Colour Cognition in Arabic and English Speakers

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Abstract

This thesis reports three sets of investigations, on Arabic and English samples, into aspects of the 'Psychology of Colour'. The first investigates the basic colour terms of Arabic. The results from colour naming and list-tasks indicate that Arabic has 11 basic colour terms that correspond to Berlin and Kay's (1969) universal terms. There was no strong evidence to suggest that two 'extra' terms for blue, *samawee,* and *khuhlie*, were basic. These findings have implications for theories of the evolution of colour terms and further research is suggested. Second, the thesis investigates whether the recently reported left hemisphere bias in categorical colour perception is independent of reading direction and basic procedural variations. First, left hemisphere colour category effect was found for Arabic speakers who read from right-to-left, as well as English speakers, who read from left-to-right, indicating that the hemispheric asymmetry in categorical colour perception is unaffected by reading direction. Second, the left hemisphere bias was independent of the number of distractors in the visual search task, and was not affected when the spatial component was removed from the target detection task. Avenues for further research are suggested. Third, the thesis investigated colour preference in Arab and English samples. Colour preference for both samples was well summarised in terms of weights on the two fundamental neural processes that underlie early colour coding: L-M; S-(L+M). The claim for a 'Universal' sex difference in the weighting of L-M cone-contrast between stimulus and background (Ling, Robinson & Hurlbert, 2006; Hurlbert & Ling, 2007) was not supported. The findings contribute to the debate about the origin and nature of colour preference, and further research is suggested. Overall, the thesis contributes in general to the debate about the origin, nature and interaction of colour language, perception and cognition.

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Chapter one

General Introduction

1.1 Overview

In this thesis, I report three sets of investigations into aspects of the 'Psychology of Colour'. The issues addressed in each series come from more general long-standing questions concerned with first, the origin of colour terms; second, the relationship between these colour terms and colour perception; and finally, what determines colour preference? This brief introduction will outline the origin of these questions, but the detailed rationale for each set of studies is given in the introduction to each empirical chapter (Chapters 2-4). In addition to providing this historical context, a brief summary of what is known about the physiological basis of colour perception will be given, and an outline of 'colour-order' systems. As will become clear, the former underpins theories of colour language and colour preference, while the latter is needed to understand the basis of the technical control of the stimuli used in the various experiments.

1.2 Historical and Conceptual Framework

The origin and nature of colour and our perception of colour has intrigued philosophers and scientists, from at least the time of Aristotle (~350BC). Although the ontology of colour continues to be debated by philosophers (see, e.g., Cohen, 2009), there is a consensus amongst scientists, that colour perception derives from a interaction between the physical properties of light (wavelength and intensity) and the way our visual system responds to the physical stimulus. Although this statement might seem tautological, it has an important implication, recognised by two great physicists, that colour is in part, a matter of psychology. 'For the Rays to speak properly are not coloured. In them there is nothing else but a certain Power and Disposition to stir up a Sensation of this or that Colour' (Newton, 1730/1952, pp 124-125). And, similarly, 'Now if the sensation we call colour has any laws, it must be something in our own nature which determines the form of these laws' (Maxwell, 1855). This recognition of the roles of the visual system led directly to posing the general questions mentioned above. What might be the role of the visual system in influencing colour language and colour preference? If there were such influences, were they the same for everybody – Universalism – or might individual visual systems differ leading to differences in colour language and colour preference – Relativism? Moreover, if visual systems differed, did the differences arise from experience – Nurture – or were they inherited – Nature?

1.3 Colour Language

Gladstone (1858) was probably the first to draw attention to the way languages differed in the ways that they named colours. He noted that the way Homer described colours differed markedly from the way Victorian English described colour. Moreover, he attributed this difference to differences in colour perception: 'that the organ of colour and its impressions were but partially developed among the Greeks of the heroic age (pp 457-499). Meanwhile, Geiger (1880) extended Gladstone's survey of ancient literature and concurred with Gladstone that the ancients used fewer colour terms than found in English, which he too attributed to differences in colour vision. He suggested that colour term systems 'evolved' systematically acquiring new terms reflecting the parallel evolution of colour vision.

Rivers (1901) seemed to have found the first empirical evidence linking differences in colour language to differences in colour vision. On finding that the languages of the Torres Straits had fewer colour terms than English, and that they did not distinguish blue from green, attributed these differences to differences in colour vision.

Of course, it should noted straight away, that in all three cases above, what had been observed was an *association* between (presumed) colour vision and colour language; even granted the validity of the observation, the attribution of 'perception causing language' does not necessarily follow. Language could change colour perception, consistent with the yet to be formalised Linguistic Relativity Hypothesis (Whorf, 1956).

Even as early as 1877, Magnus, using recently collected data, confirmed that languages differed in the way Geiger had noted, but failed to find the corresponding differences in colour vision. In the early days of the development of scientific Psychology, Woodworth (1910), while criticising Rivers, offered an explanation of Magnus's data: differences between languages reflected differences in cultural needs — the Utilitarian Hypothesis. This hypothesis came to dominate American Linguistics and Anthropology for the next sixty years. For example, Ray's views were typical: "Each culture has taken the spectral continuum and divided it into units on a quite arbitrary basis" (Ray, 1952:258).

Many of the issues summarised above are still debated today. Berlin and Kay (1969), offered an updated version of the Geiger/Magnus evolutionary hypothesis, and subsequently argued that the evolutionary path was constrained by universal visual physiology (Kay & McDaniel, 1978). Although a considerable amount of data supports their position, both the data and the interpretation are disputed (e.g., Saunders & van Brakel, 1997; Roberson, Davies & Davidoff, 2000). These modern developments are returned to in Chapter 2, which reports a study of Arabic colour terms.

1.4 Colour language and Colour Perception

As mentioned above, as early as the late nineteenth century, Gladstone, Geiger and subsequently, Rivers all assumed that differences in colour language reflected differences in colour perception. This was consistent with the commonsense view that language was determined by thought, where thought in its widest sense included perception. Language was taken to be the 'servant' of thinking being 'merely' a way of expressing thoughts.

This view was turned on its head most prominently by Whorf (1956) who argued that rather than being a passive way of expressing thoughts, language determined (heavily constrained) thought: "We dissect nature along lines laid down by our language" .

This Linguistic Relativity Hypothesis (LRH) was first introduced to experimental psychologists by Brown and Lenneberg (1954). They investigated the relationship between recognition memory for colours and the 'codability' or ease of naming of the colours. They found that the easier it was to describe a colour to someone else so that they could recognise the colour amongst distractors, the easier it was to remember (recognise) the colour amongst distractors. They argued that this showed language influencing memory, an aspect of thought. This implies that if people differed in their colour language, so should their memory for particular colours.

Heider, in a series of classic studies (Heider, 1972; Heider & Olivier, 1972), tested this implication by comparing the Dani of Iranjia whose language had only two colour terms, with English-speaking Americans. In one task, they compared recognition memory for good examples (foci) of English chromatic terms, with memory for less prominent examples. As for English speakers, names for foci were more salient than names for less good examples, following Brown and Lenneberg, memory for focals should be better than for non-focals. And, indeed, this was the result. If this pattern results from language influencing memory, then it should not be found for the Dani, who had no distinctive names for the colours. However, the Dani showed the same pattern as the English-speakers. Rosch attributed the results to the greater *perceptual* salience of the focals than of the nonfocals; and she attributed this to the way the visual system processed colour; and she assumed that this was in common to all people.

Curiously, for a study just comparing two languages, and just investigating one domain (colour), Rosch's results were taken as showing that colour perception was universal, and that language did not influence perception. Despite this small empirical base, the Zeitgeist shifted from the presumption of Relativity to the presumption of Universalism, and there was very little further empirical work until interest in the issue was rekindled by amongst others, Davies & Corbett (1997) and Roberson et al. (2000). This new wave of interest was centred on the phenomenon of categorical perception (CP) – better discrimination between colours from different categories than colours from the same category (Bornstein & Korda, 1984). As colours from different categories also have different names, the question arose of whether CP was due to the use of language in some way, and if it were, this would be evidence for the LRH. I return to this in Chapter 3.

1.5 Colour Preference

Colour usually evokes an aesthetic, expressed, for instance, in terms of preference for some colours over others. According to Chandler (1934), studies of colour preference date back to at least 1800, addressing questions such as: do people tend to prefer the same colours; do the sexes differ in patterns of preference? Embedded in both questions, is the issue of what determines preference; to what extent is it Universal, or in contrast, to what extent is it peculiar to the individual? If there are Universal patterns, are these determined by our genes, or by common experience? If experience is important, then there could be consistent cultural differences as people from the same culture are more likely to have similar experiences than people from different cultures.

Early studies were marred by lack of control over the specification of the colours and of the illuminant they were viewed under. However, half a century ago it was established that, preferences were highest for the blue-green region and lowest for the yellow and yellow-green regions (Guilford & Smith, 1959). Moreover, the preference order reported by Eysenck (1941) – blue, red, green, purple, orange and yellow – has generally been supported by more recent studies (see Ling, Hurlbert & Robinson, 2006 for a summary). Note however, the majority of these studies were conducted on Western European or American informants, and the consensus does not extend to the issue of cross-cultural variation.

Until recently, however, the question of what determines preference order was not rigorously addressed. Ling et al. (2006) report that both preference order and sex-differences are strongly associated with the physiology of colour vision (see cardinal directions of colour space in the next section). Moreover, they suggest that these patterns of preference are determined genetically, and they offer an evolutionary explanation of their origin (see Chapter 4). Their studies compared British and Chinese participants, and they claim that the fundamental patterns of preference were similar across cultures, and both showed similar patterns of sex differences. However, there were also second order cultural differences.

Chapter 4 of this thesis returns to these issues and reports a replication of Ling et al.'s work, and extends it to include a Saudi Arabian Arabic speaking sample.

1.6 Physiology of Colour Vision

Colour vision is usually defined as the ability to discriminate stimuli of equal brightness that differ in their spectral composition. In humans, this ability is associated with our experience of colour, although there appears to be no necessary connection between the two. The causal chain leading to perceptual experience starts with the nature of light, continues with the interaction between surfaces in the world and light, then the formation of the retinal image, followed by recovery of information about the relative spectral distribution of light at each point on the retina. A great deal is now known about this casual chain involving physics, molecular biology, genetics and neurology leading Mollon to claim that colour perception is the first case of understanding the pathway from physics through to conscious experience (Mollon, 2000; see Gegenfurtner & Kiper, 2003 & Conway, 2009, for reviews). The aim here, however, is to provide the basis for understanding Kay and McDaniel's appeal to perceptual physiology to explain the variation of colour terms across languages (see Chapter 2), and the origin of colour preferences as argued by Ling et al. (2006; see Chapter 4). In both cases, what is needed is an explanation of the 'cardinal directions of colour space' (Krauskopf, Heeley & Williams, 1982) and this is given below.

Sunlight, and most artificial substitutes, is composed of a mixture of different wavelengths including those in the range of about 400-700 nm, in approximately equal amounts. We experience such spectral mixtures as white or grey (achromatic). However, surfaces in the world change this equal-energy composition. The chemical structure of the surface material selectively absorbs some wavelengths and reflects the remainder. For instance, a surface appears red if it reflects long wavelengths more strongly than shorter wavelengths. The structure of light incident on an eye in the world 'preserves' its history of reflections. The optics of the eye preserves the spatial history of its trajectory: light reflected from adjacent points on a surface falls on adjacent points on the retina of the eye, hence forming an 'image' of the world. Thus, the boundary between two objects (an edge) also forms a boundary in the image. If, the spectral composition of the light reflected from either side of the edge differs, then if the visual system could detect differences in wavelength, it would have the potential to detect the edge. Thus, sensitivity to wavelength has the potential to allow recovery of the layout of objects in the world.

The visual system has evolved to exploit the properties of visual stimulation described above. The key first stage is that the retina contains four different kinds of light sensitive receptors, the rods and three kinds of cones. Each kind of receptor, although sensitive to a broad range of wavelengths, responds more strongly to some wavelengths than others. Moreover, the distribution of spectral sensitivities varies across types of receptor, due to differences in the 'photopiment' – the light sensitive chemical – they contain. As the rods are only operative at low illumination levels, in normal daylight, the primary information for vision is carried by the relative signal strengths of the three kinds of cone. The cones are usually designated as long (L), medium (M) and short (S) reflecting their relative peak sensitivities (560, 530, and 420 nm; see e.g., Gegenfurtner & Kiper, 2003; Conway, 2009).

The trichromatic stage at the receptor level is transformed into three opponent channels in the ganglion cells of the retina. Different combinations of the L and M cones are involved in each channel, but the S cone is primarily involved in just one channel. The luminance channel signals in proportion to the sum of the L and M cones (L+M). The other two channels carry potential information about relative wavelength. One encodes the difference between L and M signal strengths (L-M), while the other signals the difference between the sum of L and M, and the S cone signal strength ([L-M] –S). As well as the functional separation of these channels, they are also anatomically separate, being carried by distinct kinds of ganglion cell, and the three pathways (magno, parvo and konio) following different pathways from retina to Lateral Geniculate Nucleous (LGN), to V1.

When opponent process neurons were first discovered in monkey LGN (De Valois and Jacobs, 1968), it was thought that they were the neurological substrate of Hering's conjectured opponent primaries (Hering, 1920). Hering suggested that there were four 'unique hues' red, green, yellow and blue, and that all other colours appeared to be mixtures of these primary experiences. Orange, for instance, was a blend of red and yellow, and purple was a blend of red and blue. Moreover, while we could experience blends such as these, there were other 'impossible blends'. These were red-green and blue-yellow and Hering thought that his four primaries were organised into these mutually antagonistic pairs. De Valois and Jacobs originally thought that the peak activity of their newly discovered opponent process neurones, were red or green and blue or yellow, but it later became clear that their primary axes were more like magenta-chartreuse and orange-turquoise (De Valois & De Valois, 1993). Nevertheless, the activity of these opponent process neurones has been taken to signal the cardinal directions of colour space, and to underlie colour perception.

1.7 Colour Order Systems

The logic of the experiments presented in Chapter 3, on categorical colour perception, requires that the differences between chosen pairs of colours are equal according to some metric. The metrics most commonly used in the literature are derived from either the Munsell system or CIE systems. Both aim to represent colours in 'perceptually uniform' colour space. That is, distances within each spatial coordinate system are intended to represent 'perceptual distance': the perceived dissimilarity between colours. The greater the spatial separation between two colours is, the greater the perceived dissimilarity between the two colours should be.

Although both systems attempt to represent perceptual distance, they were derived by quite different methods. The Munsell system was empirically derived, and in its current form, is based on a 40 observers making similarity/difference judgments between many colour pairs; the total number of judgements runs into the tens of millions (Newhall, Nickerson & Judd, 1943). In contrast, the CIE system is modelled on the relative spectral sensitivities of the three types of cone (L, M S; see section 1.6) in the 'standard CIE observer'. The CIE coordinate system is thus three dimensional, based on three 'primaries' but for reasons of convenience, the cone primaries have been transformed into the CIE primaries X, Y, Z. One advantage of using these primaries is that all perceivable colours can be represented in a simple chromaticity diagram whose axes are x and y where: $x = X/(X+Y+Z)$ and $y = (Y/(X+Y+Z)$. As x and y are proportional values, by implication, there is a third coordinate, z ($z = Z/(X+Y+Z)$ which is not explicitly represented in the diagram. For present purposes, the key point is that a further transformation from x, y to u' v', results in a diagram where to a first approximation, distance in the diagram represents perceptual distance. Moreover, a further transformation to L* u* v* yields a colour 'space' where Euclidean distance (ΔE) provides a quantitative measure of perceptual distance.

Both Munsell and CIELuv try to provide a measure of perceptual distance on at least an interval scale and, to if, they have succeeded, the two distance measures should correspond. The two measures agree to a good first approximation, but the correspondence is not perfect.

Chapter 4 on colour preference uses a colour space whose axes are proportional to the signal strength of the second stage of colour vision (section 1.6) where cone signals are compared. The axes are: (L+M), or luminance, (L-M) and S-(L+M) – the cardinal directions of colour space. This space is usually is named DKL after Derrington, Krauskopf and Lennie (1984). DKL coordinates can be simply calculated as a transformation of CIE Y x y.

