulations are done by spatial attention mechanisms, attention can be focused intentionally on specific aspects of incoming stimuli like a position in space (spatial attention) or a specific feature like an unique colour (feature – based attention) for further processing (Galashan & Siemann, 2017).

1.2.1. SPATIAL COVERT ATTENTION

As we can take attention as an allocation of limited processing resources, we should consider how this allocation occurs (Anderson, 2005). Posner (1980), explains this allocation as orienting, and indicates terms overt and covert for orienting the attention. Orienting is a reflexive act which aligns the attention to/with a source of sensory input. When the orienting is done by head and eye movements, it is called overt, but if there is a mental focus shift without eye movements, it is called covert. Overt adjustments are controlling gaze directions, upon the visual scenery that is being processed by the sensitive fovea. Covert adjustments are determining which objects or regions in the visual scenery will be indicated without the gaze changes. Overt orienting can be observed and measured with eye and head movements, yet covert orienting is more of an internal adjustment that could be extrapolated from performance patterns (Klein, Kingstone, & Pontefract, 1992). As its more intrinsic nature, covert attention can be deployed simultaneously to more than one location (in parallel), or with eye movements directed to one location at a time (serial). Interaction between overt and covert attention have been investigated in many studies in the aspect of possible deployment order. The general accord is that, the covert attention precedes eye movements. And overt and covert attention effects perception often similar ways (Kowler, 2011; Nakayama & Martini, 2011). Therefore we will now continue to discuss further on covert attention in details.

1.2.2. TYPES OF COVERT SPATIAL ATTENTION

One could only attend to a restricted proportion of external and internal stimuli of the environment. Attentional deployment gets separated into two major parts. First, orienting the attention for achieving a certain goal, is called active attention, also known as “endogenous/sustained attention”. Active attention manifests itself in a top down manner (James, 1890). Secondly, attention can be attracted by the elements of the environment without a conscious intention, which is called passive side of attentional deployment, also known as “exogenous/transient” attention. Passive attention manifests itself in a bottom-up manner. (James, 1890).

The discussion between exogenous and endogenous control of attention has been indicated extendedly in the studies of Posner & Snyder (1975) and Jonides (1981). According to these studies, top down orienting requires a conscious awareness. It gets affected by subject’s expectancies and current memory load. Also it is resource-limited and easily supressable. On the other hand, bottom up orienting does not require a conscious awareness and unaffected by expectancies or memory load. Yet it is resource free and cannot be supressed.

Previous researches suggests that, the effects of exogenous attention have an automatic bottom-up component, making it arguably a more automatic processes compared to endogenous (Giordano, McElree, Carrasco, 2013). Even though a peripheral uninformative and irrelevant cue was given, it still elicit the exogenous attention and the cue could not be ignored (Montagna, Pestilli & Carraso, 2009). The appearance of an abrupt-onset stimulus at another location than the attentional sustained target location, decreased the performance at the target location (Theeuwes, Kramer, Hahn & Irwin, 1998). Additionally, even when the observers could not able to see subthreshold cues, there was still a peripheral cue benefit reflected into their performance (McCormick, 1997). Also it is argued that, exogenous covert attention is an automatic and what is mean by attention being captured by a sudden flash. It can peak around 100ms and disappears after shortly (Fuller & Carrasco, 2006).

These findings support the idea that, exogenous attention is the simplest and most automatic form of attention which could be considered purely bottom-up. Due to its importance, automaticity of exogenous attention has been addressed in the attentional capture studies as well. In order to discuss automaticity and understand the effect of cues, first we should take a look at the most common procedure to study attention. Which is Posner cueing paradigm.

1.2.3. CUEING

Capacities and processing of the attention in visual feature integration, depends on the cues. Posner (1980) cueing paradigm grants comparison between the attended condition (attention directed to target location), unattended condition (attention away from the target location) and neutral condition (attention distributed across the display). Whereas a cue is given in a performance task, it allows attention to pick up the right information and process it for perception. Attributing the right feature into the conscious perceptual information, depends on the focal attention. If the given cues are valid, attention gets benefits from it. But when a search condition is created before focusing on a single item, validation of the specific cues increases the performance and the probability of completing the focus (Prinzmetal, Presti, & Posner, 1986). We can understand that cues and attention strictly related to each other, and beneficial. However, despite the cues being valid or not, features of the stimuli still requires an association. Several studies tries to explain this feature-based attention on the visual search.

1.2.4. FEATURE - BASED ATTENTION

Classical theories of selective attention especially "Feature Integration Theory " (Treisman & Gelade, 1980) indicates two types of processing mechanisms underlying visual search.

First, parallel processing; is a pre-attentive visual processing with an unlimited capacity, generally operates to extract a salience map (Treisman & Gelade, 1980). It is mostly relied in the situations of "feature search", that requires an identification of a target by a unique feature, while the distractors have the same characteristic visual feature. It is unaffected by the number of distractors (McElree & Carrasco, 1999).

Second, serial processing; is a focal attention requiring, visual processes with a limited capacity, operates to serially allocate attention to flagged locations in the salience map, in order to identify mandatory objects or features (Treisman & Gelade, 1980). It is mostly relied in the situations of "conjunction search", that requires identification of a target among distractors while they both share one or more common visual features. When the distractor-ratio effect increases (target and distractors have more shared features) reaction time increases, and accuracy decreases (Reingold, Eyal, & Pomplun, 2003).

Feature - based attention search has an exceptional characteristic that, its effects are not constrained to the location of the stimuli which endogenously being attended, therefore it spread across the visual space. It can be deployed simultaneously in the visual field, independent of position of spatial attention, and could modulate visual processing even in the task irrelevant locations (Carrasco, 2011). Therefore, it can be assumed that features spreads over spatial attention mechanisms, and potentially works exogenously. Features of the stimuli, captures attention when they are considered as "singletons".

1.2.5. ATTENTIONAL CAPTURE

According to Duncan & Humphreys (1989) for an item considered to be a singleton, there are two conditions should be met. First, the stimulus should differ from its surrounding in some dimension. And second, the surround should considered to be relatively homogenous in that dimension.

Attentional capture occurs when an irrelevant singleton, affects the time of target detection. If the singleton matches with the target, attentional capture speeds up the performance. Or hinders the performance if the singleton is a distractor. So, it could be indicated that singletons exogenously orient attention to change prioritization and process of the stimuli (Ruz & Lupianez, 2002).

Couple questions rises in this topic. Does attentional capture processes are always automatic? Or are they possibly modulated by factors like saliency and/or top-down modulation?

1.2.6. ATTENTIONAL CAPTURE AND VISUAL SALIENCY

Several studies researched the dependence of attentional capture, on visual saliency of singletons. While the visual search was parallel, attention managed to deploy to the spatial location which occupied by a salient object, and feature singletons allowed an efficient search to occur (Theeuwes, 1991, 1992, 1994). However, while the search was serial, irrelevant singletons could not capture the attention, as attentional capture accepts irrelevant singletons captures attention as a fundamental baseline. In line with these results, Todd & Kramer (1994) indicated that singleton letters did not capture attention with the large set sizes. Salient singletons in a larger display size, speeds up the processing the unique items in larger arrays, and therefore producing a heightened attentional allocation. When the item is detected, a voluntarily attention orientation occurs (Treisman & Sato, 1990). As the saliency of an item increases in the display, its effect on attentional allocation increases as well (Theeuwes, 1990). However, Lamy & Tsal (1990) suggested that attentional capture of singletons does not require to be strictly automatic yet could be actively inhibited. Active inhibition could mean a top-down effect, or a modulation in the bottom-up processes as well, creating a debate of the automaticity of attentional capture, and how it gets effected.

1.2.7. AUTOMATICITY OF ATTENTIONAL CAPTURE

Debate on the automaticity of the attentional capture with singletons took place for several years. To address the question of "What extend should attentional capture be regarded as automatic?" several studies opinion out their results, indicating the paradigm. There came out two aspects of the topic. First, the topic of automaticity maintained as the following studies' results. Automatic processing occurs independently regarding the availability of the processing resources, and not necessarily requires conscious processing. And also it could get affected by intentions and strategies. (Posner & Snyder, 1975; Jonides, 1981). Even without a conscious perception of a cue, both normal and neuropsychological patients' attention captured and oriented by the given cue (McCormick, 1999; Danzinger, Kingstone & Rafal, 1998). Peripheral exogenous (transient) cues are extremely difficult to ignore for observers, capturing attention automatically. (Carrasco, 2011). Cue validity did not affect the benefits and costs of exogenous attentional redistribution (Giordano, McElree, Carrasco, 2013).