In Chapter 2 the use of another colour order system is reported, namely Color-Aid. Like Munsell, this system is empirically derived, but its scaling is only to an ordinal level. As Color-Aid was used just to provide a reasonable sample of 'colour-space' and no precise distance measure was needed, the relatively weak scaling did not matter. More detailed outlines of the three systems (Color-Aid, Munsell and CIELuv) are given in Appendix 1 and 3.

1.8 Outline of Experimental Chapters

The experimental chapters in the current thesis are divided into three sections. Chapter 2 reports the first studies of the basic colour terms (BCTs) of Arabic. These were carried out within the framework of Berlin and Kay's (1969) theory of universal colour categories. Pilot work had suggested that Arabic might have more than one BCT for the blue region: *azrock* 'blue', *samawee* 'light blue' and *khuhlie* 'dark blue'. Note that these glosses were taken from Arab-English dictionaries, and one aim of the studies was to investigate their appropriateness. More importantly, if Arabic proved to have more than one basic term for blue, then a comparison of Colour CP (see below) in Arabic and English speakers could be used to shed light on the role of language in CP (c.f. Roberson et al., 2000). This was the prime reason for the study.

Adult and child samples were tested using a list task (tell me all the colour terms you can) and a colour naming task (what do you call this colour). The results from both age groups and both tasks converge to suggest that Arabic has 11 BCTs that correspond with Berlin and Kay's (1969) universal terms. In addition, the terms of particular interest — *samawee* 'light blue' and *khuhlie* 'dark blue' — are not basic Arabic colour terms, and the glosses given above are appropriate. As Arabic was not an exception, the plan to make comparisons between English and Arabic speaking samples to shed light on the role of language in CP was no longer viable. However, such comparisons were made in Chapter 3, but for different reasons.

Chapter 3 reports five experiments investigating the lateralisation of colour CP. The hallmark of colour is better discrimination of colours that cross the boundary between lexical categories. Recently, Gilbert, Regier, Kay & Ivry (2005) and Drivonikou, Kay, Regier, Ivry, Gilbert, Franklin & Davies (2007) found that CP was strongest for stimuli that appeared to the right of fixation (right visual field [RVF]). As the RVF projects initially to the left hemisphere (LH) and the LH is dominant for language, these findings have been interpreted as indicating the involvement of language in CP. To date, however, there have been no studies of the lateralisation of CP on participants who read from right-to-left, as in Arabic. Chapter 3 reports such studies and compares the results to an English (left-to-right reading) sample. The Arabic blue-green boundary was first determined and then two experiments investigated the effect of reading direction. It was found that the pattern of lateralisation was unaffected by reading direction. Having shown that the lateralisation of colour CP was independent of reading direction, two further experiments investigated colour CP using variations on the search tasks used by Gilbert et al. and Drivonikou, et al. The pattern of stronger LH CP persisted across the new tasks.

Chapter 4 reports a cross-cultural study of colour preference using the same methods as Ling and colleagues (Ling et al., 2007 Hurlbert & Ling, 2007). As mentioned in section 1.5, Ling et al. claimed that there were reliable sex differences in colour preference. These sex differences were linked to differences in the weighting given to the 'red-green' cardinal direction of colour space; and were largely the same for British and Chinese participants. British and Saudi Arabian (Arabic) participants were compared, and it was found that while Saudi data replicated the previous findings of sex differences in the weighting of the (L-M) axis, curiously, the British data did not,. There was, however, a sex difference in the weighting of the 'blue-yellow' axis for both Arabic and British samples. These findings are related to Ling and colleagues' evolutionary theories of colour preference.

Chapter two

Establishing Arabic Basic Colour Terms

2.1 Introduction

Although all humans with normal trichromatic colour vision have the same general physiological basis of colour vision (Mollon, 1999), there is noticeable diversity among languages in the way they categorise the continuum of visible colours. Some languages are reported to use as few as two terms to describe all colours (Heider, 1972); others use many more (Kay, Berlin, & Merrifeld, 1991; MacLaury, 1987). Although a considerable amount of material has been written on this subject, relatively little has been written on colour terms in Arabic.

This chapter reports two experiments conducted within the framework of Berlin & Kay's (1969) theory of universal colour categories to identify the 'basic colour terms' (BCTs) of Arabic. Pilot work had suggested that Arabic might have more than one BCT for the blue region — *azrock* 'blue', *samawee* 'light blue' and *khuhlie* 'dark-blue' — and thus a subsidiary aim was to investigate this possibility. Experiment 1 used the method of elicited lists which is a simple and fast method of identifying likely BCTs (Davies & Corbett, 1994; Özgen & Davies, 1998). It provides two measures — frequency of use and order of occurrence — and assumes that the psychologically more salient terms will appear in more lists and in higher positions than less salient terms. Pich and Davies (1999) found that primary categories (WHITE, BLACK, RED, GREEN, YELLOW, and BLUE) appeared more frequently than derived categories (BROWN, PINK, ORANGE, PURPLE, and GREY). They also found that, in general, the 11 BCTs (both primary and derived) were more frequently used than non-BCTs. The second experiment required participants to name a representative sample of colour-stimuli (those used by Davies & Corbett, 1994, 1997, and Özgen & Davies, 1998) under controlled conditions. This method assumes that BCTs have specific perceptual referents and, consequently, participants will agree on names for these referents.

2.1.1 Berlin and Kay's Theory of Colour Universals

In 1969, Brent Berlin and Paul Kay devised their seminal theory of colour universals that proposed the existence of semantic universals in colour vocabulary. In addition, the theory also proposed that all languages acquire their tokens of the colour universals in one of a small number of possible sequences. They derived the theory partly from studies of native speakers of 20 different languages including samples of all major linguistic families, and partly from published language descriptions such as dictionaries.

They gathered their data in two stages. In the first stage, the list task, informants wrote down as many colour terms as they could in their native language. After this, the informant was given a stimulus board consisting of 320 Munsell colour chips[1] as shown in Figure 1. For each colour term informants used in the first stage, they were asked to indicate all chips that were exemplars of each term, and to indicate the best exemplar of each term.

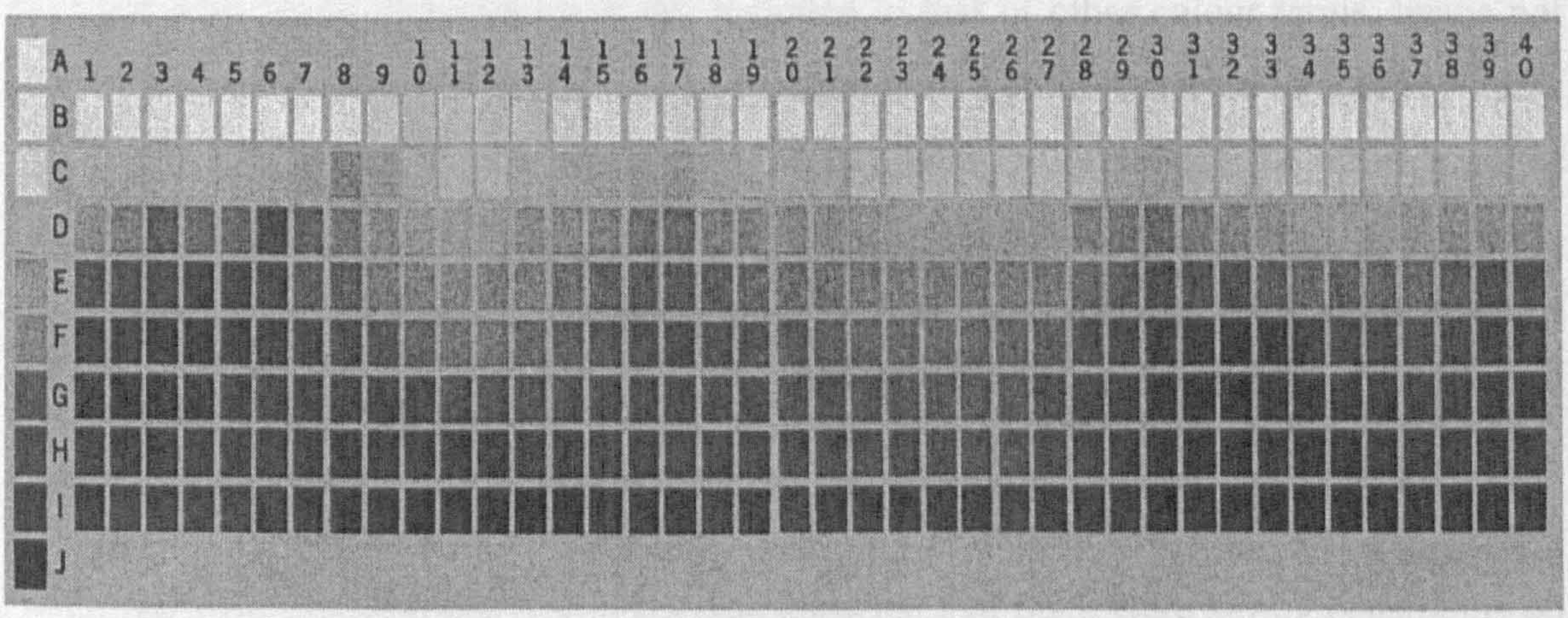


Figure 1. The World Colour Survey (WCS) array of Munsell colour chips.

[1]Munsell chips are small pieces of cardboard which are painted in carefully controlled pigments, so that the colours of the chips are systematically spaced over the range of all possible colours, at least in as far as it is possible to create the appropriate pigments. Munsell chips, and the Munsell system of ordering colours (Cleland 1937), are, by and large, common standards in linguistic research.

Although there was considerable variation across languages in both the number of colour terms and the colours included in the terms, the distribution of the best or most typical examples (the prototype) of colour terms was not so variable. They claimed that most of these were placed in just a few areas of the Munsell chart and that the foci of these colour terms were more or less the same for all languages. These 'universal foci' were to have a central place in the theory. They suggested that the way to determine equivalent terms across languages was to ignore the extent to which exemplars overlapped, and to define equivalence by having common foci. Looked at in this way, they claimed that there were just eleven terms that accounted for the majority of terms in the 20 languages.

A further manoeuvre – identifying 'basic colour terms' (BCTs) – restricted the emerging theory to what they claimed were the 'necessary' or 'core' colour terms of each language. Berlin and Kay (1969) defined BCTs according to the following criteria: 1) the term is monolexemic — that is, its meaning is not predictable from the meaning of its parts; hence not *light blue;* 2) Its significance is not included in that of other colour terms; hence not *scarlet* which is included in *red.* 3) Its application must not be restricted to a narrow class of objects; hence, not blonde. 4) It must be psychologically salient for informants, as evidenced, for instance by having high frequency in elicited lists. However, Kay, Berlin, Maffi and Merrifield (1997) state that these criteria for basicness were more a set of guidelines than a formal definition and in practice, the criteria reduce to 'simple and salient' (Hardin & Maffi (1997).

Following these two manoeuvres, it became apparent that there were strong constraints on what combinations of colour terms occurred across the languages. Berlin and Kay expressed these regularities using the implicational hierarchy shown in Figure 2.

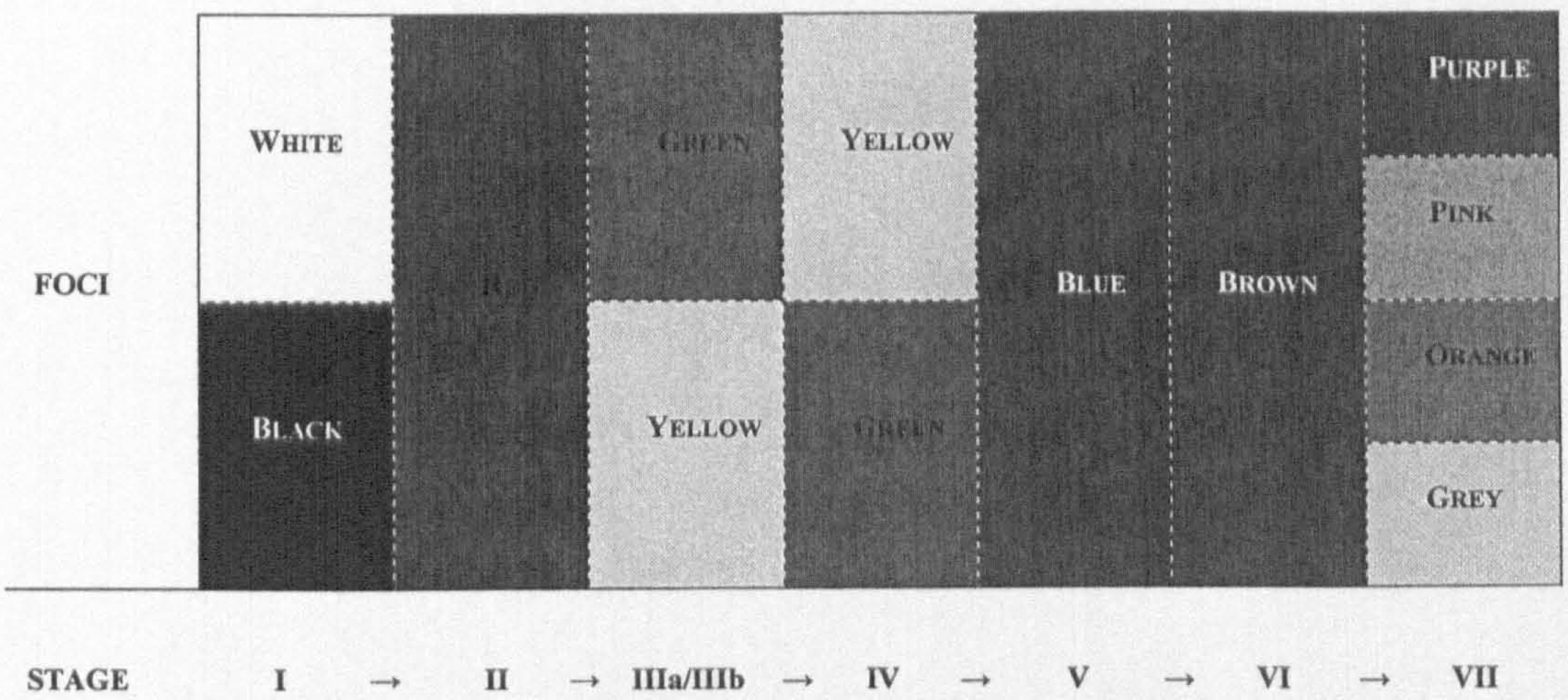


Figure 2. The Berlin and Kay's hierarchy for basic colour terms.

All languages appeared to have terms with prototypes for WHITE and BLACK, shown at the left of the hierarchy, but some languages had no other basic colour terms. However, if a language had a term for any of the colours further right in the hierarchy, it always had terms for all the others to the left in the hierarchy. For example, if a language had a term with its prototype at GREEN, then it would also have terms with the prototypes at WHITE, BLACK, AND RED. If terms shared a place on the hierarchy, such as GREEN and YELLOW, then knowing a language had one of the terms implies nothing about whether the language should also have the other term.

As well as these synchronic constraints on 'permissible' combinations of terms, Berlin and Kay also suggested that the hierarchy encapsulated diachronic constraints on the orders that languages acquired terms. As alluded to above, they proposed that all languages started with terms for BLACK and WHITE, then added a term for RED, then for either GREEN or YELLOW, and so on, up to the maximum of eleven BCTs.

2.1.2 Beyond the eleven

Kay and McDaniel (1978) developed the Berlin and Kay (1969) theory using a system of fuzzy logic, consistent with the prototypical properties of natural categories (Rosch, 1973, 1975). Kay and McDaniel (1978) proposed that six fundamental neural responses (FNRs) were directly responsible for the perception and linguistic structure of what they called the 'primary' colours — namely, black, white, red, green, yellow, and blue. They drew a distinction between two types of non-primary colour categories: composite and derived categories. Composite categories are the fuzzy union of two FNRs. For instance, it is common to have a single term that includes both the universal categories BLUE and GREEN —'GRUE'. Derived categories are the fuzzy intersection of two FNRs; so, for example, ORANGE is the fuzzy intersection of RED and YELLOW.

One implication of the Kay and McDaniel (1978) theory is that there are logically possible fuzzy unions and intersections that are not included in the Berlin and Kay (1969) hierarchy. For example, Zollinger (1984) argues that the space between blue and green is wide enough to be encoded by the term turquoise, derived from the fuzzy intersection of these two FNRs. Adding a blue term appears to be the most common way that languages move beyond the eleven Berlin and Kay basic colour terms (stage seven). Russian, (Davies & Corbett, 1994), Turkish (Özgen & Davies, 1998) and Greek (Androulaki, Gômez-Pestaña, Mitsakis, Lillo, Coventry & Davies, 2006) all have 12 BCTs, encoding the blue region with two basic terms distinguishing between light and dark blue. The extra blue term could either be the fuzzy intersection of BLUE and BLACK, resulting in 'dark blue', or the intersection of WHITE and BLUE, resulting in 'light blue'. Pilot work suggested that Arabic might have three terms that designate different kinds of blue: *azrock* 'blue', *samawee* 'light blue' and *khuhlie* 'dark-blue'. The majority of our informants sorted the blue stimuli into groups that they named *samawee* 'light blue' and *azrock* 'blue', suggesting that a more apt gloss for *azrock* may be 'dark-blue'.

2.1.3 Aims of the current set of experiments

The overall aims of the present study were to determine the BCTs of Arabic and to explore the status of the putative extra blue terms. Two groups of Saudi Arabic speakers were tested: children 8 to 12 years old and adults 18 to 25 years old. Two methods were used: elicited lists and colour naming The status of the three blue terms *azrock* 'blue', *samawee* 'light blue' and *khuhlie* 'dark blue' was of particular interest.

2.2 Experiment 1. Elicited Lists

2.2.1 Introduction

Participants were required to write down as many colour terms as they could think of. As BCTs have high salience, they should be offered by the majority of informants, and we use frequency in the lists as one measure of basicness. The most salient terms should also tend to be among the earliest terms offered, and we use mean list position as a second measure of basicness.

2.2.2 Method

2.2.2.1 Participants

Two groups of Arabic speakers took part, the child group and the adult group. The child sample consisted of 113 boys and 140 girls, with an age of 8 to 12 years (mean = 10:6). They were drawn from three different primary schools in Riyadh and were tested in school. All of the participants were monolingual Arabic speakers. There were 200 informants in the adult group, half were men and half were women, with an age range of 18 to 25 years (mean = 19.83). They were students at King Saud University and they were all native Arabic speakers with some knowledge of English.

2.2.2.2 Procedure

For both samples, data was collected by a first language speaker of Arabic and instructions were given in Arabic. The child sample was tested in a group in a classrooms and the adult sample was tested in a group in lecture theatres or classrooms. Informants were given a sheet of paper, and were asked to write down all of the colour terms they could think of. The child sample was told they had four minutes to complete the task, while the adult sample was told they had one minute to complete the task.

2.2.3 Results

The terms offered by each group were examined in terms of the percentage of each sample that offered each term, and mean list positions. The glosses given are consistent with the Arabic - English Dictionary (1974), and with the colour-naming experiment data that will be reported later.

2.2.3.1 Child lists

The mean number of terms offered was 12.99, and the range was from 2 to 26. Forty three terms were offered by the boy sample (mean = 12, SD = 3), and 40 terms by the girl sample (mean = 13, SD = 4).

Frequency of use, Table 1 shows the terms offered by at least 10% of the child sample (column 1) ordered by frequency of use; their English gloss (column 2); and their frequency of use across the sample (column 3).. It can be seen that the most frequent terms were *ahmar*, 'red', *azrock*, 'blue', *akhdar*, 'green', *asfer*, 'yellow', *asswed*, 'black' and *abiyadh*, 'white'. Each of these six terms was offered by at least 88.8% of the sample and they appear to be the Arabic tokens of the six universal primary categories. The terms *boartoogaalee*, 'orange', *bonee*, 'brown', *wardee*, 'pink', *banafsagee*, 'purple' were the next most frequent terms, each offered by almost 78% of the sample, and they appear to be the Arabic tokens of four of the universal derived terms. *Rassasee*, 'grey' was the next most frequent term; it was offered by 63.3% of the sample. *Samawee* 'light blue' and *khuhlie* 'dark blue' scored 40% and 38.6% respectively at positions 12 and 13.

Mean list position, Mean list positions for each term are shown in Table 1 column 5. The first 13 terms according to frequency of use also occupy the first 13 positions in mean list position, although the two orders differ a little. *Samawee,* 'light blue' and *khuhlie,* 'dark blue' were at positions 12 and 13 according to both measures

Table 1. Child list task (N = 253): terms offered in the list task by at least 10% of the Child sample, their English glosses, the percentage of respondents that offered each term, and the mean list position.

Term	Gloss	Percentage	Percentage order	Mean list position	Mean list position order
Ahmar	Red	98.8	01	02.41	01
Akhdar	Green	96.0	02	05.31	03
Asfer	Yellow	95.2	03	05.29	02
Azrock	Blue	92.8	04	05.95	04
Asswed	Black	90.0	05	07.95	05
Abiyadh	White	88.8	06	08.81	06
Bonee	Brown	82.5	08	10.32	07
Boartoogaalee	Orange	80.1	07	11.08	08
Wardee	Pink	76.1	09	12.39	10
Banafsagee	Purple	74.5	10	12.27	09
Rassasee	Grey	63.3	11	15.76	11
Samawee	Light blue	40.6	12	19.19	12
Khuhlie	Dark blue	38.6	13	19.55	13
Dahabee	Golden	34.3	14	19.96	14
Fadhee	Silver	31.9	15	20.63	15
Enaabee	Dark red	26.3	16	21.44	16
Beige	Beige	19.5	17	22.42	17
Zeatee	Oil-green	16.7	18	22.80	18
Tufahee	Apple	14.7	19	23.21	19
Sukaree	Sugar	12.0	20	23.58	20
Fosforee	Phosphoric	10.0	21	23.76	21

2.2.3.2 Adult list terms

The mean number of terms offered was 10.97, and the range was from 6 to 17. The number of terms offered by the male sample was 43 (mean = 11 SD = 2), and 38 terms by the female sample (mean = 11, SD = 3).

Table 2 shows the adult data laid out as for Table 1. The terms and their rank orders on both main measures are very similar to those from the child data. The first 13 terms are the same as those for the children, with minor variations in their rank order. *Ahmar,* 'red', *akhdar*, 'green', *asfer* 'yellow' and *azrock* 'blue' have the four highest scores, and the remaining Berlin and Kay BCTs occupy the next seven places. Note however, *rassasee*, 'grey', was offered by less than half the sample (47.5%). *Samawee* 'light blue' and *khuhlie* 'dark blue' occupy ranks 12 and 13 on both measures, but they were offered less frequently (~ 10%) than by the children.

Table 2. Adult list task (N = 200): terms offered in the list task by at least 10% of the Adult sample, their English glosses, the percentage of respondents that offered each term, and the mean list position.

Term	Gloss	Percentage	Percentage order	Mean list position	Mean list position order
Ahmar	Red	99.0	01	02.26	01
Akhdar	Green	96.0	02	04.27	02
Asfer	Yellow	93.0	03	05.02	03
Azrock	Blue	90.0	04	05.42	04
Asswed	Black	89.5	05	07.05	05
Banafsagee	Purple	82.0	06	08.86	07
Abiyadh	White	81.0	07	08.18	06
Boartoogaalee	Orange	72.0	08	10.06	08
Bonee	Brown	70.0	09	10.83	09
Wardee	Pink	67.5	10	10.99	10
Rassasee	Grey	47.5	11	13.79	11
Samawee	Light blue	30.0	12	15.22	12
Khuhlie	Dark blue	27.5	13	15.56	13
Beige	Beige	18.5	14	16.52	15
Tarquazee	Turquoise	17.5	16	16.51	14
Dahabee	Golden	16.5	17	16.65	18
Zeatee	Oil-Green	16.0	15	16.67	16
Foshy	Fuchsia	16.0	18	16.64	17
Fadhee	Silver	13.0	19	17.06	19
Enaabee	Dark red	11.5	20	17.13	20
Tufahee	Apple	11.0	21	17.14	21

2.2.4 Discussion

Essentially the same patterns of scores were found across both samples and across both measures. The Arabic versions of the six universal primary categories: *asswed* 'black', *abiyadh* 'white', *ahmar* 'red', *akhdar* 'green', *asfer* 'yellow' and *azrock* 'blue' tended to be found among the first six or seven places on both measures, and they were each given by a clear majority of both samples. The five derived terms *bonee* 'brown', *boartoogaalee* 'orange', *wardee* 'pink', *banafsagee* 'purple', and *rassasee* 'grey', tended to occupy the next five or six places, and with the exception of *rassasee* 'grey', and they were all offered by about 75% of each sample or more. The score for *rassasee* 'grey' was just less than 50% for the adults.

The blue terms of interest, *samawee*, 'light blue' and *khuhlie* 'dark blue' occupied the 12th and 13th positions for both groups on both measures. However, the majority of each group did not offer these terms: their scores were about 40% for the children and about 30% for the adults. The remaining terms were offered by a clear minority of each group, with the highest score being for *dahabee* 'golden' at about 35% for the children.

2.3 Experiment 2. Colour Naming

2.3.1 Introduction

Participants were required to name each of a set of 65 colours approximately evenly distributed across colour space. This set has been used extensively in investigations of BCTs across a range of languages, starting with Setswana (Davies, MacDermid, Corbett, McGurk, Jerrett, Jerrett and Sowden, 1992) and most recently by Uusküla (2008) on Finno-Ugric and Slavonic languages. Data were examined in terms of various indicators of salience and consensus of use (the percentage usage for each of tile; frequency of use per term, 'dominant' colour term per colour tile, and the 'specificity' index). Basic terms should tend to have high scores across these indicators (Davies and Corbett, 1994, 1997; Özgen & Davies, 1998).

Estimates of the prototypes for each Arabic BCT were also derived. If Arabic BCTs are tokens of Berlin & Kay's eleven universal categories, then the Arabic prototypes should be very similar to the universals. Similarity was assessed by comparing the location of Arabic and universal foci in the CIE (1976) uniform chromaticity diagram (see Appendix 1 for an outline of the CIE system).

2.3.2 Method

2.3.2.1 Participants

There were two groups of participants, children (aged 8-12 years) and adults (aged 18-28 years), drawn from the same sources as for Experiment 1. There were 60 in the adult group, half men and half women, and 61 children (31 boys and 30 girls). All were first language Arabic speakers, although some in the adult group knew a little English.

2.3.2.2 Stimuli

The stimuli were 65 coloured 'tiles', measuring 50 mm square and 4 mm thick. They were made of cardboard covered with coloured paper selected from the Colour-Aid Corporation range of colours so that they were a representative sample of the full range. Table A in the Appendix 1 shows the Color-Aid codes and the CIE chromaticity coordinates. Figure 3 shows the location of the tiles in the CIE (u' v') uniform chromaticity diagram, along with the loci of the 11 universal colour foci (Heider, 1971) that can be used as 'landmarks'. As can be seen from the graph, the best example of blue is located at the bottom of the graph, moving through green in the upper left and out to red in the upper right. Yellow is located at the top-centre and achromatic colours (white, black and greys) are located at the centre of the graph. Stimuli were named under the natural day light.

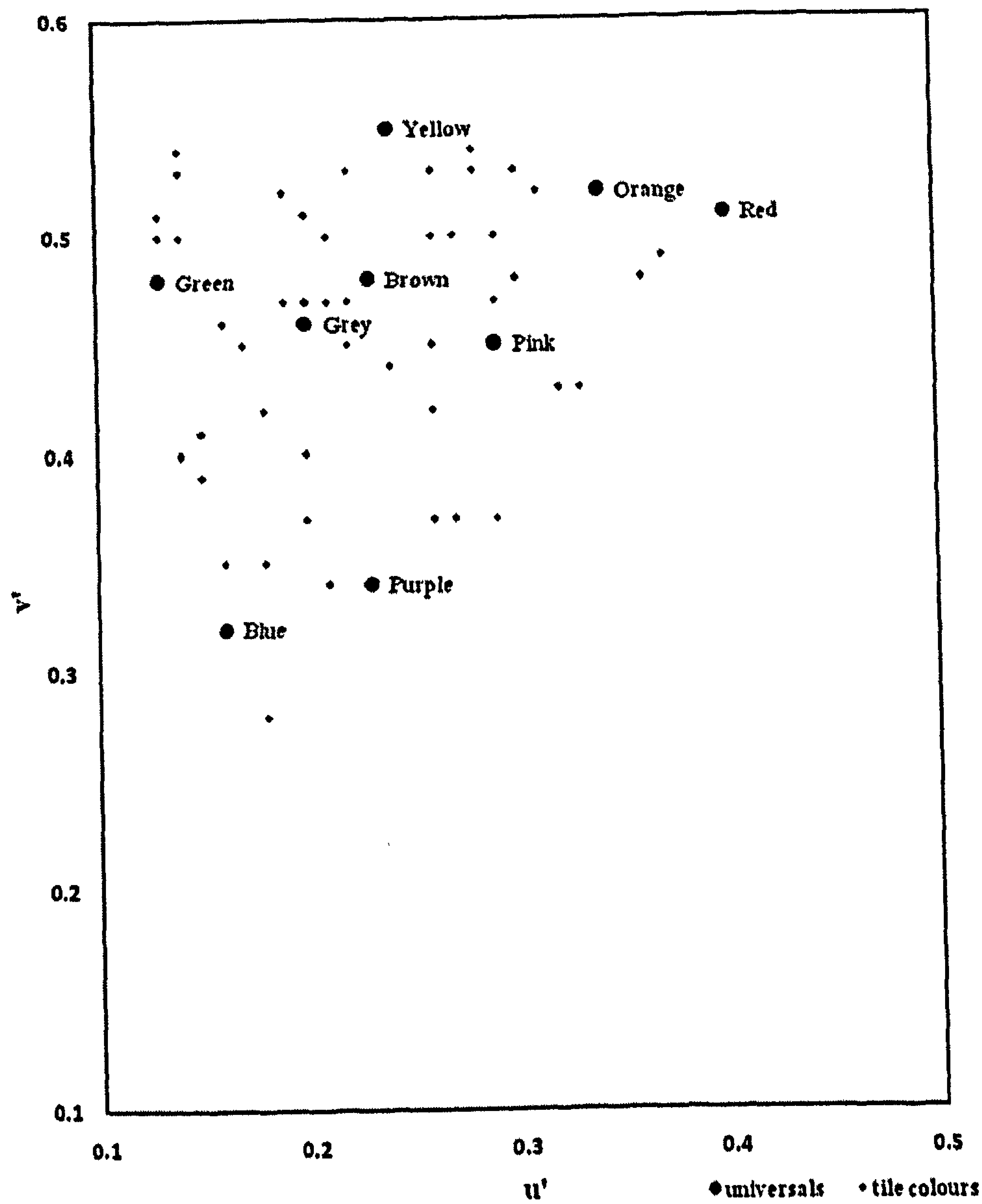


Figure 3. Location of the chromatic stimuli in CIE (1976) colour space (u'v').

2.3.2.3 Procedure

Participants were tested individually by an Arabic speaker and instructions were in Arabic. Male informants were tested by the author and female informants by a female lecturer from King Saud University. Participants first had their colour vision tested and those who failed were excluded from the experiment. Males were tested with *Ishihara's Test for Colour-Blindness* (Ishihara, 1987). Females were assessed by the *City University Colour Vision Test* (Fletcher, 1980) as they tested in a separate building than males. Stimuli were presented one at a time, in a different random order for each subject, until all 65 tiles had been presented. The instructions were to name each tile using a simple, every-day colour term.