Second aspect of automaticity on the attentional capture is the idea of its getting modulated. Following studies gives out an idea on the matter. When attention was previously focused on a particular spatial location, attentional capture could be

modified by the subject’s intentions (Yantis & Jonides, 1990; Theeuwes, 1991).
While the participants needed to perform a very demanding task, and the task requiring a focused attentional state, it seemed that attentional capture by irrelevant information (automaticity) was less likely to be occurred (Lamy & Tsal, 1999).
Attentional capture and its effect on processing the target, could be modified by the observers’ strategies which they had adopted to deal with the concurrent task (Folk et al, 1992; Lupianez et al., 2001; Lupianez & Miliken, 1999; Theeuwes, Atchley and Kramer, 2000).

The general conclusion to be drawn here is that attentional capture might be a default automatic process, yet it still could be either enhanced or supressed by endogenous attentional factors (Ruz & Lupianez, 2002). The key point here for this thesis is that, uninformative, peripheral cues would not requiring to have a top-down component necessarily, therefore it could still be thought to capture attention automatically (Giardono, McElree, Carrasco, 2013).

A bigger picture about how we can accept a processes as automatic, is drawn from the debates we indicated so far. A purely automatic process should not be affected by cue validity in terms of costs or benefits. However, if the cue validity modulates cost-benefit effects, an intentional process should be threatened (Kinchla, 1980; Shaw & Shaw, 1977; Sperling & Melchner, 1978; Vossel, Thiel & Fink, 2006). Cue validity here is the attentional capture mechanism that is being manipulated.

We can now underline the automaticity of a processes by weighting how it gets effected by attentional orientation. Dual nature of colour allows us to use its perceptual feature part, and apply attentional orientation over categorical discriminations. However many studies in the attentional literature discusses about colour, some finding interesting categorical results.

1.3. **COLOUR PERCEPTION AND ATTENTIONAL FACTORS**

When colour taken in hand with perceptual aspects (as a feature), the implications of attentional processes can be considered. Perception is derived from two functionally independent stages, pre-attentive and focal processing. In the pre-attentive stage feature models such as colour, size, shape and orientation are searched and processed parallel (all items in at once). In this parallel process, searching for a single feature (such as colour) is appearing to be independent from search time and number of items in display, therefore "pops-out" from the background of the stimuli and capture attention. In the focal processing, coded features would be integrated (Treisman, 1988).

Psychophysical side of the influence of colour on visual attention, were indicated by several studies. Colour singletons (feature itself) "pop-out" in large search displays while the reaction times did not depend on the size of the display (Treisman & Gelade, 1980). Additionally, colour singletons captured the attention regardless of the observers' attentional set (Theeeuwes, 1994).

As discussed above within the debate of attentional capture and allocation, task difficulty in visual search could be modulated by top-down guidance, in regards of display size, low target-distractor discriminability, and low-salience. Non-separable searches which are demanding in terms of attention, contingent on the top-down modulation (Laarni, Koski & Nyman, 1996). For example, in a stimulus array all colours were categorized as "blue" would provide no categorical information to assist the search and it would remain difficult being a non-separable search (Daoutis, 2006). However when the target could be identified as a different exclusive category from the distractors, search efficiency increases. A unique attribute of a target in a grouping with heterogeneous distractors, may assist with a "categorical effect" to facilitate the search via assigning the unique attribute. (Wolfe, Friedman-Hill, Steward and

O'Connell, 1992).

Cross-category discriminations of colour stimuli pops out both in linearly separable and non-separable conditions. Therefore discusses the advantage of cross-category, could be due to the perceptual distance between across and same (with-in) colour categories, even the distances are perceptually uniformed (CIE space) in stimuli sets. This explanation lightens up the idea of, for a target detection in the cross-category condition, the discrimination could be driven by the physical characteristics of the stimuli, making it a bottom-up process (Daoutis, 2006).

Another explanation that could be argued on the other hand is that, a top-down process for the categorical advantage guides attention to target. So it eases up the target-distractor discrimination (Duncan & Humpherys, 1989). Supporting this explanation, Bornstein & Korda (1984) indicated, categorical code (top-down) and physical code (bottom-up) parts of the stimuli works in parallel to facilitate search.

If we put up the processing nature of colour category discriminations to one side, we simply can argue that a target stimulus could be identified by its unique colour. Time required to find the stimulus, independent from the number of distractor stimuli presented, achieved by a simple parallel search. Regarding to the stimuli that differ in colour feature, Carter (1982) suggested a serial search aspect that when the target and distractor stimuli had a small colour difference, finding the target required more time increasing linearly with the number of distractor stimuli. Nagy & Sanchez (1990) indicated that depending on the extent of the colour difference between target and the distractors, a serial or parallel search could be attained. While the colour difference was small and constant, search times increased linearly with the number of distractors, requiring a conscious searching on the display to fixate and locate. Whereas the colour difference was large, search times were constant, target popped out of the display. These results expressed a boundary for pop-out effects of colour in visual search, addressing big difference between target and distractor (cross category discrimination) could be obtained by a parallel search, and a small difference discrimination (within category discrimination) requiring a serial search. For the within-category searches, if there is no mechanism that could set a boundary between target and distractors were available, search is difficult. However, when such a boundary gets available, it facilitates the search, when the target known in advance (D'Zmura, 1991), yet if the target was unknown, search was still difficult (Hodsoll & Humpherys, 2001). To sum up all the information here, it seems like a facilitation is required to use proper search mechanisms, regarding to features of stimuli. So far we can say that the facilitation could be a top-down interference or a "pop-out or not". A common pattern here is; for colour category discriminations to occur, target should be uniquely colour featured, or should have a vast difference than the distractors. For within-category discriminations to occur, there should be a boundary in order to efficiently search. However this boundary between similar featured stimuli, accessed by top-down knowledge. Therefore shows similarity to the "categorical facilitation" (Witzel, 2019). From this point of view, this thesis will indicate three hypotheses:

Hypothesis I: If the process of cross colour category discriminations purely bottom up, it shouldn't be affected by cue congruency (attentional orientation).

Hypothesis II: However, if the within-category colour discriminations requires a top-down modulation cue congruency should affect the performance.

Hypothesis III: If cross category and within category discriminations of colour shows two different cognitive mechanisms (top-down / bottom-up) by attentional orienting, it could imply that attention has a role on categorical facilitation for within-category colour discriminations.

METHOD - EXPERIMENT 1

The method implemented here derived from the ideas of many studies. Although some studies used cues and colour together to make discriminations, I have encountered with some shortcomings on colour selection, constant set size, cue congruency and lateralization. Therefore I created a simple method to evaluate cross category and within category discriminations in terms of RT and Accuracy.

Strong variations of colour differences in the stimuli, could distort empirical evidence for categorical colour perception. Due to selected colour stimuli, unnatural patterns can be seen. Selection can potentially cover larger differences in cross category boundaries or strong variation of colour differences to create more categorical patterns (Witzel, 2019). Therefore, as the many studies in the literature used, colour stimuli differing according to a “perceptual metric” (Drivonkiou et al, 2007, Franklin & Davies, 2004, Özgen & Davies, 2002, Özgen, 2004), that are also “perceptually equal” will be used in the study.

Hick (1952) showed that in choice reaction time experiments response times are proportionally linked to number of different possible stimuli, meaning if there are more targets as a possible stimulus to search, reaction time rises. Sternberg (1969) indicated in his recognition experiments that as the memory set increases, reaction times rises. Reaction times increased by about 40msec per item. Therefore, in this method we limited our search with four possible target stimuli, yet two possible regions to attend and react.