2.3.3 Results

For children, 33 colour terms were used to describe the stimuli, in 3924 naming assignments out of a possible 3965 responses (61 participants × 65 tiles). Adults used 30 terms in 3831 responses out of a possible 3900 (60 x 65). Summaries of the most frequent terms used to name each tile are shown in Tables A and B in Appendix 2.

Here, to provide the basis for deciding which terms are basic, the pattern of usage across tiles is summarised in Tables 3 and 4 for children and adults respectively. Column 3 in both tables shows the percentage frequency of use for each of the terms collapsed across all tiles and all informants. The tables are ranked by the frequency of occurrence of the term starting with the most frequent term. For example, *akhdar* 'green' was the most frequent term for both samples with a score 15.8% for children and 15.7% for adults. The Arabic versions of Berlin and Kay's BCTs: *asswed* 'black', *abiyadh* 'white' *ahmar* 'red', *akhdar* 'green', *asfer* 'yellow', *azrock* 'blue', *bonee* 'brown', *banafsagee* 'purple', *wardee* 'pink', *boartoogaalee* 'orange' and *rassasee* 'grey' occupy the first eleven positions in the frequency column for the child sample, but the primary basics and derived basics are intermingled. The Berlin and Kay terms tend to have the highest scores for the adults as well, except *abiyadh* 'white' appears after *samawee* 'light blue'.

The second summary measure is the number of tiles for which a given term was the most frequent term across the sample (*nmf*). For instance, *akhdar* 'green' was the most frequent term for 11 out of the 65 tiles for children and for 13 tiles for adults. It can be seen that there are 13 terms that have *nmf* scores of one or greater; these are the Arabic versions of the Berlin and Kay universals plus *samawee* 'light blue' and *zeatee* 'oil green' both of which have scores of one for both samples.

The *nmf* is an index of consensus of use, but a relatively weak one. For example, a term can be the most frequent term even though it is not used by the majority of the respondents; e.g., see tile RVR Hue in Table A in the Appendix 2 where *banafsagee* 'purple' was the most frequent even though it was only used by 31.1 % of the sample. Columns 5-7 in Tables 3 and 4 show more stringent indices of consensus: the 'Dominance' indices. A term is dominant for a particular tile if the proportion of the sample using it exceeds a given threshold. For instance, 11 tiles were named *akhdar* 'green' by at least 50% of the child-sample and the D_{50} score for *akhdar* 'green' is 11. Of these 11 tiles, 8 were named *akhdar* by at least 75% of the sample, and its D_{75} score is 8; finally of these 8 tiles, 7 were named *akhdar* 'green' by 90% or more of the sample, and its D_{90} score is thus 7. It can be seen from Tables 3 and 4 (column 5) there were twelve terms that achieved dominance in both samples at the D_{50} criterion, the 11 BCTs, plus *zeatee* 'oil green' in the children's results and *samawee* 'light blue' in the adult sample; *zeatee* 'oil green' and *samawee* 'light blue' were dominant for only one tile each. The 11 Berlin and Kay terms each had at least one tile that achieved the D_{75} threshold, and these were the only terms to do so. Of the 11 Berlin and Kay terms, all also met the D_{90} criterion in the child–sample: except *wardee* 'pink', and *banafsagee* 'purple'. In the adult sample, all the Berlin and Kay terms except *azrock* 'blue' met the D_{90} threshold.

One problem with the dominance indices as measures of consensus, is that they are influenced by the distribution of colours in the set. For instance, the region of colour space labelled *akhdar* 'green' is considerably larger than the region labelled *asfer* 'yellow' and this is reflected in the dominance scores for the former being higher than for the latter. The final column (8) in Tables 3 and 4 shows a further measure of agreement, the 'specificity index', which is independent of the overall frequency of use. This score reaches its maximum of 1 if the term is only used to name tiles with 'high' consensus and reaches its minimum (0) if it is never used with high consensus. The consensus could be just for one tile or it could be based on many tiles. As the name suggests, it is an index of how precisely or specifically a terms was used. The version we use here is the ratio of the sum of its frequency of use for tiles that were dominant at D_{50} divided by its total frequency of use across all tiles. It can be seen that the terms that had non-zero scores in both samples were the Arabic tokens of the "universals" plus, *zeatee* 'oil green' in the child-sample, which scored 0.31 and *samawee* 'light blue', for adults with a score of 0.35. In both cases, the specificity index is much lower than the minimum score for a Berlin and Kay term (0.65).

Comparing the two samples, it can be seen that the overall level of consensus was higher for adults than for children: for adults, 56 tiles out of 65 had a dominant term at D_{50}; 38 at D_{75}; and 26 at D_{90}. For children the corresponding scores were: 55 at D_{50}, 33 at D_{75}, and 18 at D_{90}.

Table: 3. Child tile-naming summary (N = 61): terms used, their English glosses, the percentage of total usage, the number of tiles for which a term was the most frequent, and the dominance and specificity indices.

Term	Gloss	%	No. of tiles Most frequent	No. of tiles dominant D_{50}	No. of tiles dominant D_{75}	No. of tiles dominant D_{90}	Specificity Index S
Akhdar	Green	15.8	11	11	8	7	0.46
Azrock	Blue	11.3	9	6	4	1	0.32
Wardee	Pink	10.6	10	7	2	0	0.75
Banafsagee	Purple	9.5	7	5	4	0	0.32
Boartoogaalee	Orange	9.2	6	6	3	2	0.85
Bonee	Brown	7.4	5	5	3	2	0.80
Rassasee	Grey	6.2	4	4	3	1	0.79
Asfer	Yellow	5.3	4	4	1	1	0.85
Ahmar	Red	5.2	3	2	2	1	0.53
Asswed	Black	3.6	2	2	2	2	0.82
Abiyadh	White	2.9	2	2	1	1	0.89
Zeatee	Oil Green	2.7	2	1	0	0	0.31
Samawee	Light blue	2.5	1	0	0	0	0.00
Khuhlie	Dark blue	1.1	0	0	0	0	0.00
Beige	Beige	1.1	0	0	0	0	0.00
Lahmee	Meaty	1.0	0	0	0	0	0.00
Tarquazee	Turquoise	0.4	0	0	0	0	0.00
Fuoshee	Fuchsia	0.4	0	0	0	0	0.00
Enaabee	Dark red	0.4	0	0	0	0	0.00
Fadhee	Silver	0.3	0	0	0	0	0.00
Ashbee	Light green	0.3	0	0	0	0	0.00
Halibee	Cream	0.3	0	0	0	0	0.00
Dahabee	Golden	0.2	0	0	0	0	0.00
Ramalee	Sandy	0.2	0	0	0	0	0.00
Audee	Dark brown	0.2	0	0	0	0	0.00
Sukaree	Sugar	0.1	0	0	0	0	0.00
Fostoqee	Pistachio	0.1	0	0	0	0	0.00
Tufahee	Apple	0.1	0	0	0	0	0.00
Kamonee	Cumin	0.1	0	0	0	0	0.00
Basalee	Onion	0.0	0	0	0	0	0.00
Fosforee	Phosphoric	0.0	0	0	0	0	0.00
Kurbazee	No Gloss	0.3	0	0	0	0	0.00
Don't know		1.03	0	0	0	0	0.00

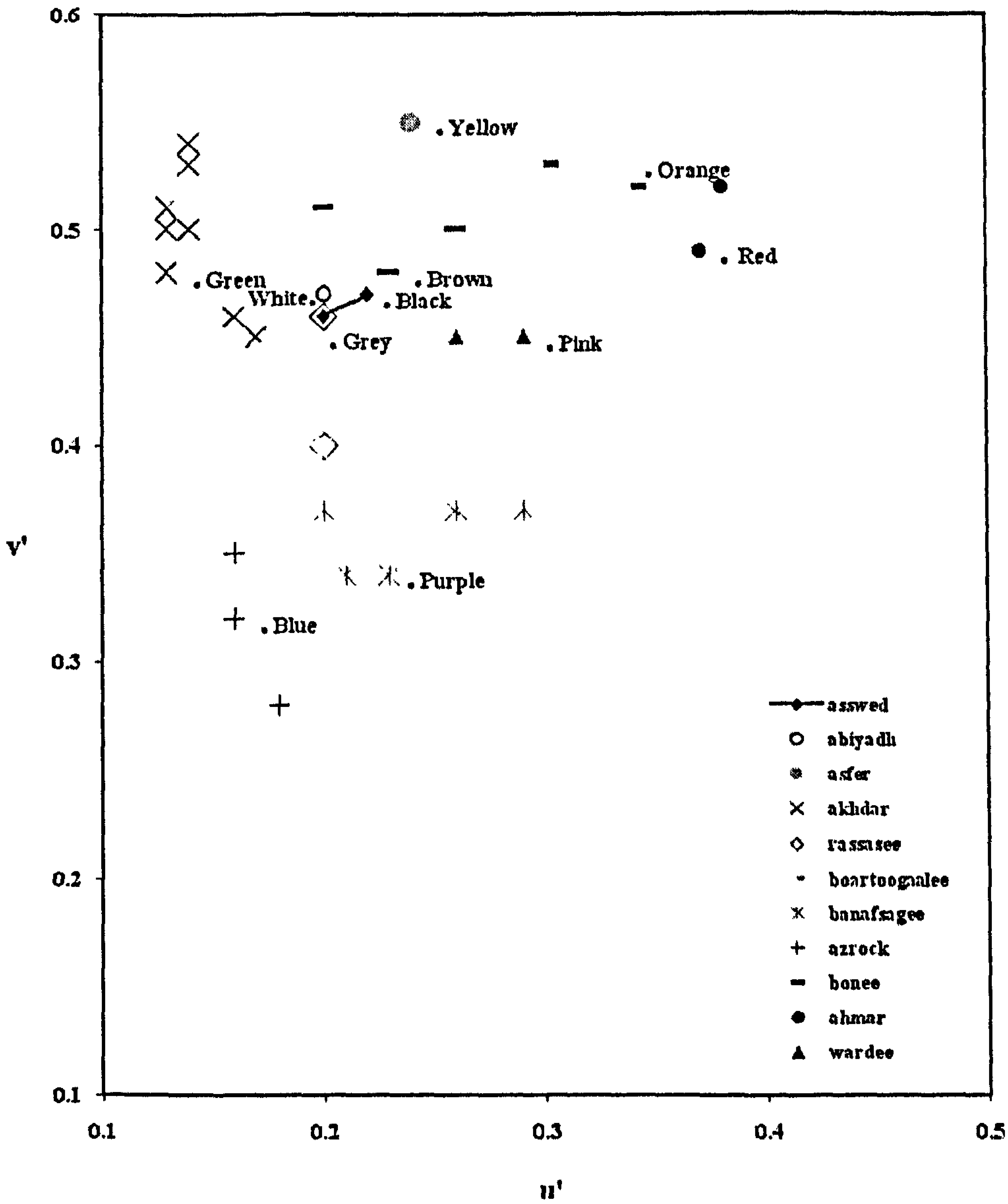
Table: 4. Adult tile-naming summary (N = 60): term used more than once in the tile-naming task by Adult. English glosses, the percentage of total usage (over 0.05), the number of tiles for which a term was the most frequent, and the dominance and specificity indices

Term	Gloss	%	No. of tiles Most frequent	No. of tiles dominant D_{50}	No. of tiles dominant D_{75}	No. of tiles dominant D_{90}	Specificity Index S
Akhdar	Green	15.7	13	10	8	5	0.85
Wardee	Pink	10.67	7	7	4	3	0.81
Banafsagee	Purple	10.44	7	7	5	4	0.80
Boartoogaalee	Orange	9.54	7	6	4	2	0.78
Bonee	Brown	8.51	7	6	4	3	0.92
Azrock	Blue	7.90	6	5	3	0	0.69
Rassasee	Grey	6.30	4	4	4	4	0.93
Asfer	Yellow	5.18	4	4	2	1	0.91
Ahmar	Red	3.62	3	2	1	1	0.69
Asswed	Black	3.13	2	2	2	2	0.98
Samawee	Light blue	2.95	1	1	0	0	0.35
Abiyadh	White	2.72	2	2	1	1	0.97
Zeatee	Oil Green	2.38	1	0	0	0	0.00
Khuhlie	Dark blue	1.38	0	0	0	0	0.00
Fuoshee	Fuchsia	1.00	0	0	0	0	0.00
Tarquazee	Turquoise	0.87	0	0	0	0	0.00
Enaabee	Dark red	0.87	0	0	0	0	0.00
Kurbazee	No Gloss	0.82	0	0	0	0	0.00
Beige	Beige	0.67	0	0	0	0	0.00
Ashbee	Light green	0.46	0	0	0	0	0.00
Tufahee	Apple	0.38	0	0	0	0	0.00
Meshmeshee	Melon	0.26	0	0	0	0	0.00
Firozee	Turquoise	0.23	0	0	0	0	0.00
Fostoqee	Pistachio	0.18	0	0	0	0	0.00
Kamonee	Cumin	0.18	0	0	0	0	0.00
Shangaree	No Gloss	0.18	0	0	0	0	0.00
Batrwlee	Petrol	0.10	0	0	0	0	0.00
Halibee	Cream	0.08	0	0	0	0	0.00
Lahmee	Meaty	0.08	0	0	0	0	0.00
Basalee	Onion	0.08	0	0	0	0	0.00
Don't know		1.77	0	0	0	0	0.00

2.3.3.1 Location of colours with dominant terms in CIE u' v'

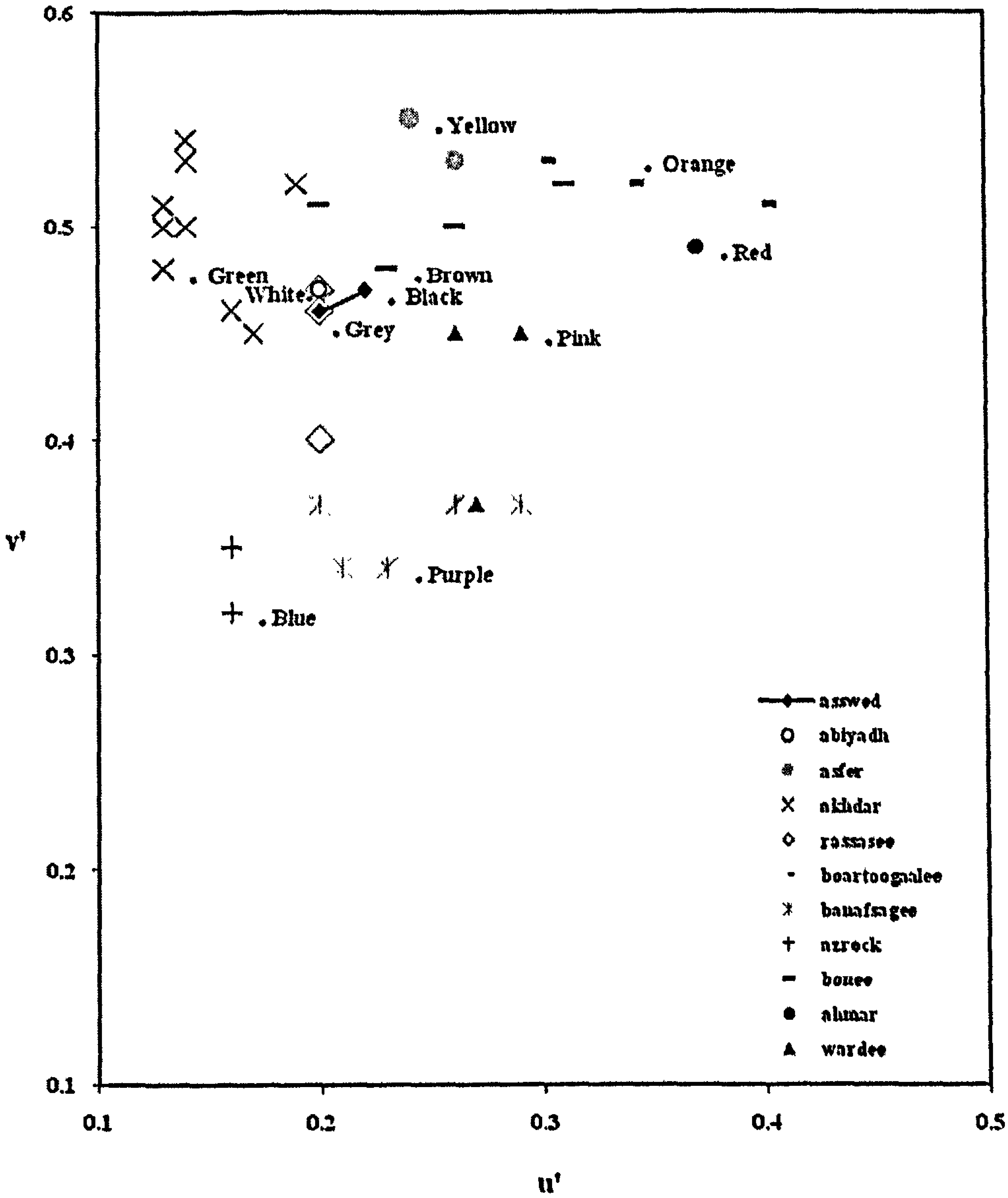
Figures 4 and 5 show the location of all stimuli that met the D_{75} criterion and above in the CIE uniform chromaticity diagram. Eleven colour terms: *asswed* 'black', *abiyadh* 'white' *ahmar* 'red', *akhdar* 'green', *asfer* 'yellow', *azrock* 'blue', *bonee* 'brown', *banafsagee* 'purple', *wardee* 'pink', *boartoogaalee* 'orange' and *rassasee* 'grey' are shown in each diagram. The locations of the exemplars of the various terms are very similar. As can be seen, blue stimuli lie at the bottom of the graph, moving through green in the upper left and out to red in the upper right. Yellow is located at the top-centre and achromatic colours (white, black and greys) are located at the centre of the graph.

Location of Arabic 'focal colours' the colour chip with the highest frequency of use for each term was taken as an estimate of the category prototype or foci. In the few cases where no single tile had the highest score, the prototype was taken to be the mean (centroid) of the CIE coordinates of the tiles with joint highest scores. The tiles used to estimate the location of the prototypes are shown in Tables C and D in Appendix 2. Figures 6 and 7 show the location of the best example of the 11 Arabic BCTs in the CIE uniform chromaticity space in the two-axes (u' v') for child and adult samples. These Arabic foci were compared to the location of the loci of the 11 universal colour foci (Heider, 1971). It can be seen that for both samples the Arabic prototypes are close to the appropriate universal focus.



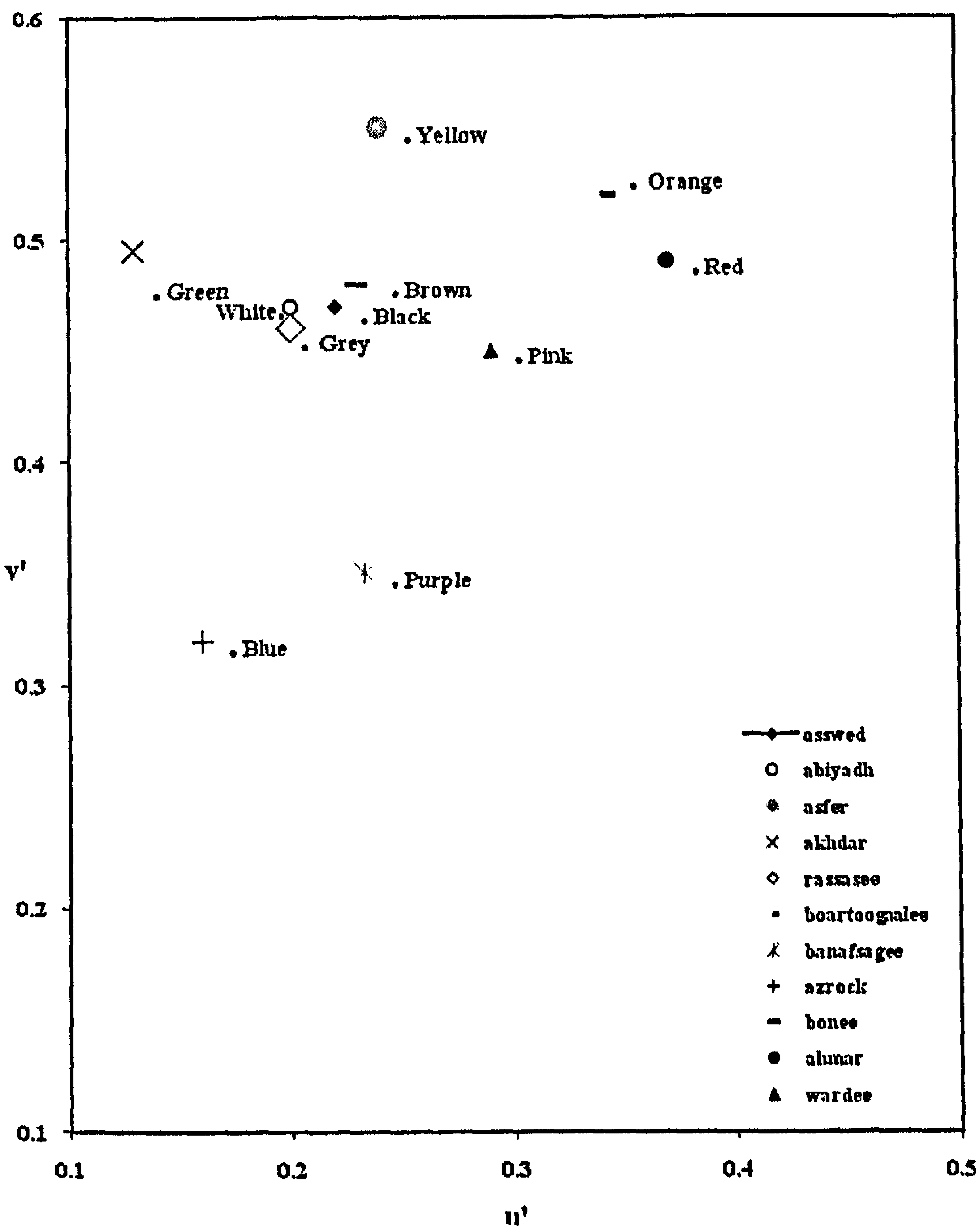
Asswed 'black', *abiyadh* 'white' *ahmar* 'red', *akhdar* 'green', *asfer* 'yellow', *azrock* 'blue', *bonee* 'brown', *banafsagee* 'purple', *wardee* 'pink', *boartoogaalee* 'orange' and *rassasee* 'grey.

Figure 4. Location of stimuli named with agreement level of 75% and above in the CIE (1976) chromaticity diagram (u' v') for the child sample. Texts in the figure show the location of the loci of the 11 universal colour foci (Heider, 1971).



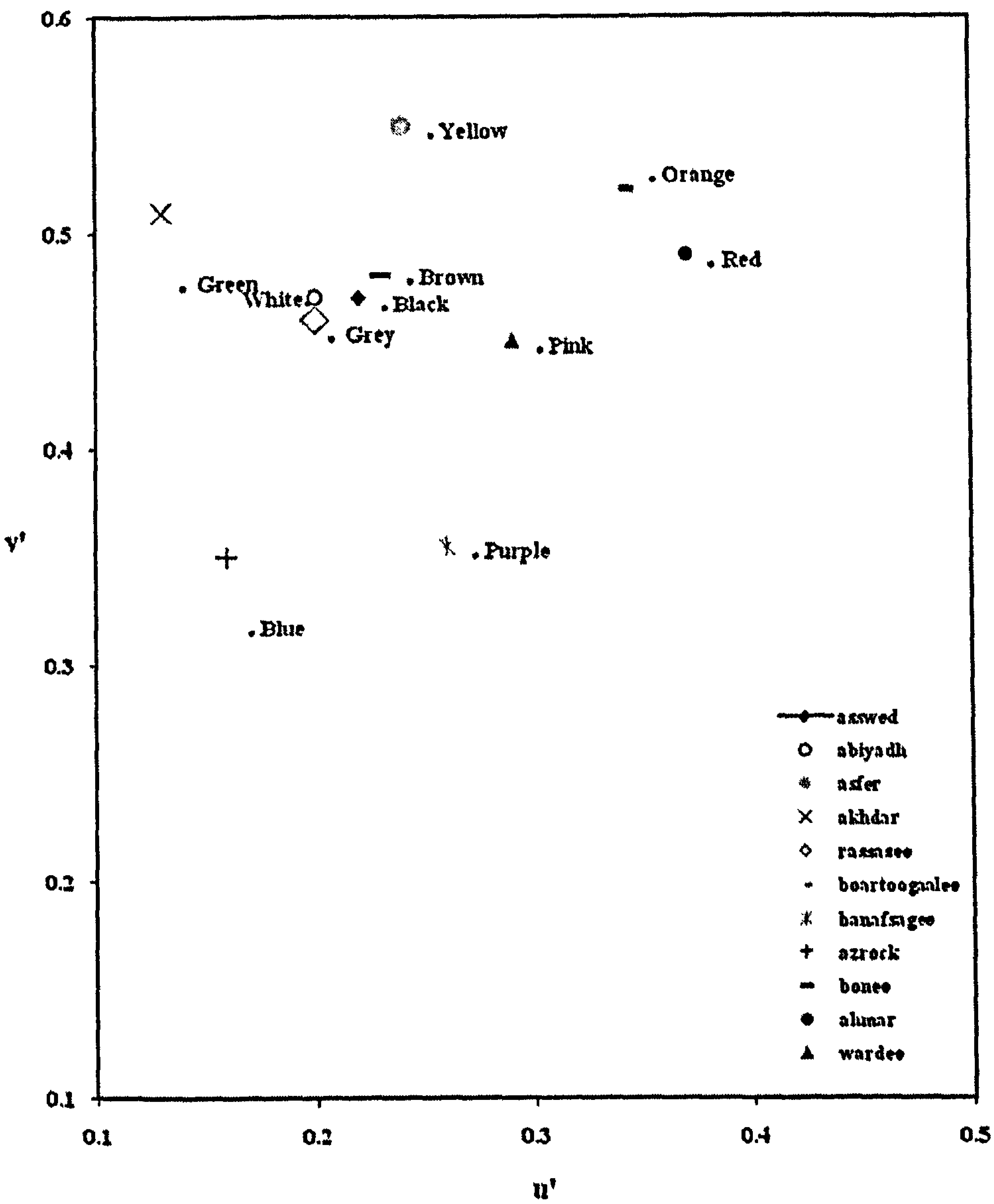
Asswed 'black', *abiyadh* 'white' *ahmar* 'red', *akhdar* 'green', *asfer* 'yellow', *azrock* 'blue', *bonee* 'brown', *banafsagee* 'purple', *wardee* 'pink', *boartoogaalee* 'orange' and *rassasee* 'grey.

Figure 5. Location of stimuli named with agreement level of 75% and above in the CIE (1976) chromaticity diagram (u' v') for the adult sample. Texts in the figure show the location of the loci of the 11 universal colour foci (Heider, 1971).



Asswed 'black', *abiyadh* 'white' *ahmar* 'red', *akhdar* 'green', *asfer* 'yellow', *azrock* 'blue', *bonee* 'brown', *banafsagee* 'purple', *wardee* 'pink', *boartoogaalee* 'orange' and *rassasee* 'grey.

Figure 6. Location of the 11 best example of the Arabic BCT which have the highest agreement level in the colour naming in the CIE (1976) chromaticity diagram (u' v') for the child sample. Texts in the figure show the location of the loci of the 11 universal colour foci (Heider, 1971).



Asswed 'black', *abiyadh* 'white' *ahmar* 'red', *akhdar* 'green', *asfer* 'yellow', *azrock* 'blue', *bonee* 'brown', *banafsagee* 'purple', *wardee* 'pink', *boartoogaalee* 'orange' and *rassasee* 'grey.

Figure 7. Location of the 11 best example of the Arabic BCT which have the highest agreement level in the colour naming in the CIE (1976) chromaticity diagram (u' v') for the adult sample. Texts in the figure show the location of the loci of the 11 universal colour foci (Heider, 1971).

2.3.4 Discussion

The child and adult results for the naming task provide converging evidence that Arabic has eleven BCTs that are consistent with Berlin and Kay's universal colour categories: *asswed* 'black', *abiyadh* 'white', *ahmar* 'red', *akhdar* 'green', *asfer* 'yellow', *azrock* 'blue', *bonee* 'brown', *banafsagee* 'purple', *wardee* 'pink', *boartoogaalee* 'orange', and *rassasee* 'grey'. These are the same terms as suggested by the elicitation task. These terms have high frequency of use, are used with consensus as shown by the dominance scores, and their use is relatively constricted to regions of high agreement as shown by high specificity scores. Moreover, estimates of the category foci reveal that they are very similar to Berlin & Kay's universal foci. The term *zeatee* 'oil green' had the 12th highest frequency of use for the child sample, and was the most frequent term for two tiles, and was dominant at 50% for one tile. However, its specificity index was low (0.31) and the twelve terms with higher frequency of use all achieved dominance at least 75%. The additional blue term, *samawee* 'light blue' had the 12th highest frequency of use for the adults and 13th for children; it was the most frequent term for one tile for both samples, and was dominant for the same tile for the adult sample. However, it too had the lowest specificity index of all terms with a nonzero dominance index. *Azrock* 'blue', the likely BCT for blue, had a low specificity score for the children, and it was the only primary BCT not to be dominant for at the 90% level for at least one tile for the adults. This may be due to *samawee* 'light blue' sometimes being used as an alternative.

2.4 General Discussions

The results from the two experiments suggested that *ahmar* 'red', *akhdar* 'green, *asfer*, 'yellow', *azrock* 'blue', *asswed* 'black', *abiyadh* 'white', *banafsagee* 'purple', *boartoogaalee* 'orange', *bonee* 'brown'', *wardee* 'pink' and *rassasee*, 'grey' have the strongest claim to basic status. Arabic therefore corresponds perfectly with Berlin and Kay's stage VII of colour term evolution. These 11 terms were the most frequently offered terms in the elicitation task with scores of almost 70% or more for both samples except for *rassasee*, 'grey' which scored about 50% in both samples. The terms rank orders on both main measures were very similar with just minor variations in their positions. The tokens of the Kay and McDaniel's primary categories – *ahmar, akhdar, asfer, azrock, asswed,* and *abiyadh* were the six most frequent terms and they were offered by over 80% of the samples. *Banafsagee, boartoogaalee, bonee, wardee, and rassasee* were the next frequent terms and they are the Arabic derived categories.

All of the measures from the naming task also suggest that the eleven terms just given are probably BCTs in Arabic. They had high frequency of use, high dominance scores and high specificity indices. Although, *zeatee* 'oil green', in the child results, and *samawee* 'light blue', in the adult data were dominant at 50% for one tile, most other possible BCTs achieved higher dominance scores, the specificity scores (~ 0.30) were low. *Samawee* ('light blue') and *khuhlie* ('dark blue') may merit further investigation. For the current samples, they are probably not basic; exploring their status in older Arabic samples and in Arabic speakers from other regions could be interesting.

2.5 Conclusion

Arabic probably has eleven basic colour terms and these correspond with Berlin and Kay's eleven universal categories. The terms are that *ahmar* 'red', *akhdar* 'green, *asfer*, 'yellow', *azrock* 'blue', *asswed* 'black', *abiyadh* 'white', *banafsagee* 'purple', *boartoogaalee* 'orange', *bonee* 'brown'', *wardee* 'pink' and *rassasee*. Two probable secondary terms –and *samawee* 'light blue', *zeatee* 'oil green' had the next highest claim to being basic and may deserve further investigating.