Cues will be arranged as the implications of onset capture cues and contingent capture cues. (Du & Abrams, 2009). The hallmark of onset capture cues is, it occurs without expectations or top-down control (Schreij, Owens, & Theeuwes, 2008). Contingent capture on the other hand is which an irrelevant stimulus captures attention when its features are similar to searched target. It is involuntarily as well but its contingence upon top-down control (Du & Abrams, 2009). Therefore, cues in this study will be exogenous pull cues (Yantis, 1988).

By using a horizontal space across fixation point and randomizing the target locations it is aimed to eliminate any hemispheric effects could be seen in colour perception (see further, Gilbert et al., 2006). Additionally, as the attention studies with cues reported several evidences about RVF advantage of attentional capture for colour (Pollmann, 1996/2000), out method would equate the attentional weighting over both visual fields to eliminate that effect as suggested in Mondor & Bryden (1990)'s study.

2.1. **PARTICIPANTS**

Seventeen observers attended the experiment with a mean age of 22.5. In order to reach observers snowballing technique were used. All observers were given a consent form at the start of the trials and given explanatory information about the upcoming trial. All observers had normal or corrected-to-normal vision and in order to test colour blindness Ishihara's Colour Blindness Test Plates were used to assess each individual before the experiment trials. All observers passed the colour blindness test.

2.2. **STIMULI & APPARATUS**

The stimuli presented on a colour calibrated CRT monitor with a refresh rate of 60 Hz and a resolution of 1600 × 1200 pixels. The colour calibration was done by external devices with appropriate calculations. A keyboard with a highlighted left and right standard keyboard key was used for response taking. Stimuli was presented on an achromatic grey background with CIE Illuminant D65 (Daylight, 6500 Kelvin) (Wysczecki & Stiles, 2000). Each observant participated in a sound-attenuated, dimly lit room, with a chair adjusted for a comfortable height and comfortably away from the display monitor to observe binocularly.

The stimulus were consisted four squares horizontally placed along a fixation point and 6 ° eccentricity used to make stimulus presented exogenously. Size of the squares were 200 pixels. The colours that used in the experiment were selected from Munsell Colour System which is commonly used in literature for its perceptual uniformity between colour metrics.

Categorical perception distances, where distance *d* in a uniform space can be clustered into equal proportions. In a perceptually uniform colour space "*d"* could be explained as the colour steps. Taking Blue-Green border as a baseline (5BG for cross category border), moving one *"d"* to the either of directions are considered as a one step. In this study "d" was taken as 2.5 in the axis of value. A one-step was 2.5 change and two-step was 5 value change.

Colour pairs in Munsell Colour System equivalents were given in the table below. A cross shaped fixation point forming from dark lines, centred in the testing area was presented.

Table 1. Colour Pairs and Perceptual Categories

Colour Pair Number	Munsell Colour System	Step / Category
1	7.5G – 10G	1 Step Within
2	7.5G – 2.5BG	2 Step Within
3	5BG – 7.5BG	1 Step Cross
4	2.5BG – 7.5BG	2 Step Cross
5	5B – 7.5B	1 Step Within
6	2.5B – 7.5B	2 Step Within

2.3. **PROCEDURE**

The experiment session were expected to end in total 5 to 10 minutes for each observant. A session were consisted of 20 trials as practice to learn paying attention to fixation point in all presentations. Experimental procedure repeated 96 times to cover all randomized hue, saturation, cue location, target location in counterbalanced order (6 colour pairs, 4 target, 2 cue conditions, 2 congruency conditions).

Brief explanation of experiment were given. Observers were instructed beforehand the trials for fixating their attention to the given cross in the middle of the screen. After that they were instructed to respond for “Which side had a different square?” with keyboard. Orientation response were taken by keyboard keys (left-right) with his/her index fingers, until a response was completed but the observant were encouraged to give a response as fast as possible, they can. Observers were informed for the squares would always have three same coloured squares, but one is always different. Additionally, information about the white circular shaped cue given as it would help or misdirect them about the odd coloured square. Observers were also informed about if the given answer were not accurate a beeper sound would hear but the sound is just for giving feedback.

A fixation point were given for 500ms, followed by a 200ms presentation of the white cue target congruent or incongruent locations. 500ms interval followed the cue and stimuli were presented for 200ms. In order to prevent saccadic movement cue and target presentations were limited to 200ms, since saccades in general takes 200ms for eye movement to begin (Purves, Augistine, & Fitzpatrick, et al editors. 2001).

Presented stimuli were two squares each side of the periphery in same or different colour conditions derived from the colour pairs given in Table 1. In total four squares were presented at the same time. Three of the four squares were always one of each pair’s first colour and the other square was the second colour of the pair.

Observers given responses to changing colour stimuli with different cue congruency conditions. The task was always to detect the location of the different coloured square which would be in the left or right visual field. Colour changing stimuli were counterbalanced to eliminate carry-over and practice effects.

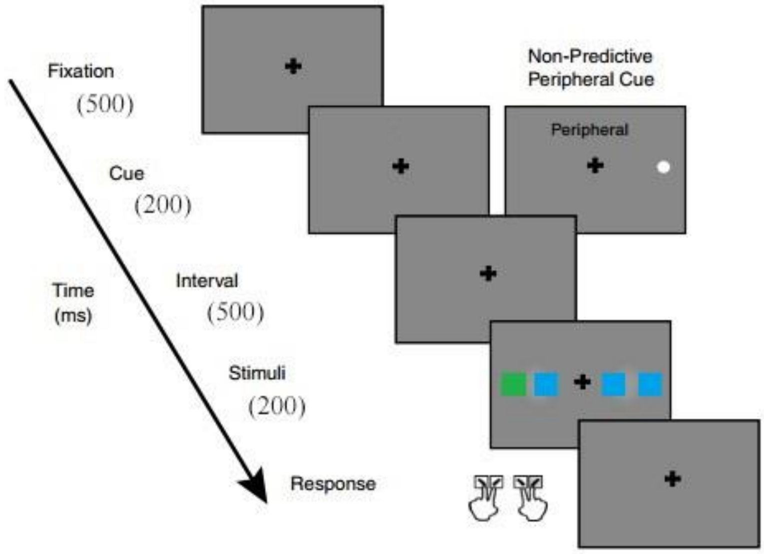

Figure 3. Schematic of the used method

RESULTS – EXPERIMENT 1

3.1. REACTION TIME

In order to test effect of congruency, discrimination difficulty and colour pair categories over reaction time, a 2x2x2 Repeated Measures ANOVA was conducted with Congruency (2 Levels: Congruent, Incongruent), Discrimination Difficulty (2 Levels: 1 Step, 2 Step) and Pair Category (2 Levels: Within, Cross).

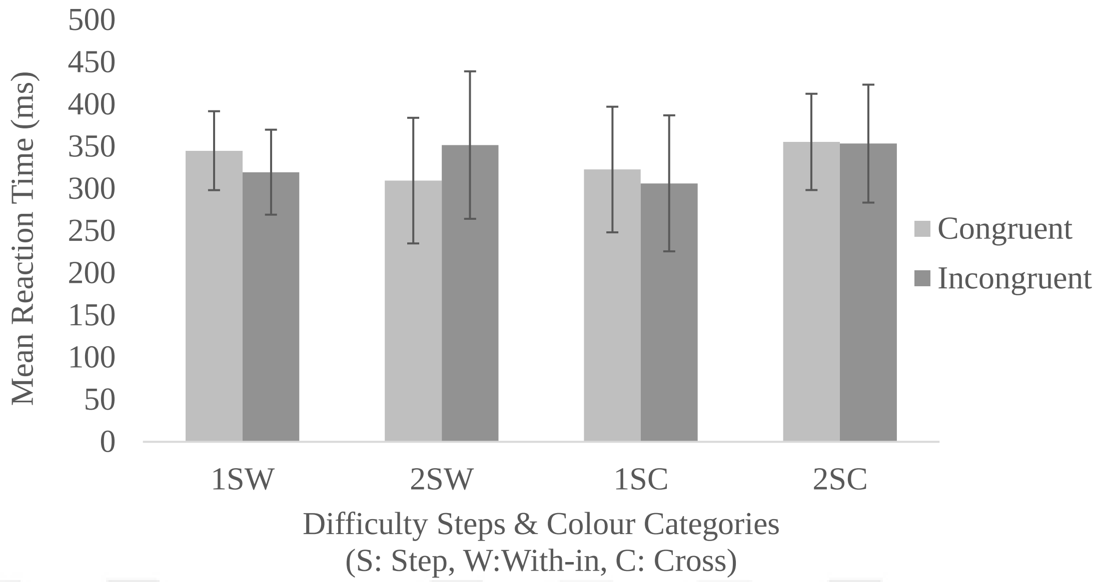

Figure 4. Mean RT Scores across colour categories, cue congruency and discrimination difficulty. Error bars shows %95 Confidence Interval

Figure 4 shows mean RT scores across colour categories, cue congruency and discrimination difficulty. It can be seen that attentional cues did not affect reaction times interacting with colour categories and difficulty. Main effect of congruency was not statistically significant, F (1, 16) = .003, p=.957, η^2 =0. Also, main effect of difficulty was not statistically significant, F (1, 16) = 2.434, p=.138, η^2 =.132. Main effect of category was not statistically significant, F (1, 16) = .026, p=.847, η^2 =.002. Although the interaction between difficulty and category was not statistically significant, F (1, 16) =.867, p=.366, η^2 =.051, and also interaction between congruency, difficulty and category was not statistically significant, F (1, 16) = 1.229, p=.284, η^2 =.071.