Chapter Three

Left Hemisphere Lateralisation of Colour CP among Roman and Arabic script readers

3.1 Introduction

The universal colour category hypothesis that all languages draw their BCTs from a universal inventory of just eleven colour categories was examined in a series of experiments on Arabic language speakers in the previous chapter. It was found that Arabic speakers have eleven basic colour categories, like English, that correspond to Berlin and Kay's (1969) universal categories. The current chapter examines a colour category effect (categorical perception of colour) whereby the category of colours appears to affect colour discrimination. Previous research has found that this colour category effect is stronger in the left hemisphere (LH) than in the right hemisphere (RH) of the adult brain. As the LH is dominant for language, some have argued that this implies the (implicit) involvement of language in CP, supporting the 'Linguistic Relativity Hypothesis' (LRH) – the language we speak influences the way we think and perceive. The current chapter investigates this lateralised colour category effect, by considering whether it is independent of reading direction and of the spatial decision required by the methods used so far to investigate the effect.

3.1.1 Categorical Perception

The colour spectrum is a physical continuum but it is perceived discontinuously, as discrete categories or segments of hues (Harnad, 1987). This is part of an effect called Categorical Perception (henceforth, CP). CP is found when a continuum is divided into categories, and when these categories appear to affect discrimination. In operational terms, CP can be defined by faster and/or more accurate discrimination of pair of stimuli that cross a category boundary (across-category), than two stimuli from the same category (within-category), even when the stimulus differences between the pairs of stimuli are equal. This definition of CP will be used throughout, and is illustrated in the classic form shown in Figure 8.

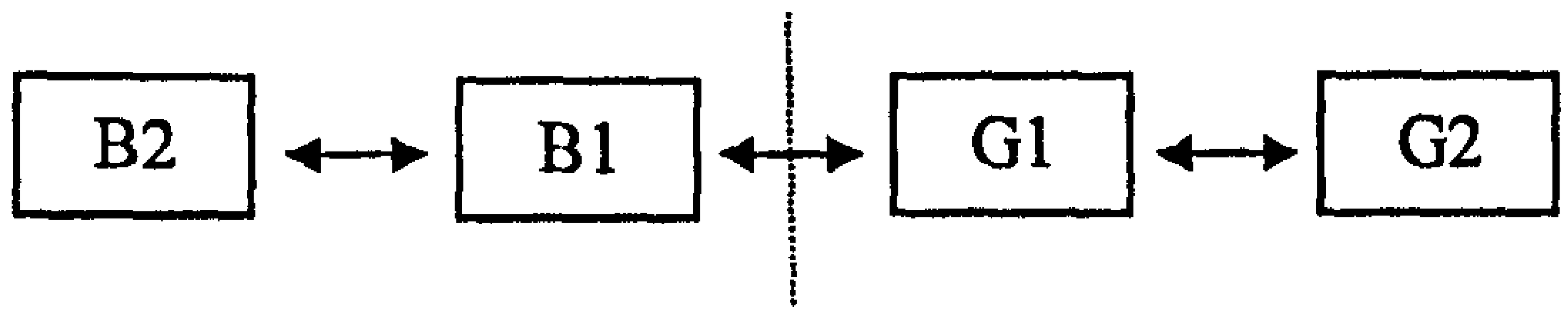


Figure 8. Diagram representing CP. There are four colours: two blues (B2, B1) and two greens (G1, G2). The arrows show the separation between adjacent pairs which are equally separated. The vertical line shows the category boundary.

Figure 1 shows four stimuli designated as B2, B1, G1 and G2. Two (B2, B1) belong to the same the linguistic category, blue, and two (G1, G2) belong to the linguistic category green, with the category boundary between B1 and G1. The separation between the adjacent stimuli is equal. Discrimination of the cross-category stimulus pair (B1, G1) is faster and/or more accurate than discrimination of the within-category stimuli, (B1, B2) or (G1, G2).

CP was first shown in speech perception. Liberman, Harris, Hoffman and Griffith, (1957) tested participants on an X-AB task. The participant's task was to indicate whether stimulus X is the same as stimulus A or B. The speech stimuli were from a continuum of sounds, varying in equal steps from one phoneme to another. Participants showed better discrimination when the target stimuli and test stimuli were from different phonemic categories than when they were from the same category. CP occurs for a range of perceptual phenomenon. For instance, perception of non speech sounds (e.g., Cutting & Rosner, 1974; Pastore, Li & Layer, 1990), perception of line length (Tajfel & Wilkes, 1963), and also dimensions of face perception such as facial expressions (e.g., Etcoff & Magee, 1992; Beale & Keil, 1995; De Gelder, Teunisse & Benson, 1997; Campbell, Woll, Benson & Wallace, 1999; Bimler & Kirkland, 2001; Campanella, Chrysochoos & Bruyer, 2001; Rossion, Shiltz, Laurence, Pirenne & Grommelinck, 2001; & Levin & Angelone, 2002;).

Evidence for CP has also been reported on a wide range of colour perception tasksFor example, recognition memory and X-AB tasks (e.g., Uchikawa & Shonida, 1996; Roberson, Davidoff & Braisby, 1999; Roberson & Davidoff, 2000, Roberson, Davies & Davidoff, 2000; Pilling, Wiggett, Özgen & Davies, 2003) same-different tasks (e.g., Bornstein & Korda, 1984, Boynton, Fargo, Olson & Smallman, 1989) similarity judgements (e.g., Laws, Davies & Andrews, 1995; Roberson, Davidoff & Braisby, 1999) and target detection and visual search tasks (e.g., Franklin, Pilling & Davies, 2005; Daoutis, Franklin, Riddett, Clifford & Davies, 2006; Daoutis, Pilling & Davies, 2006). In the 2-X-AB task, a target stimulus (e.g., blue1) is presented followed by two test stimuli; one of the test stimuli is identical to the target and the other one (the foil) is different. The foil can be either from same category as the target (e.g., blue2), or from a different category (e.g., green1). The task is to decide as fast as possible which of the test stimuli is identical to the target. The results showed that target identification was faster and/or more accurate for different category than same category foils. In the search task, a target stimulus is presented among other stimuli (distractors); the distractors can either be from the same category as the target (e.g., blue1 among blue2s) or from a different category to the target (blue1 among green1s). The task is to detect the location of the target as fast as possible. Detection of a target that is from a different category to the distractors is faster and/or more accurate than detection of a target from the same category as the distractors.

3.1.2 Theories of CP

Although CP has been reported in a wide range of studies, it is not clear what the origin and nature of this effect is. The degree to which language and perception contribute to the category effect has been extensively debated. Three main ideas have been emerged from the literature to account for the origin and nature effect of the CP: CP is 'hardwired' into the visual system – it is innate; CP is due to verbal labelling; CP is due to perceptual change.

3.1.2.1 Innate perceptual effect

The principal claim of the Naturalistic theories (e.g., Bornstein, 1987; Snowden, 1987) is that, CP is an inborn, universal perceptual effect. Naturalistic theories are potentially supported by evidence for CP in young infants and in animals. Pre-linguistic participants perceive colour categorically before colour terms are learned. Bornstein, Kessen and Weiskopf, (1976) tested 4- month old infants for colour categorisation. Infants were habituated to a target coloured stimulus, then they were shown a test coloured stimulus. The test stimulus either belonged to a different category, or to the same category, as the target stimulus. Although physical distances between stimuli were equal, infants dishabituated to the novel stimulus only when the test stimulus belonged to a different category to the habituated stimulus. Franklin and Davies (2004) also found evidence that infants had colour categories. Following familiarisation to one hue, infants only show novelty preference for a novel hue, if it comes from a different category to the familiarised hue. The findings are completely consistent with Bornstein et al.'s. Another study by Franklin, Pilling and Davies (2005) tested 4 -to- 6 month old infants for colour CP on a target detection task. Infants were shown a coloured target on a coloured background, with the target either from the same or different lexical category to the background. Infant eye movements to the target were recorded. Infants showed faster fixation of the target when the target and background were from different categories than from the same category. This findings provide strong evidence to support the naturalistic account of CP. Macaque monkey have also shown better discrimination for colours drawn from different categories than colours from the same category (Sandell, Gross and Bornstein, 1979). However, even if colour categories are found in pre-linguistic infants and in primates, colour categories need not necessarily be innate – even pre-linguistic colour categories could be learnt.

3.1.2.2 Verbal labelling

Labelling theories argue that CP is driven by verbal labelling rather than by perception, and thus CP is not truly a perceptual phenomenon (e.g., Fujisaki and Kwakshima, 1971; Kay and Kempton, 1984; Roberson and Davidoff, 2000). It is assumed that discrimination between perceptually different stimuli from different lexical categories is easier than stimuli from the same lexical category due to the different labels aiding discrimination. Thus, it is assumed that CP should not be shown when verbal labelling is absent. Evidence of the verbal account of the CP comes from cross-cultural and verbal interference studies. From the cross-cultural approach several studies (e.g., Kay & Kempton, 1984; Roberson, Davies & Davidoff, 2000; Daoutis, Franklin, Riddett, Clifford & Davies, 2006) report that CP only occurs when the categories boundaries are marked linguistically. Another set of studies investigated the contribution of verbal labelling to CP by adding verbal interference to the colour task (e.g., Roberson & Davidoff, 2000; Pilling, Wiggett, Özgen & Davies, 2003; Winawer, Witthoft, Frank, Wu, Wade & Boroditsky, 2007). For instance, Roberson and Davidoff (2000) used a successive X-AB task. Participants were shown a target colour followed, after 5 secs, by two test colours, the target and the foil. As described earlier, the foil was either from the same category as the target, or from a different category; the perceptual distance between the foil and the target was the same for both conditions. The participant's task was to decide which colour in the test pair was identical to the target. Three types of interference were used in the ISI period: visual interference, verbal interference and no interference. CP was found in the visual and no interference conditions, but not in the verbal interference condition. The elimination of CP by verbal interference was assumed to be due to the interference impeding the retention of the name (verbal label), thus forcing the task to be done using visual memory alone. As no CP now occurs, this was taken as evidence that the benefit of CP is due to comparison of verbal labels enhancing cross-category comparisons, but not enhancing within-category comparisons.

3.1.2.3 Perceptual change

Perceptual change theories (e.g., Harnad, Hanson & Lubin, 1991; Goldstone, Lippa & Shiffrin, 2001) maintain that learning plays an important role in warping the representation of perceptual space. It is argued that learning to name a new stimulus dimension either in massed practice or in learning to distinguish the stimuli lexically leads to change in the representation of the stimulus dimension. Evidence from the perceptual learning experiment by Özgen and Davies (2002) has supported this idea. Participants were trained to learn a novel colour category such as yellowy-green vs. bluey-green. CP was then found around the recently learned category boundary.

3.1.3 Lateralisation of colour CP to the Left Hemisphere (LH)

To investigate further the contribution of language to CP, recent studies have considered how the effect is lateralised (e.g., Gilbert, Kay, Regier & Ivry, 2006; Drivonikou, Kay, Regier, Ivry, Franklin & Davies, 2007; Roberson, Park & Hanley, 2008. Gilbert et al. 2006). Gilbert et al. reasoned that, as the left hemisphere is dominant for most language functions, if colour CP is related to language it should be stronger in the LH. To test this, Gilbert and colleagues used a visual search task where targets were lateralised to the left or right visual field (LVF/RVF). Stimuli were shown in a display of twelve coloured squares in a clock shape; eleven of the squares (the distractors) were identical in colour, and one (the target) was different. The relationship between the distractors and the target stimulus was manipulated so targets and distractors were either from the same colour category (e.g., blue1-blue2 or green1-green2), or from a different colour category (e.g., blue1-green1 or green1-blue1). While looking at a central fixation cross, participants had to decide whether the target was to the left or to the right of fixation. Gilbert et al. found that RTs were faster when target and distractors were different categorically (blue1 among green1s) than when target and distractors were just perceptually different (blue1 among blue2s). However, this category effect was found only if the target was presented to the RVF. Gilbert et al. argued that this pattern of lateralisation was consistent with CP being due to the implicit use of language.

As a further test of linguistic involvement in CP, Gilbert et al. used a version of the interference methods used by Roberson and Davidoff (2000) described earlier. In the verbal interference condition, a colour term was presented before the search display and had to be retained until after the response to the search display had been made. In the visual interference condition, a black and white chequer-board pattern presented before the search display had to be remembered until after the response to the search display. The trial started with fixation cross followed by either verbal or visual interference then the visual search display appeared. The LH category effect disappeared with verbal interference, but remained with visual interference.

The first replication of Gilbert et al. (2006) came from a re-analysis of a previous visual search study conducted by Daoutis, Pilling and Davies (2006). They used a visual search task that required the detection of a target colour amongst two kinds of distractors. A target was only present on half of the trials and the task was to decide as quickly as possible if the target was present. Although on target present trials, half the time the target appeared in the LVF and half the time in the RVF, in the original paper, the possibility of visual field effects had not been considered. A reanalysis including visual field as a factor showed a stronger categorical effect for targets appearing in the RVF than for those appearing in the LVF. Drivonikou and colleagues then investigated whether lateralised CP would be found in a simplified version of Gilbert et al.'s search task, where there was a single target colour on a background of a different colour (see Franklin et al., 2005). Participants had to detect a circular coloured target that appeared in one of 12 locations on a coloured background. The target and background were from either just perceptually different (e.g., blue1 among blue2s) or physically and categorically different (e.g., blue1 among green1s) with the target-background perceptual distances equated across conditions. The results showed that RTs were faster when target and background were categorically different, than when they were just perceptually different. This category effect was found in both visual fields, but was larger in the RVF than LVF. In the same study, Drivonikou et al. also tested the blue-purple category boundary, and again, a category effect was found in the RVF, but not this time, in the LVF.

There is also evidence that LH lateralised colour CP only occurs if the category boundary is marked in the language. Korean has a lexical boundary between *yeondu* (yellow-green) and *chorok* (green) that is not marked in English. Roberson et al. (2008) compared English and Korean speakers using Gilbert et al.'s (2006) visual search task where the target-distractor relationship was either within-*yeondu* or –*chorok*, or between *yeondu* and *chorok*. CP was shown by Korean participants but not English participants, but there was no visual field by category interaction (the usual signature of lateralised CP). However, dividing the Korean group into fast and slow responders, using a median split, revealed that CP was lateralised to the RVF-LH for fast responders, but was present in both VFs for slow responders. Roberson et al. suggested that for slow responders, there was sufficient time for information to be transferred from the LH to the RH across the corpus callosum allowing language to influence performance in both visual fields.

Another cross-cultural study by Drivonikou, Davies, Franklin and Taylor (2007) compared hemispheric asymmetry in colour CP for three samples: Greeks, English and 'Africans'. The same target detection task as in Drivonikou et al. (2007) was used. Greek and English were tested for a category effect across two Greek basic colour categories *ble* 'dark blue' and *galazjo* 'light blue' which is not marked in English. A category effect was found for Greeks but not for English; moreover, for Greeks, the category effect was lateralised to the LH. The same task was used to test English and African participants for a category effect across the English blue-green boundary that is not marked in the various languages spoken by the African group. A category effect was found for the English group but not for the African group and for the English group, it was stronger in the LH than the RH.

Lateralisation of colour CP to the LH has been also been investigated using functional magnetic resonance imaging (fMRI: Siok, Kay, Wang, Chan, Chen, Luke & Tan, 2009) and the event-related potential (ERP) technique (Liu, Li, Campos, Wang, Zhang, Qiu, Zhang & Sun, 2009). In Siok et al. Chinese participants' brain activity was scanned while they performed a visual search task. The task, procedure and design were the same as

Gilbert et al.'s. (2006). There was stronger activity in the language regions of the brain (the posterior temporoparietal area, the middle temporal gyrus and the inferior prefrontal cortex) in the left cerebral hemisphere for across- than for within-category discriminations in the RVF. This was also associated with greater activation in visual cortex for across- than for within-category discriminations. Liu et al. (2009) tested 12 adult Chinese on the same visual search task. N2pc (N2-posterior-contralateral) was used as an index of the attentionional demands of within- and across-category target-distractor relationships in the visual search task. The N2pc components in the LH were larger for the cross-category condition than for the within category conditions.