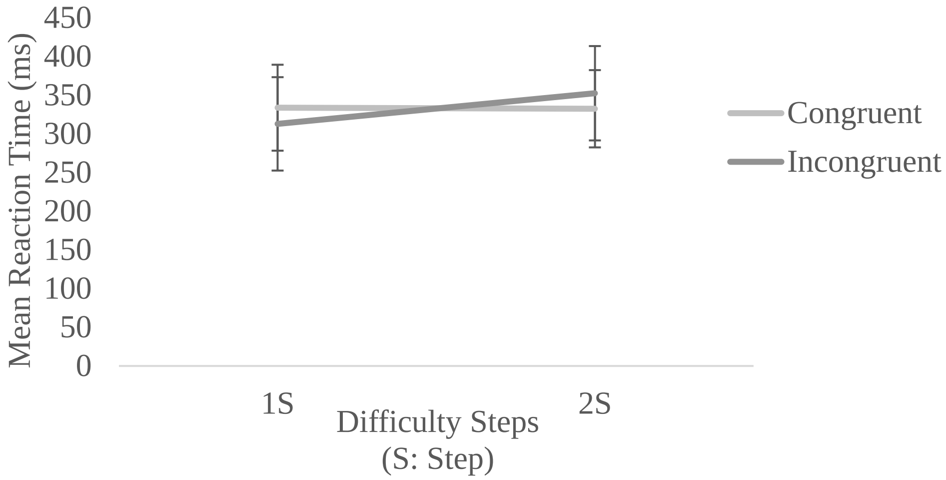

Figure 5 . Mean RT Scores across discrimination difficulty and cue congruency. Error bars shows %95 Confidence Interval

Figure 5 shows the mean RT scores across discrimination difficulty and cue congruency. It can be seen that there was an interaction over difficulty and attention orientation. The interaction between congruency and difficulty was statistically significant F (1, 16) =20.235 p<.001 η^2 =.026.

3.2. **ACCURACY**

In order to test effect of congruency, colour step and colour pair categories over accuracy, a 2x2x2 Repeated Measures ANOVA was conducted with Congruency (2 Levels: Congruent, Incongruent), Discrimination Difficulty (2 Levels: 1 Step, 2 Step) and Pair Category (2 Levels: Within, Cross).

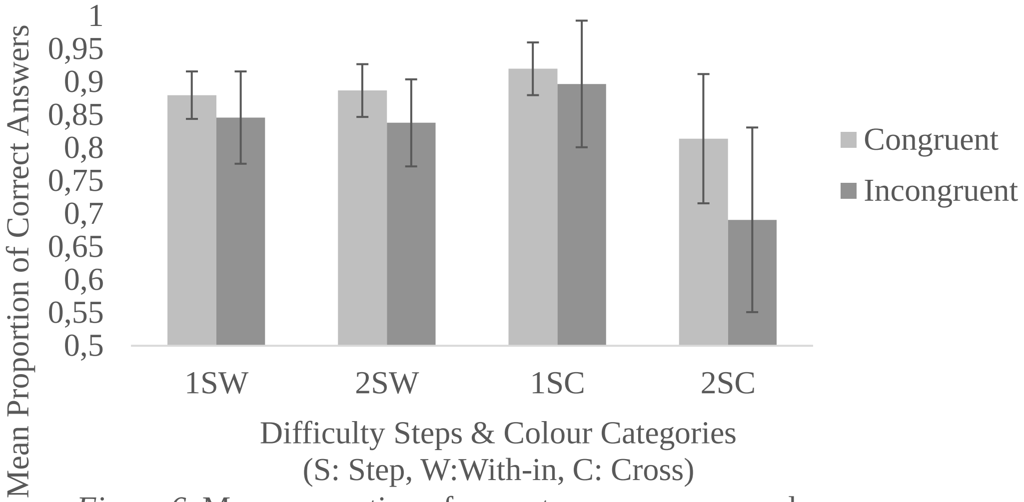

Figure 6. Mean proportion of correct answers across colour categories, cue congruency and discrimination difficulty. Error bars shows %95 Confidence Interval

Figure 6 shows mean proportion of correct answers across colour categories, cue congruency and discrimination difficulty. It can be seen that attention orientation did not interact with colour categories and discrimination difficulty. Main effect of congruency was statistically significant, F (1, 16) = 6.075, p=.025, η^2 =.275. Main effect of discrimination difficulty was not statistically significant, F (1, 16) = 4.112, p=.06, η^2 =.204. Main effect of category was not statistically significant, F (1, 16) = .931, p=.349, η^2 =.055. Interaction between congruency and discrimination difficulty was not statistically significant, F (1, 16) = 2.544, p=.13, η^2 =.137. Interaction between congruency and pair category was not statistically significant, F (1, 16) = 1.079, p=.314, η^2 =.063. Interaction between congruency, colour step and pair category was not statistically significant, F (1, 16) = .962, p=.341, η^2 =.057.

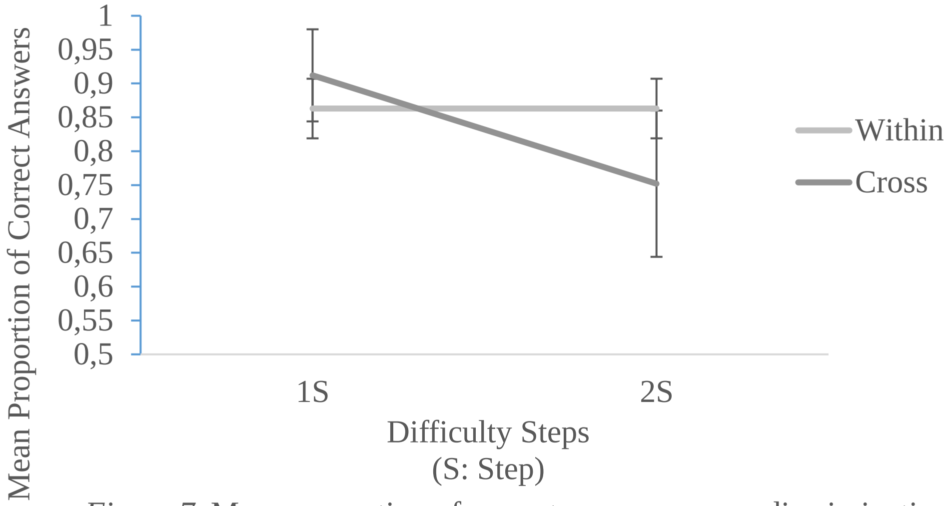

Figure 7. Mean proportion of correct answers across discrimination difficulty and pair category. Error bars shows %95 Confidence Interval

Figure 7 shows mean proportion of correct answers scores across discrimination difficulty and pair category. It can be seen that within category discrimination accuracy stays the same level when difficulty increases. However cross category discriminations got worse when the difficulty decreased. Interaction between colour step and pair category was statistically significant, F (1, 16) = 5.144, p=.038, η^2 =.243.

DISCUSSION – EXPERIMENT 1

Results of Experiment 1 were doubtful. Analyses of reaction time showed no interaction overall. As the previous literature suggested (Hanley, 2015), I was expecting that cross category discriminations would be more accurate and quicker than the within category variants. Therefore, results did not show a similar pattern, leading to the question whether the method had some wrong applications. Despite testing the hypotheses, results not even indicate the colour categorical perception in terms of reaction time and accuracy in a basis. Hence, I cannot evidence a categorical facilitation of attention, nor attentional factors effecting categorical perception with this data set.

Troubling argument continues in the results for reaction time. Despite the attention orientation did not affect the response latency, when the discrimination difficulty increased, incongruent cues decreased reaction time whereas congruent cues did not change over difficulty. Meanwhile as the responses of participants indicated individually, I found out that some participants were even faster in incongruent, 1 step, within category discriminations than other conditions. How the participants performed better in supposedly hardest condition, than the easiest ones was a further question to ask for a follow up experiment.

On the other hand, accuracy showed significant difference with attention orientation. Although overall accuracy changed with an attentional orientation, it did not explain whether it was a categorical facilitation, or different attentional capture mechanisms playing a role. Congruent cues were arguably could have created a baseline for attentional saliency yet failed to direct attention covertly (Parr & Friston, 2019). Also another crucial thing was participants could also have failed to perceive the colour discrimination demands of the task because the orienting of the stimuli (target appearing randomly on left or right side in the grid) might create a motion bias that our abrupt colour change could be effected by this motion change as well, creating a two-dimensional feature search itself (Cavanagh, Tyler & Favreau, 1984). This two-dimensional search itself combined with pull cues, would have been eliminated the effects of colour perception because of the uneven attentional balancing.

Additionally, many studies indicated that simple reaction times for college-age individuals are 190ms for visual stimuli (Brebner & Welford, 1980; Fieandt et al., 1956; Galton, 1899; Welford, 1980). However, in experimental psychology there is commonly agreed on that there are proof of three types of RTs (simple RT, recognition RT and choice RT), differing in latency length (Donders, 1868/1969). Discrimination reaction can be explained by a combination of recognition and choice tasks (Baayen & Milin, 2010). Therefore, it is known that in choice reaction time experiments, response latency strongly depends on the sacrifice of speed for accuracy or vice versa. According to Ollman's (1966) Fast Guess model, there could be two types of responses could be made. First the fast "guess" responses that hauls no information about stimulus and secondly the slower responses representing an outcome of a recognition process can also be called as stimulus-controlled responses "SCR's" (Yellott, 1967).

As the participants given a really short window to answer and react over to the stimuli, there might be possible speed – accuracy trade off. This could be discussed with a common problem that might be occurred in a general. Although in psychological experiments such as this one, participants are typically instructed to give responses as fast as possible while expected to keep their accuracy high. However, this instruction might be interpreted as a speed – accuracy trade off that varies over experiments, participants and conditions (Liesefeld & Janczyk, 2019).

Even though in the experiment a horizontal space were used to eliminate visual field effects for colour perception, Bryden & Mondor (1991)'s indication of repeated trials regardless of attention equation methods being used would lead to an RVF advantage than LVF for the tasks should be taken in hand. This procedure might trigger an RVF advantage leading to an arguably overhaul of colour categorical perception and attentional capture in a single visual field to impair each other. The evidence that lateralized categorical effects due to differences in attention to the visual fields (Alvarez et al., 2012 cited in Witzel, 2018), risen a question of visual field and attentional weighting done equally in my method?

Another factor was that, Luce (1986) and Sanders (1998) strongly recommends that experiments should be employed about 20 participants, adequate number of times each per condition, with a minimal collection of 300 reaction times per person. Our study here falls short 96 trials in total (96 reaction time data), for an unfair comparison of 16 items per congruent vs 4 items for incongruent conditions. This shortcoming might have been the overall explanation of my inconsistent results.

Within the light of all this information and the mistakes I did in my first experiment, another study required to make proper indications.

METHOD – EXPERIMENT 2

5.1. PARTICIPANTS

Twenty-Six observers from Yasar University Psychology freshmen were attended to the experiment. Students were offered course credit in exchange to participate in series of experiments being researched in the department. All observers were given a consent form at the start of the trials and given explanatory information about the upcoming trial. All observers had normal or corrected-to-normal vision and in order to test colour blindness Ishihara's Colour Blindness Test Plates were used to assess each individual before the experiment trials. All observers passed the colour blindness test.

5.2. STİMULİ & APPARATUS

The stimuli presented in the same monitor as the Experiment 1, however this time in order to compensate possible flickers and to arrange better visual angle refresh rate of the monitor were increased to 100Hz and the resolution decreased to 1024 x

768 pixels. In addition to experiment 1 room conditions an adjustable chin rest placed 57cm away from the monitor to keeping a constant seating and viewing distance.

The stimuli were consisted four squares horizontally places along the fixation point with a 10 ° visual angle eccentricity in order to achieve exogenous presentation. The colours that were presented in the experiment 2 selected from CIELCh colour scale this time to use a more consistent perceptually uniform colour space than Munsell.

The CIELAB colour space (CIE L*a*b) is a colour space (specific organization of colours) defined by the CIE in 1976. Colour is expressed by three values which are L: Lightness (black to white), a* (green to red) and b* (blue to yellow). However, the CIELCh colour space used in this experiment is a derivation of CIELAB, expressed in a cylindrical form where chromaticity components a-b replaced by correlates of chroma and hue. In CIELCh C* represents chroma, h represents the hue angle in the colour wheel, and L remains as Lightness unchanged.

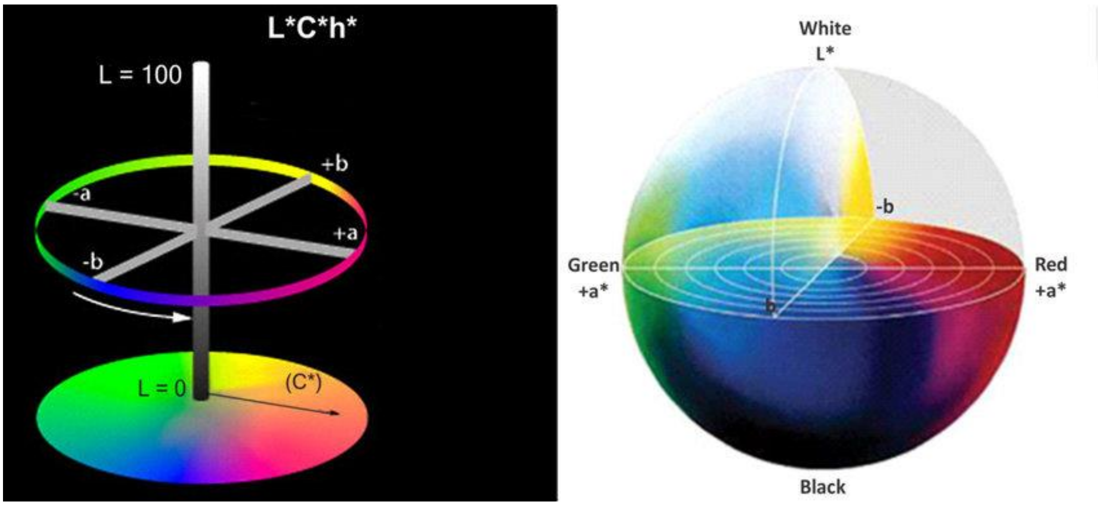

Figure 8. CIE L*C*h and CIE L*a*b colour spaces (Tolchair, Crohare, Gallará, 2015)

Munsell colour space equivalents for the CIELCh selected colours that used in the experiment could be seen in table below.

Table 2. CIE L*C*h codes for Munsell Equivalents

Colour Code CIE L*C*h	Munsell Chart Equivalent
0.3137254902 | 0.5215686275 | 0.3960784314	7.5G
0.3019607843 | 0.5215686275 | 0.4156862745	10G
0.282352941 | 0.529411765 | 0.435294118	2.5BG
0.2745098039 |0.5176470588 |0.4588235294	5BG
0.2705882353 |0.5176470588 |0.4823529412	7.5BG
0.2666666667 |0.5137254902 |0.5058823529	10BG
0.278431373 |0.509803922 |0.521568627	2.5B
0.3019607843 |0.5019607843 |0.5411764706	5B
0.337254902 |0.4941176471 |0.5490196078	7.5B

Same colour pairs, difficulty and colour categories were used in experiment 2 as experiment 1.