3.1.4 Hemispheric Asymmetries in Colour CP in Pre-linguistic infants

As discussed earlier, 4-6 month old infants also respond categorically to colour (Bornstein, et al., 1976, Franklin & Davies, 2004). Lateralisation of the category effect in infancy was tested by Franklin, Drivonikou, Bevis, Davies, Kay and Regier (2008). If the LH category effect is due to language, as the previous studies suggest, then there should be no LH bias for the category effect in infants. To investigate this, infants' and adults' eye movements were recorded on a target detection task, with across- and within-category conditions. Although the chromatic difference between the stimulus pairs (across- and within-pairs) was the same, both samples were faster at initiating an eye movement to the target on a background from a different category than a background from the same category. For adults, the category effect was stronger for the RVF than for the LVF. In contrast, for infants the category effect was only found for targets presented to the LVF. Therefore, it appears from this study that pre-linguistic CP is actually lateralised to the *RH*.

Franklin, Drivonikou, Clifford, Kay, Regier and Davies (2008) then investigated whether the lateralisation of colour CP switches from LH to RH as colour terms are learned. Two to five year old toddlers were tested on the same task as the study of lateralised colour CP in infants. The participants were divided into two groups. One group had knowledge of the terms for the colours used in the study, and the other group was still learning these terms. Toddler's eye movement initiation times to the target were measured. Both groups showed a category effect, but the pattern of lateralisation was different for the two groups. For the group who knew the words for the blue and green, CP was found in the RVF (LH) – the same pattern as found in adult studies described above. For toddlers who did not know the words for blue and green, the CP effect was found only in the LVF (RH). It was concluded that the acquisition of colour terms was related to the RH-LH switch in colour CP.

3.1.5 Lateralisation of Categorical Processing beyond Colour

Gilbert, Regier, Kay & Ivry, (2007) also investigated whether LH lateralisation of category effects in adults extended beyond the colour domain. They used their original visual search task but instead of colour, the stimuli used were drawings of cats or dogs. The key comparison was, as usual, whether the target-distractor relationship was within-category (e.g., cat1-cat2) or between-category (e.g., cat1-dog1). The results showed that the cross-category targets were detected more quickly than the within-category targets in both visual fields, but the effect was stronger in the RVF (LH) than in the LVF (RH).

There are also examples of LH category effects in adults for types of categorical responding other than CP. For example, Kosslyn, Koenig, Barrett, Cave, Tang and Gabrieli (1989) reported a series of experiments that explored the contribution of the left and right hemispheres to computing categorical and metric spatial judgments. The results of these experiments indicated that categorical judgments (such as on/off, left/right, and above/below) are faster for RVF (LH) stimuli, whilst metric judgments, such as the evaluation of absolute distance (is it 2 mm, 3 mm, 2.54 cm), are faster for LVF (RH) stimuli. This difference in hemispheric processing modes has been supported by a large body of subsequent research (see Jager & Postma, 2003 for a review).

3.1.6 Potential Influences on the Lateralisation of CP

So far, the LH bias in colour CP has been related to the linguistic nature of the LH and converging evidence to support this hypothesis has been presented. However, it is also possible that other factors contribute the LH bias in category effect in adults. The first two experiments in this chapter explore whether the LH bias in category effect could be, in part, due to an attentional bias arising from the habitual left to right scanning pattern occurring in reading for those using Roman script.

Eviatar (1995 and 1997), compared left-to-right and right-to-left (Hebrew readers) using a target detection task. Targets occurred in one visual field together with irrelevant distractors in the other field. Left-to-right readers were impaired by LVF distractors, but not by RVF distractors. Hebrew-readers showed the opposite pattern: they were impaired by RVF but not by LVF distractors. Eviatar suggested that the habitual reading direction resulted in attentional priority being given to the LVF for left-to-right readers and to the RVF in right-to-left readers. The effect was 'automatic' and could not easily be 'turned off' even when it impaired performance.

Applying this to Gilbert et al.'s search task, (see Figure 13), detecting a LVF target should not be impaired by the simultaneous presence of RVF distractors. In contrast, detection of RVF targets should be impaired by LVF targets. If this holds, then there should be an overall visual field effect with LVF detections being better than RVF detections. However, Gilbert et al.'s crucial result, is not about *overall* visual field effects; rather, the crucial result is that detecting RVF (LH) targets is better than for LVF(RH) targets, but *only* for across-category target-distractor displays. Without additional ad hoc assumptions, it is not clear how Eviatar's hypothesis could lead to the crucial field by category interaction. Nevertheless, it is possible that right-to left readers would not be inhibited by LVF distractors, and could show stronger RVF detection than left-to-right readers.

There is a second effect related to reading direction that could also benefit RVF detection over LVF target detection. Simola, Holmqvist and Lindgren (2009) found that right-to-left readers benefited from parafoveal information to the *right* of fixation, while left-to-right viewers, benefited from parafoveal information to the *left* of fixation. Applying this to the search and target detection tasks, suggests that as observer's are fixating the centre of the display, target detection should be better in one visual field than the other; and the direction of the effect should depend on habitual reading direction.

As earlier, it is not clear how the field biases just described could produce the pattern of lateralisation found by Gilbert et al and Drivonikou et al. However, it does suggest that there could be overall differences in visual field biases related to habitual reading direction.

Although it is not entirely clear how to predict the effect of habitual reading direction on target detection tasks, I decided that it was worth exploring to test the generality of laterality effects across cultures and reading directions. Han and Northoff (2008) describe several instances of cultural differences being associated with differing neural organisations, and argue that in general, it is good practice to test the generality of findings across a range of cultures. Their exhortation is consonant with the motivation behind this chapter, which is to test that patterns of lateralisation are independent of seemingly small scale procedural task variations, as well as generalising across culture and reading direction.

As, to date, no studies of lateralised CP have been conducted on right-to-left readers and as there are some 500 million of them (Kazandjian & Chokron, 2008), the next two experiments report comparisons of readers of Arabic and readers of English using the target detection task.

3.1.7 Aims of the Chapter

The first aim of the chapter is to investigate whether the lateralisation of colour CP is affected by reading direction. All of the studies that have tested the LH lateralised of colour CP in adults (e.g., Gilbert et al. 2006; Drivonikou et al. 2007 a & b; Roberson et al. 2008; Tan, Chan, Kay, Khong, Yip & Luke, 2008; Liu et al. 2009) have examined the lateralisation of colour CP with left–to–right script readers. However, the influence of reading habits to perception has been shown in several studies (e.g., Eviatar, 1995, 1997; Farid, & Grainger 1996; Prunet, Beland & Adrissi 2000; Berent 2002; Schwalm, Eviatar, Golan & Blumenfeld, 2003). This chapter investigates the possible effect of habitual scanning on lateralisation of colour CP, by comparing participants from two languages who vary in their reading direction: left-to-right in English and right-to-left in Arabic. A preliminary Experiment (Experiment 3) established the location of the *azrock* 'blue'- *akhdar*, 'green' boundary in Arabic. As the boundary was at more or less the same location as in English, Lateralisation of CP was then tested in the two groups using first, a visual search task, (Experiment 4) and then a target detection task with eye-movement latencies as the dependent variable (Experiment 5).

In addition, the second aim of the chapter is to establish whether the LH colour category effect is unaffected by seemingly small scale procedural variations. So far, all studies have used either the visual search task of Gilbert et al. or the target detection task, with most of these tasks involving a spatial decision about whether the target is on the left or the right. Experiment 6 and 7 extended the investigation to include two other types of tasks. First, a search task that varied the number of distractors. And second, a visual search task with targets only present on half the trials, and the task was to decide whether there was a target present or not, rather than decide the location of the target. The aim here was to see whether this colour search task exhibited 'pop-out' (Treisman & Gelade, 1980) or 'efficient search' (Wolf, 1994).

3.2 Experiment 3. Establishing Arabic Blue-Green Boundary

3.2.1 Introduction

This experiment aimed to establish the location of the Arabic *azrock* 'blue'- *akhdar*, 'green' category boundary. The Munsell Colour System (MCS) was used. MCS identifies colour in terms of three attributes: Hue (as in red, orange, yellow etc.), Value (lightness) and Chroma (similar to saturation) see Appendix 3 for more details. Two groups of Arabic participants took part in this study: one was asked to identify the best example of *azrock* 'blue' and of *akhdar* 'green' from a set of stimuli varying in value and chroma, at each of five Hues (Experiment 3a; from now on, as this thesis is in English, the terms blue and green will be used rather than their Arabic equivalent). Then, having established which combination of value and chroma contained the best examples of blue and green, a second group named each of five hues at the selected Value and Chroma (Experiment 3b).

3.2.2 Experiment 3a: Lightness and Saturation for the blue-green boundary

3.2.2.1 Introduction

The overall aim of Experiment 3 was to establish the Arabic blue-green category boundary. Experiment 3a determined the saturation and lightness levels in which stimuli were named blue and green with high agreement. Experiment 3b then estimated where the boundary was using hues at the value/chroma combination found in 3a.

3.2.2.2 Method

Participants, Ten participants (five men and five women) took part in the value and chroma task. They spoke Arabic as their first language and most were undergraduate students at King Saud University. Based on self-reports, all were right-handed and had normal colour vision, as indicated by the City University Test (Fletcher, 1981). Their ages ranged from 18 to 34 years with a mean of 24.3 years (SD = 5.29).

Stimuli, Twenty-five stimuli were used made up from the combination of five hues (2.5 BG, 5 BG, 7.5 BG, 10 BG and 2.5B) at each of five combinations of value and chroma (6/7, 6/7, 6/8, 7/7, 7/8). Each Hue-set was presented as five circular stimuli (diameter = 5.5 cm; visual angle = 6.5°) equally spaced on the circumference of an imaginary circle around a fixation cross in the centre of the screen, on a neutral grey back ground (see Figure 9). The CIE (1931) Y, x, y chromaticity coordinates of the grey point of the monitor were (19.47 cd/m^2. 0.336, 0.344).

Equipment, Stimuli were displayed on a 17-inch calibrated CRT Sony Trinitron monitor (model GDM-F520). Colour readings were made using a Cambridge Research Systems colourCAL colourimeter (Rochester, U.K.). An example of the task is given in Figure 9.

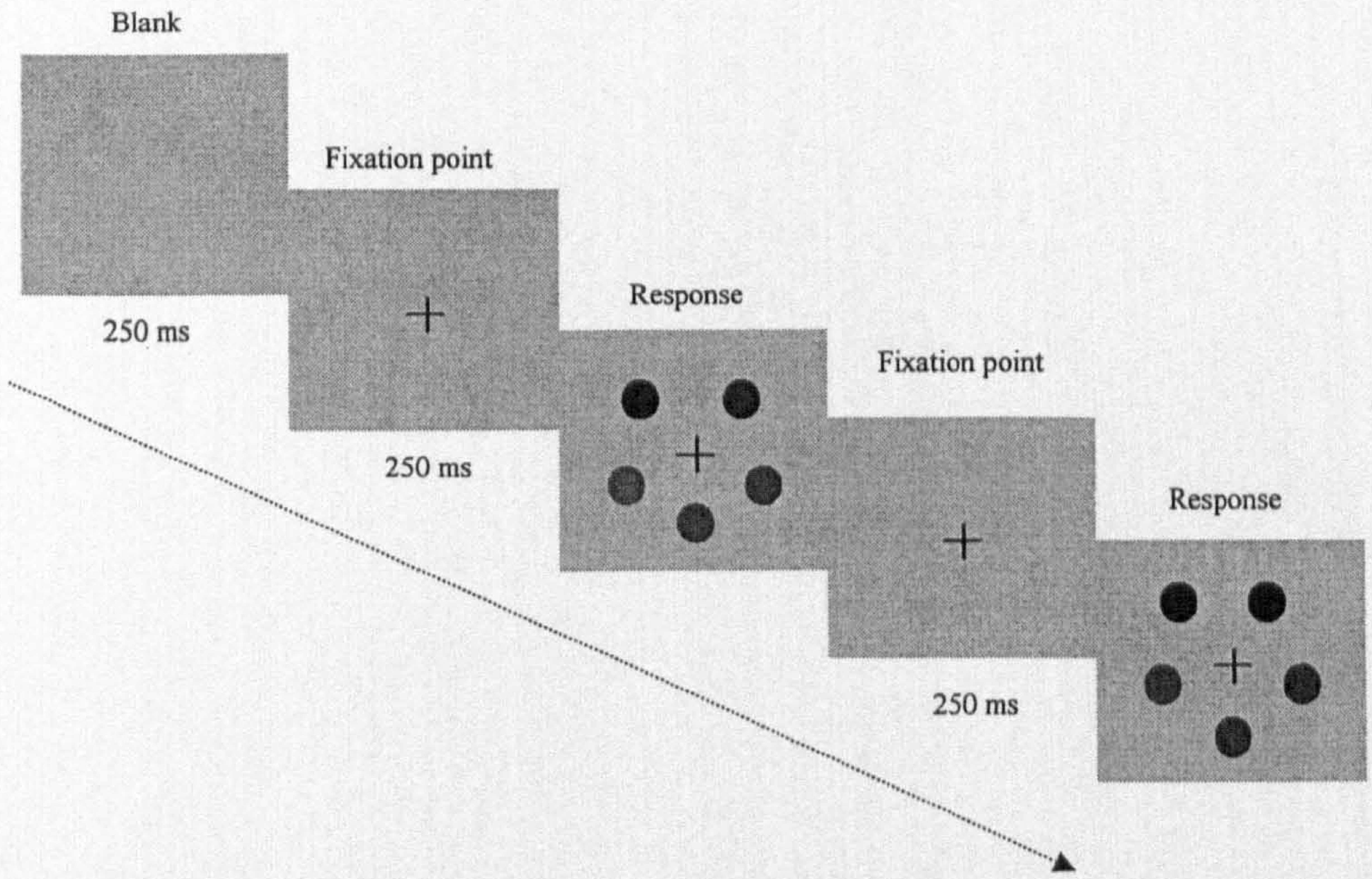


Figure 9. Example of the hue selection task. Each display contained the same hue (circles) at each of five different combinations of value and chroma. The five hues were used in different displays

Procedure, The experiment was conducted in a dark room. On each trial, one Hue-set was presented and remained on the screen until a response was made. Participants viewed the display at a distance of 60 cm. They were told that on each trial the display would consist of five circular coloured stimuli in a clock shape against a grey background. Their task was to decide which one of these five stimuli was the best example of either blue or green. Responses were made verbally and recorded by the experimenter.

3.2.2.2 Results and Discussion

The percentage of participants selecting each colour as the best example, for each Hue, is shown in Table 5.

Table 5. The percentage of times that each stimulus was chosen as the best example of either blue or green Arabic terms.

(V/C)	2.5 BG	5 BG	7.5 BG	10 BG	2.5 B
6/6	0	0	0	0	0
6/7	70	70	70	60	30
6/8	20	20	30	20	70
7/7	0	0	0	0	0
7/8	10	10	0	20	0

As can be seen, 6/7 was the most frequently selected 'best example' for the first four hues: 2.5 BG, 5 BG, 7.5 BG, 10 BG and 2.5 B with a score of 70% for the first three and 60% for 10BG. However, stimulus 6/8 was the best example for 2.5B with a score of 70% and was the second most frequently chosen for the rest of the hues.

In summary, Experiment 3a was designed to identify the value and chroma for which the hues are defined as blue or green in Arabic. Arabic participants show that 6/7 had high percentage agreement for Hues: 2.5 BG, 5 BG, 7.5 BG and 10 BG in the blue-green category and 6/8 value and chroma was the highest agreement only for 2.5B.

3.2.3 Experiment 3b: Colour naming for the blue–green region

3.2.3.1 Introduction

Experiment 3a showed that stimuli were the best example at value 6 and chroma 7 for the five hues tested. The aim of the current experiment was to identify location of the hue boundary for the Arabic blue-green category boundary before conducting research on the lateralisation of blue-green colour CP in Arabic in Experiments 4 and 5.

3.2.3.2 Method

Participants, Twenty-two participants took part in the naming task. Their ages ranged from 19 to 35 years with a mean of 22.6 (SD=4), and all were undergraduate students at King Saud University. Based on self-reports, all were right-handed and had normal colour vision, as indicated by the City University Test (Fletcher, 1981).