5.3. PROCEDURE

Some alterations were made to experiment 1's procedure. Experiment covered randomized and counterbalanced order for 6 colour pairs, 4 target conditions, 2 cue conditions, 2 congruency conditions and 2 hemispheric conditions all total repeated 2 times in total 384 trials. This time repetition of trials have been increased and properly equated in visual fields, according to the mistakes of Experiment 1 that I have discussed.

A fixation point were given for 500ms, followed by a 200ms presentation of the white cue for congruent or incongruent locations. 500ms interval followed the cue and stimulus this time presented for 120ms in order to eliminate possible ceiling effect by stimulus presentation time, indicated from the results of experiment 1.

Response mechanics were same as the experiment 1. Reaction time and accuracy collected as data for congruency, difficulty, colour category and visual field conditions. Re-arranging of the visual angle for shown stimuli and constant viewing distances, allowed to collect data for indicating hemispheric effects.

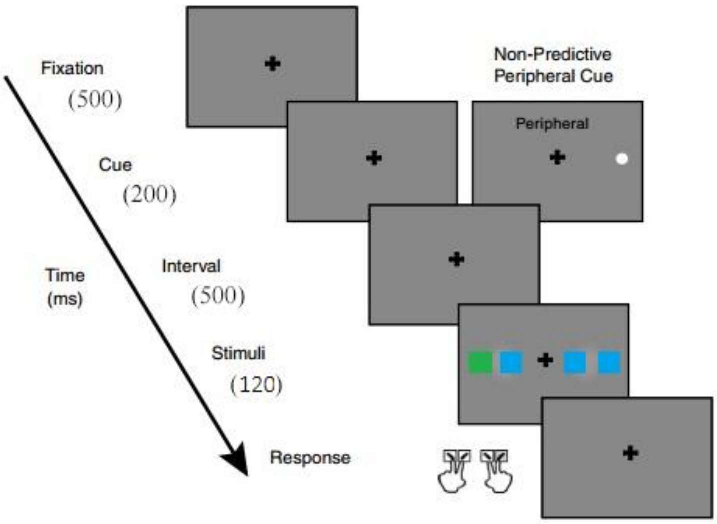

Figure 9. Schematic of the experiment 2 procedure

RESULTS AND DISCUSSION – EXPERIMENT 2

First of all, individual data sets analysed to indicate outliers, and for each individual proportion of errors were calculated for both cue conditions. As the proportion of chance level for 2AFC tasks are 0.5 for weak signals up to 1.0 for very strong one, a detection threshold defined for correct responses at .75 as suggested in the literature (McKee, Klein, & Teller, 1985). Overall proportion of correct responses were calculated for each observer and 6 participants failed to reach .75 proportion of correct responses, that their data cut off from the study, decreasing total 26 observers' individual data to 20.

Since the raw data includes 2 different colours (Blue and Green) for within-category discrimination pairs, firstly the differences between these conditions analysed in order to make assumptions of within vs. cross category pairs. As expected, Sidak pairwise comparisons showed that although there was a significant difference between cross category colour and both blue (p<.001) and green (p<.001) colours, difference between blue and green was not statistically significant (p=.105). Therefore, for following analyses colour category condition safely decreased to two by combination of conditions. A 2x2x2x2 Repeated Measures ANOVA was conducted with Congruency (2 Levels: Congruent, Incongruent), Difficulty (2 Levels: 1 Step, 2 Step), Pair Category (2 Levels Within, Cross), Visual Field (2 Levels: Left Visual Field, Right Visual Field). Main effect of visual field was not statistically significant F (1, 19) = .302, p=.589, η^2 = .016. For further analyses data has been restructured to combine visual field conditions into one for each other condition. Finally, 2x2x2 Repeated Measures ANOVA was conducted with Congruency (2 Levels: Congruent, Incongruent), Difficulty (2 Levels: 1 Step, 2 Step), Pair Category (2 Levels Within, Cross) for Accuracy, Reaction Time and Inverse Efficiency Scores. All three measurements will be reported in order to see overlapping and diverging points.

6.1. **ACCURACY**

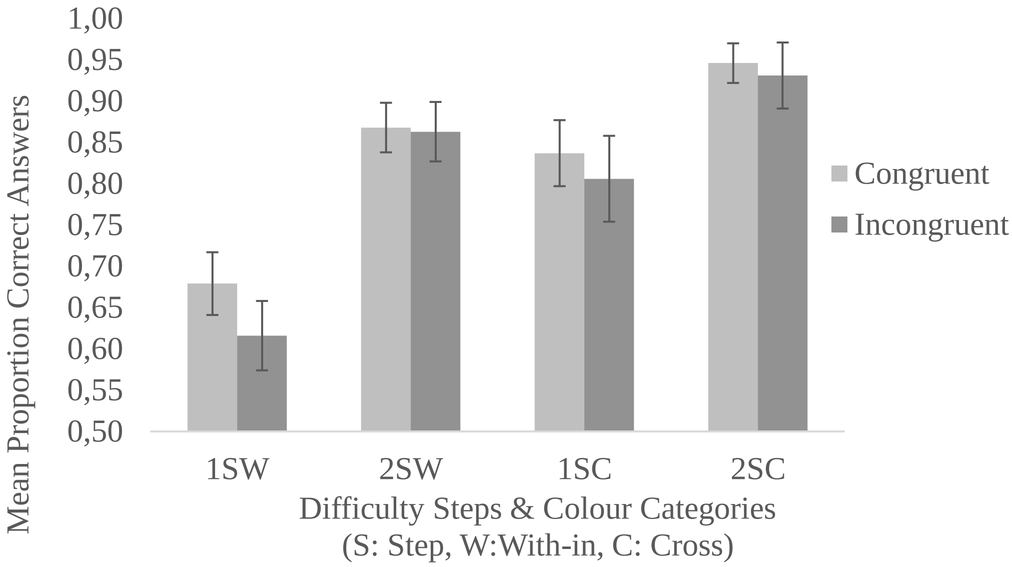

Figure 10. Mean proportion of correct answers across colour categories, cue congruency and discrimination difficulty. Error bars shows %95 Confidence Interval

Figure shows mean proportion of correct answers across colour categories, cue congruency and discrimination difficulty. It can be seen that accuracy did not changed regarding to interactions between colour categories, difficulty and attention orientation. Main effect of congruency was statistically significant, F (1, 19) = 5.496, p = .03, η^2 = .224, indicating that attention orientation was effective on accuracy. Main effect of difficulty was statistically significant, F (1, 19) = 155.176, p<.001, η^2 =.891. Main effect of category was statistically significant, F (1, 19) = 82.925, p<.001, η^2 =.814. The interaction between congruency and difficulty was not statistically significant, F (1, 19) = 3.085, p= .095, η^2 =.14. The interaction between congruency and category was not statistically significant, F (1, 19) = .392, p=.539, η^2 =.02. The interaction between difficulty and category was statistically significant, F (1, 19) = 23.969, p<.001, η^2 =.558, indicating that as expected from the literature, discrimination of cross categories and easier pairs were most accurate. However, as the interaction between congruency, difficulty and category was not statistically significant, F (1, 19) = 82.925, p<.001, η^2 =.814, it indicates that the discrimination does not interacted with attention orientation. This bigger picture needed to be investigated more with t-tests to reveal out how cross and within category discriminations were handled via attention orientation.

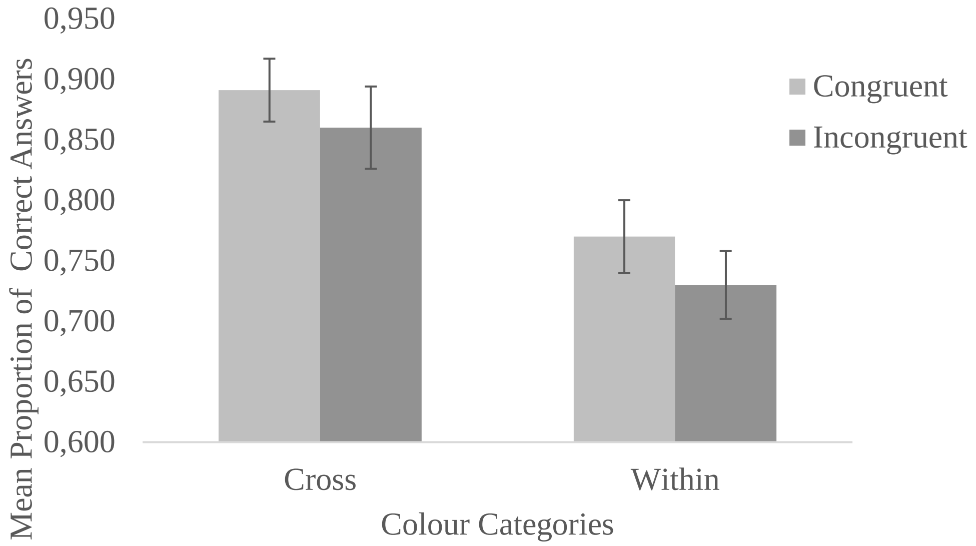

Figure 11. Mean proportion of accuracy across colour categories and cue congruency. Error bars shows %95 Confidence Interval

Figure 11 shows the mean proportion of correct answers across colour categories and cue congruency. It can be seen that for both colour categories, attention orientation did not affect the accuracy. Congruent cross category discriminations were not significantly different than incongruent cross category discriminations, t (19) = 1.617, p=.122. However paired samples t-test showed that congruent within category discriminations were significantly different than incongruent within category discriminations, t (19) = 2.11, p=.048, d= .47.

6.2. **REACTION TIME**

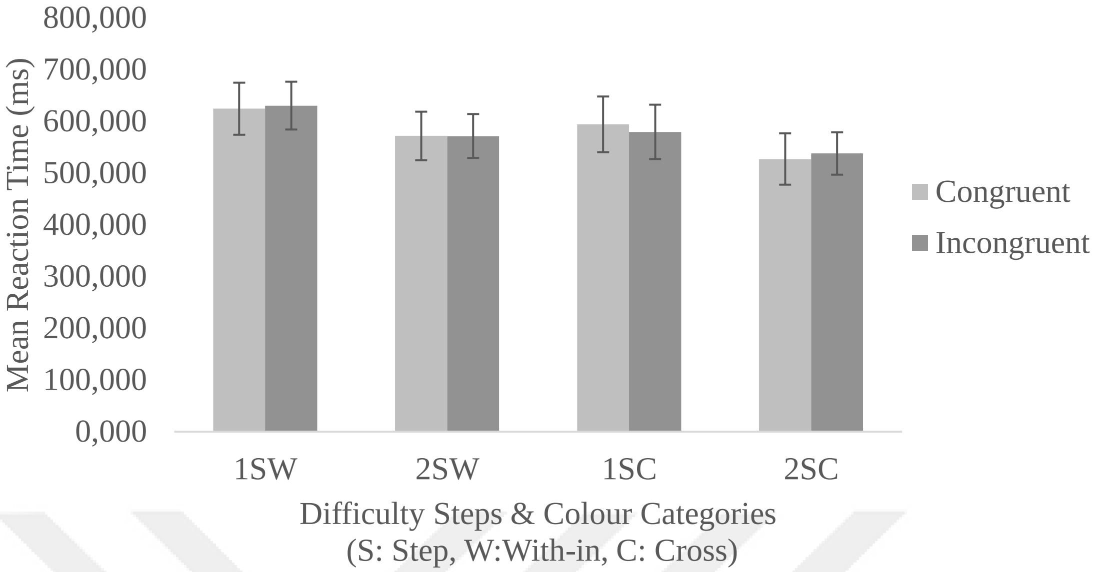

Figure 12. Mean RT Scores across colour categories, cue congruency and discrimination difficulty. Error bars shows %95 Confidence Interval

Figure 12 shows mean RT scores across colour categories, cue congruency, and discrimination difficulty. It can be seen that reaction times did not changed with an interaction. Main effect of congruency was not statistically significant, F (1, 19) = .009 p=.926, η^2 =0, indicating that attention orientation did not change the reaction times of observers. As expected from the literature, main effect of difficulty was statistically significant, F (1, 19) = 55.354, p<.001, η^2 =.744, and also main effect of category was statistically significant, F (1, 19) = 35.409, p<.001, η^2 =.651.

The interaction between congruency and difficulty was not statistically significant, F (1, 19) = .632, p=.437, η^2 =.032. Additionally, the interaction between congruency and category was not statistically significant, F (1, 19) = .256, p=.619, η^2 =.013. Also, the interaction between difficulty and category was not statistically significant too, F (1, 19) = .012, p=.913, η^2 =.001. Yet overall the interaction between congruency, difficulty and category was not statistically significant, F (1, 19) = 3.365, p=.082, η^2 =.15.

Congruent cross category discriminations were not significantly different than incongruent cross category discriminations, t (19) = .229, p=.821. However this time congruent within category discriminations were not different, statistically significant than incongruent within category discriminations, t (19) = -.478, p=.638.

Although the possibility of a speed – accuracy trade off (yet not evident), the results showed a significant effects in accuracy yet inconsistent results for RT. Situations like this debated in many previous studies, that they come up with a solution of integrating accuracy and RT to argue predicted directions (Bruyer & Brysbaert, 2011). In order to analyse the performance of the observers with Reaction Time (RT) and Proportion of Errors (PE), and provide a better summary “Inverse efficiency score” (IES) was used (Townsend & Ashby, 1978). IES is an integrated measure which takes reaction time and proportion of correct responses into an observable measure that could be expressed as the average energy consumed by the observer over time. IES scores are derived by RT of the correct responses in the condition divided by 1-PE or by proportion of correct responses (PC). Also, it can be considered as the RT corrected for the amount of errors committed (Vandierendonck, 2017).

$$IES = \frac{RT}{1 - PE} = \frac{RT}{PC}$$

Figure 13. IES Calculation

Since RTs are expressed in millisecond, dividing RT into proportions still make IES being expressed in millisecond as well (Bruyer & Brysbaert, 2011).

6.3. **IES**

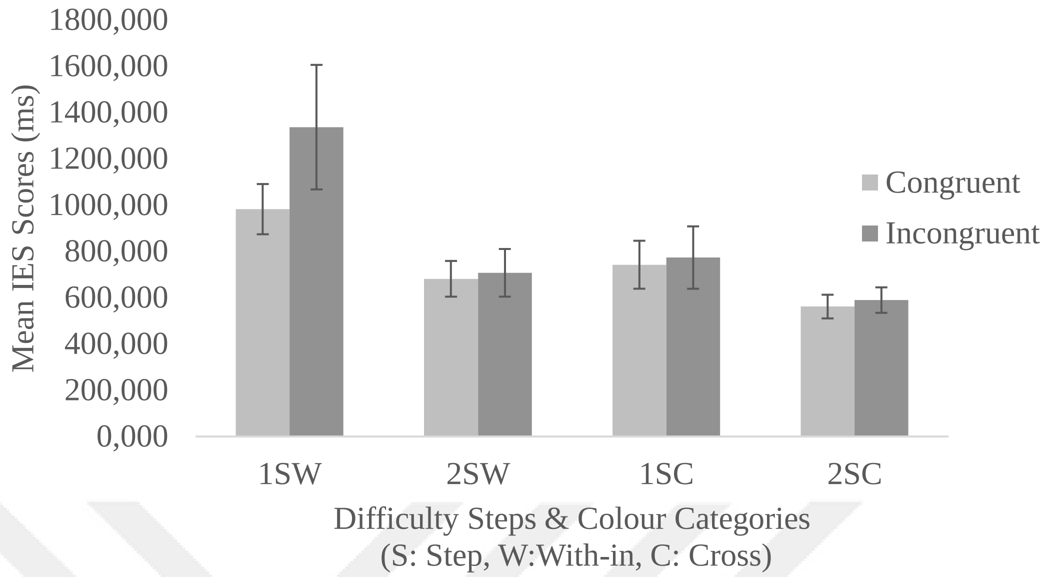

Figure 14 . Mean IES Scores across colour categories, cue congruency and discrimination difficulty. Error bars shows %95 Confidence Interval

Figure 14 shows mean IES Scores across colour categories, cue congruency and discrimination difficulty. It can be seen that performance changed across cue congruency, difficulty and category. Main effects of congruency was statistically significant, F (1, 19) = 9.033, p = .007, η^2 =.322. Main effect of difficulty was statistically significant, F (1, 19) = 57,959, p<.001, η^2 =.753. Main effect of category was statistically significant, F (1, 19) = 54.825, p<.001, η^2 =.743. The interaction between congruency and difficulty was statistically significant, F (1, 19) =5.595, p=.029, η^2 =.227. The interaction between congruency and category was statistically significant F (1, 19) = 5.513, p=.03, η^2 =.225. The interaction between difficulty and category was statistically significant, F (1, 19) = 25.448, p<.001, η^2 =.573. The interaction between congruency, difficulty and category was statistically significant F (1, 19) = 7.865, p=.012, η^2 =.288. Overall interaction shows that attention has a facilitating role over colour perception.

Further comparisons by using paired samples t-test showed that as we did in previous measurements, congruent cross category discriminations were not significantly different than incongruent cross category discriminations, *t* (19) = -1.656, *p*=.114, *d*= .37 However congruent within category discriminations were different statistically significant than incongruent within category discriminations, *t* (19) = -2.775, *p*=.012, *d*= .62. The difference between congruent cross and congruent within category discriminations was statistically significant, *t* (19) = -6.669, *p*<.001, *d*= 1.49. Also, for incongruent aspect, again the difference between cross and within category discriminations was statistically significant *t* (19) = -5.331, *p*<.001, *d*= 1.19. In order to compare these findings with the previous RT ones following figure could be indicated.

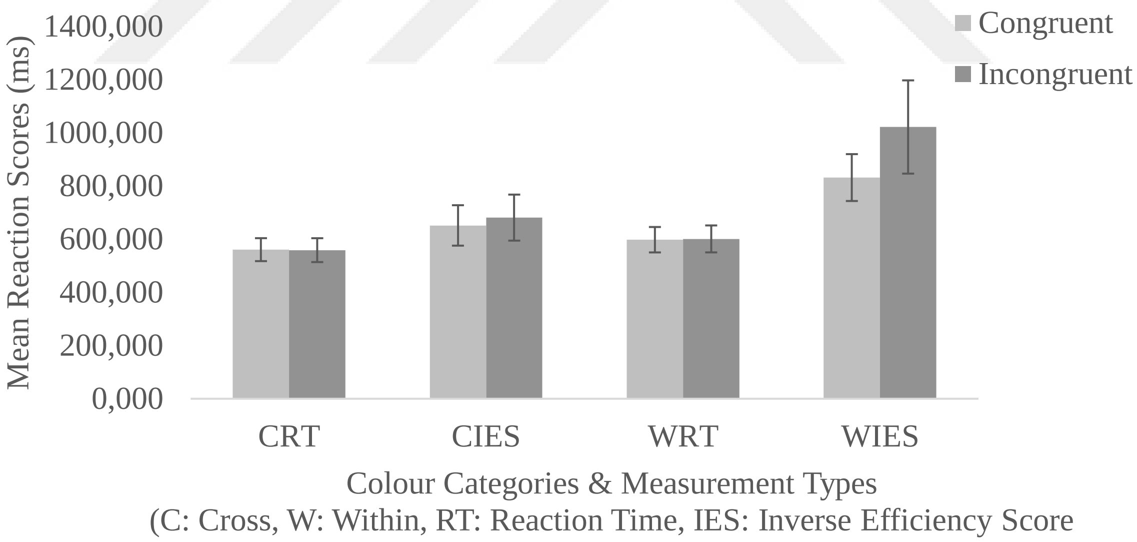

Figure 15. Mean reaction scores across cue congruency, colour categories and different measurement types. Error bars shows %95 Confidence Interval

Figure 15 shows mean reaction times across cue congruency, colour categories and RT and IES measurement types. It can be seen that, regarding of the measurement condition cross category discriminations did not affected by cue congruency. However, within category discriminations controversially got effected by cue congruency. Therefore, we suggest the idea of cross category discriminations are bottom-up processes, yet within category discriminations have a top-down aspect.

GENERAL DISCUSSION

In this thesis I have tried to find an opinion about how attention orientation if/might affect the colour categorical perception. Results managed to give insight with three different measurements of accuracy, RT and IES.

Results of significant main effects managed to capture suggested assumptions of Bornstein & Korda (1984) and Hanley (2015). Discrimination of cross colour categorizations are easier than the within categories. Attention orientation was evidenced as the main effects of congruency implies. Performance wise, the interaction between cue congruency, colour categories and difficulty showed significance. This interaction could be interpreted within the light of Witzel (2019)'s arguments:

Categorical colour perception does not undoubtedly require meaning that, colour perception is purely categorical, yet humans cannot distinguish same colour categories. Rather humans use colour perception as a tool to see progressive changes in colour (both within and cross categories).

In all three measurements, results showed that congruent cross category discriminations did not get effected by cue congruency (attention orientation). This alone reasonably supports the hypothesis 1. Therefore, cross category discriminations might be a purely automatic process, as they did not get effected by cue validity in terms of costs or benefits. However, the pattern of results came out in the within category discriminations, shown that it got effected by cue validity. Thus, an intentional process got involved (Kinchla, 1980; Shaw & Shaw, 1977; Sperling & Melchner, 1978; Vossel, Thiel & Fink, 2006). Hypothesis 2 got supported within the light of this results.

Although the categorical facilitation suggests shifts of observers' attention over to linguistic categories, it also can be interpreted as, shifting one's attention over to existing categorical knowledge, in order to make accurate discriminations. Combining "categorical facilitation" with the information assisted serial search that my results showed, I can assume that the role of attention in the categorical facilitation takes part for colour, when the stimuli cannot be identified uniquely by its perceptual feature, therefore facilitates a serial search at the same time requiring a prior categorical or boundary knowledge. Therefore, hypothesis 3 got supported yet open to questions.

Lateralization for both attentional factors and colour categorical perception, were one of the agenda that I tried to take a control on. Results have shown no lateralization effect, therefore assuming that both Alvarez et al. (2012) and Mondor & Bryden (1990) were right in their assumptions. Equal weighting of attention to two visual field, potentially eliminated the lateralization effects for our population sampling.

FUTURE DIRECTIONS AND APPLICATIONS

Albeit of the results we demonstrated here, the results did not produce enough evidence to discuss cognitive penetrability. Attention orientation triggered a top-down modulation on search and discrimination processes of within colour stimuli, but this alone cannot be purely indicated as cognitive penetration.

Empirical measurements allowed previous studies to indicate an argument of colour discrimination and discrimination thresholds are shaped by second-stage mechanisms, not by colour categories (Brown et al. 2011, Witzel & Gegenfurtner, 2018). Green-Blue boundary that associates with these second-stage mechanisms (Malkoc et al. 2005; Witzel & Gegenfurtner, 2018), therefore demonstrates higher discrimination performance on green-blue boundary attributes to categorical perception. Therefore, I should suggest a future direction that attention orientation could be tested in newly acquired categories. It could indicate a whole another level of debate of “if” only existed across colour categories pops out, or newly acquired across categories would pop out too.

Stimuli that was used in the study did not consist of fairly verbal elements, nor verbal outputs for tasks. But we cannot also totally ignore the fact that participant might affected by verbal interference, yet verbal interference modulate categorical facilitation by diverting attention (Witzel, 2019). In further studies, we suggest of at least equating verbal interference by adding a verbal response aspect to the tasks for both cross and within colour category discriminations. Therefore, a more in-depth assumption could be made for categorical facilitation and attention as well.

Everyday applications or the applied side of this thesis would be that how presentation of the colours in the different feature involving zones such as in the posters, advertisements, marketing and etc. could capture the attention of the human eye. For the situations like response timing is so crucial (piloting, driving, etc.), understanding how colour stimuli will be perceived by changing attentional factors and orientations might help designing better technology.

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