Equipment and stimuli, There were five stimuli used in this experiment 2.5BG, 5BG, 7.5BG, 10BG and 2.5B. These stimuli varied only in Munsell hue with Value and Chroma constant (6/7). Their CIELUV coordinates (u* v*) were: -44.79. 6.01; -45.65. -2.73; -45.61. -10.29; -44.83. -18.68; and -43.31. -26.01; L* = 61.70. The stimuli were displayed on the same monitor that was used in Experiment 3a and were measured with the colourCAL colourimeter used in the previous experiment.

Procedure, A rectangular shape (120 × 60 mm) on a grey background (40 × 30 cm) was presented on a monitor in a darkened room at a viewing distance of 60 cm. Stimuli were viewed one at a time, in a random order, remaining on display until a naming response was made. Responses were made using a computer keyboard. There were five repetitions of each stimulus and the twenty-five trials were in a random order. The task was to label the stimuli as *azrock* 'blue', *akhdar,* 'green' or *azrock-akhdar* 'blue-green' if the participant could not decide whether the stimulus was blue or green. The term ' *azrock-akhdar* 'blue-green' was described to the participants as a colour which mixed half blue and half green (50% blue and 50% green). An example of the task is shown in Figure 10.

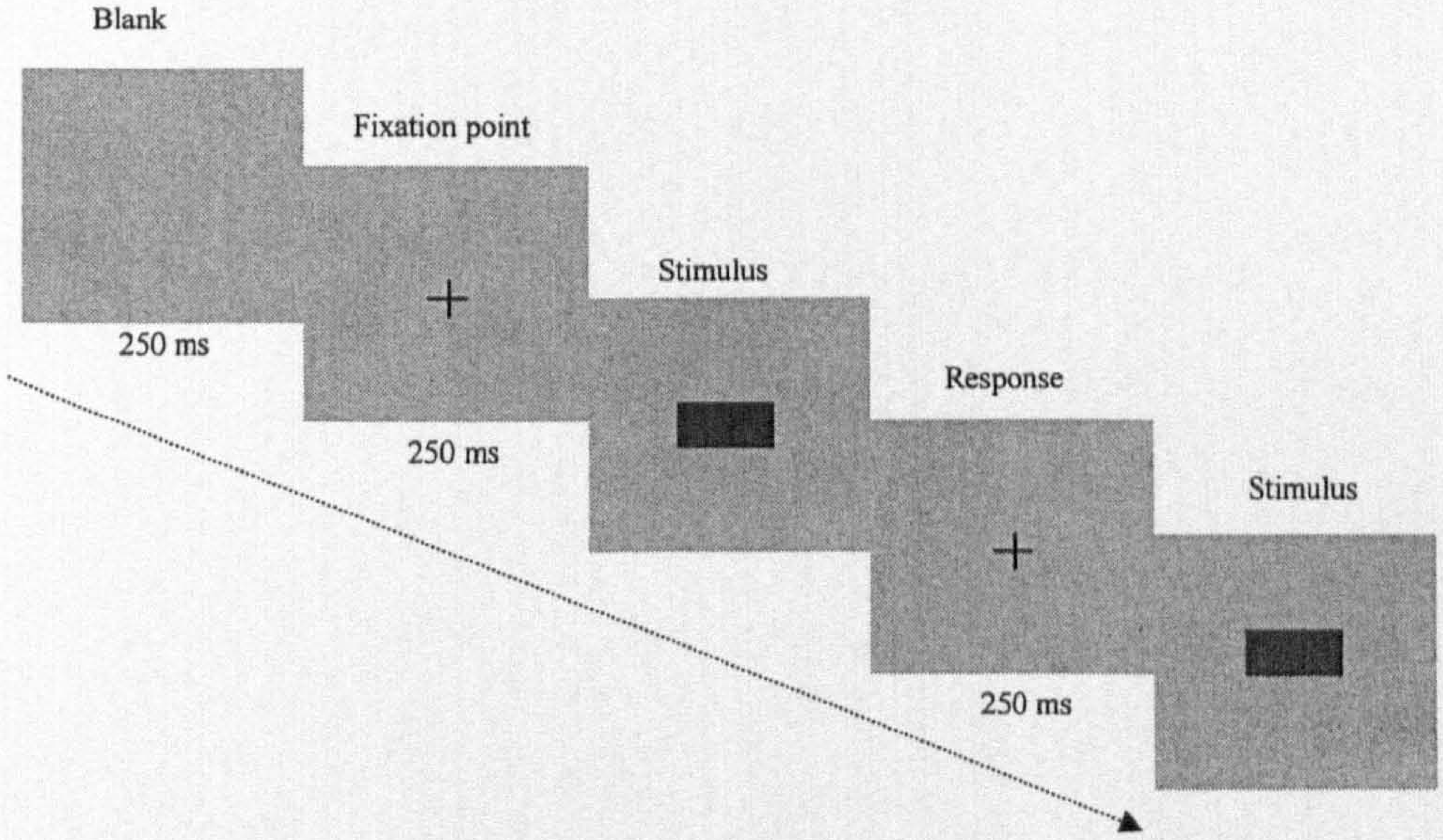


Figure 10. Example of the colour naming task.

3.2.3.3 Results and Discussion

The agreement curve for blue-green colour naming for Arabic speakers is shown in Figure 11. Participants used three terms to name the five stimuli. The graph represents the percentage of blue, green and blue-green responses to each of the five stimuli in the continuum.

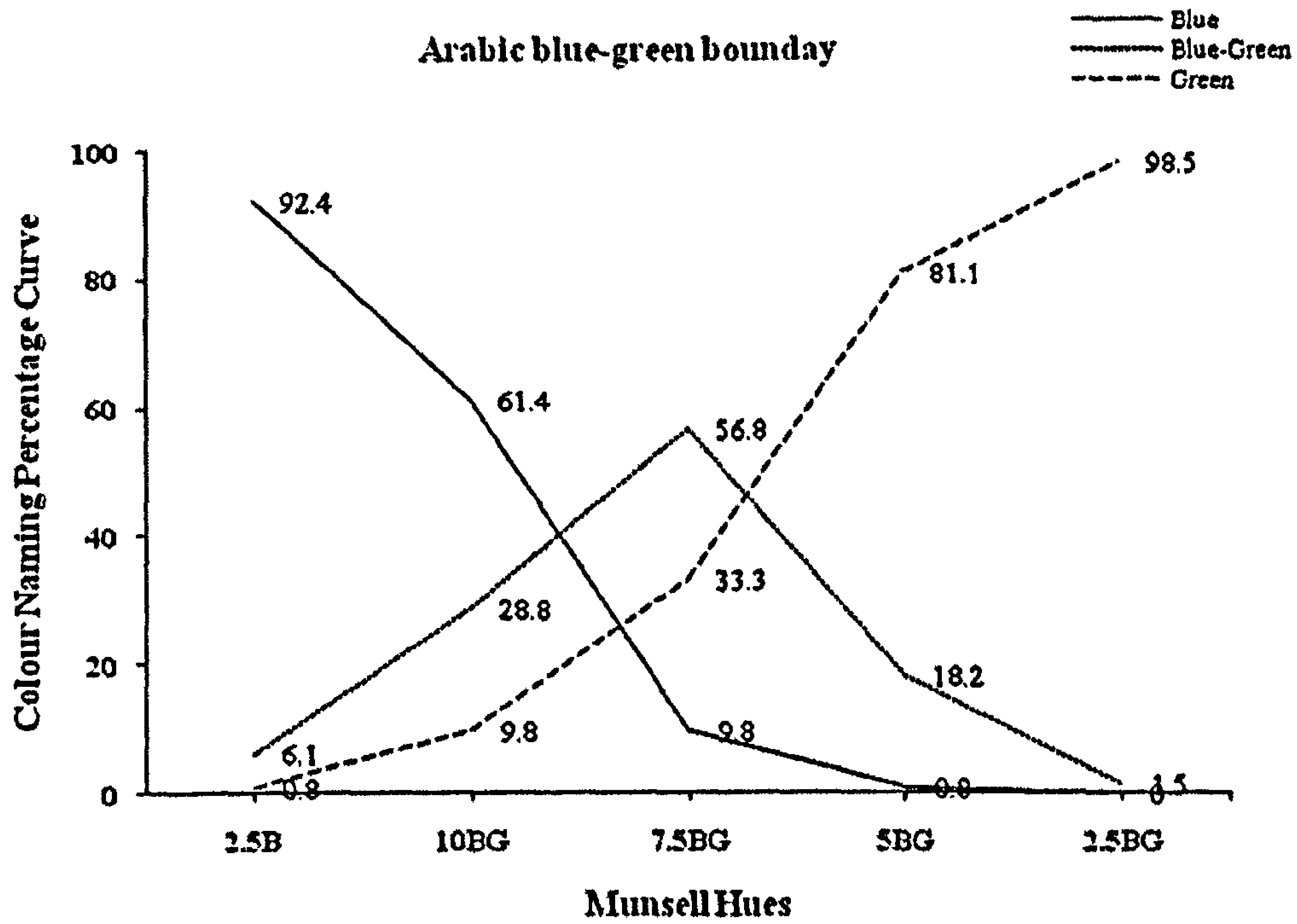


Figure 11. Percentage naming frequencies across observers for the five hues.

As can be seen, for the green term, the agreement curve peaks at 98.5% of the sample and falls gradually towards the blue region of the range reaching the lowest point at 2.5B with 0.8 %. The term green was given to two stimuli, (2.5 BG and 5BG) by over 80% of the sample. In contrast, the agreement curve for the blue term shifted towards a hue value of 5BG with 93.1 % and gradually fell towards the green region. Two stimuli out of five in the continuum were named 'blue' by over 61% of the sample. It can be seen that the level of consensus for the 'blue-green' term was highest only for the stimulus 7.5BG when it was offered by at least 57% of the sample.

Based on these results, it appears that the Arabic blue-green category boundary was around 7.5BG with the most frequent responses to the two stimuli to the right being 'blue' and for the two to the lest of the boundary being 'green'. It appears that the Arabic blue-green boundary is in the same location as for English (Bornstein and Monroe, 1980).

3.3 Experiment 4: Hemispheric Asymmetries in Visual Search Task

3.3.1 Introduction

Gilbert *et al.* (2006) used a lateralised visual search task to investigate the lateralisation of colour CP. The results of Gilbert *et al.* and other studies (Daoutis et al, 2006; Drivonikou et al, 2007; Roberson et al, 2008; Tan et al, 2008; & Liu, 2009) showed that left-to- right script readers discriminated pairs of stimuli from different colour categories faster than same-category pairs, even though the separation of within- and between-category pairs of were equal. Crucially, however, this categorical effect is strongest for RVF (LH) targets.

Experiment 4 was carried out to investigate whether habitual reading direction might affect the pattern of lateralisation. Arabic speakers, who read from right-to-left, and English speakers who read from left-to-right, were tested. CP was investigated using a version of the search task originally used by Gilbert et al., described earlier.

3.3.2 Method

3.3.2.1 Participants

There were two groups of subjects: 'English' and 'Arabic'. The English group consisted of eleven native English-speakers who were undergraduate students or staff at University of Surrey. Their ages ranged from 18 to 40 years with a mean of 25.6 (SD=8). The Arabic group consisted of 15 undergraduate students at King Saud University, with ages ranging from 19 to 23 years with a mean of 20.4 (SD=1). All participated for course credits, or were paid for their participation. Based on self-report, all the participants were right-handed and had normal colour vision, as indicated by *the City University Test* (Fletcher, 1981) for the English speakers and by *Ishihara's Test for Colour-Blindness* (Ishihara, 1987) for the Arabic participants.

3.3.2.2 Stimuli

As shown in Figure 12, three stimuli were used so that two of them fell into the blue category and the other fell into the green category. The Munsell hues were 5BG, 10BG and 5B. The value and chroma were constant at (6/7), and the separation was 5 hue steps ($\Delta E \sim 15$). Their CIELUV coordinates (u^* v^*) were -45.65, -2.73; -44.83 -18.68; and -39.62 -32.97; all at $L^* = 61.70$. The Y x y coordinates for the grey background and the white point of the monitor were: 19.47, 0.336, 0.344; 64.80. 0.326. 0.335.

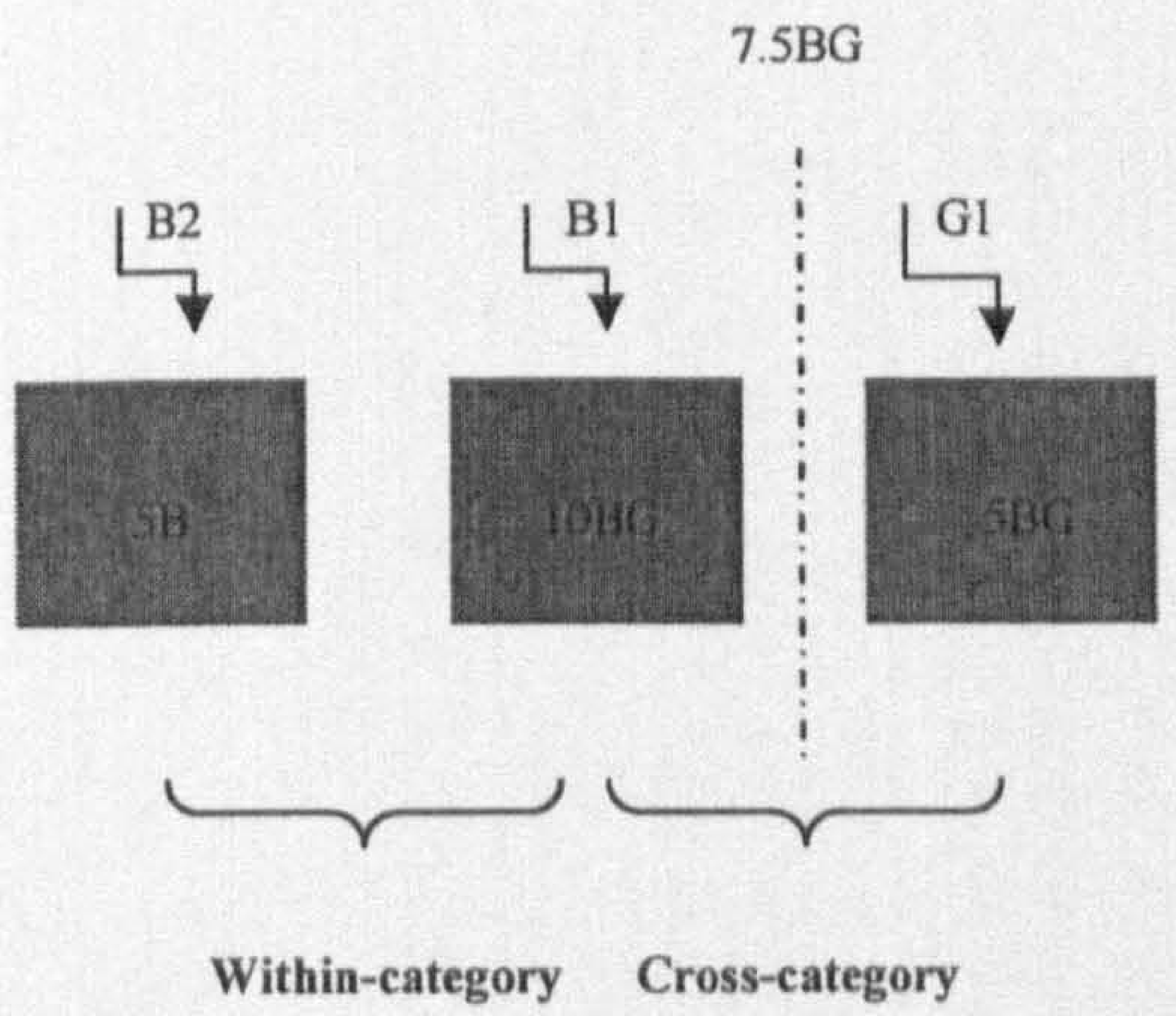


Figure 12. Illustration of the Munsell codes of the three stimuli used. Stimuli B2 and B1 are from the same category, while stimulus G1 belongs to a different category. Stimuli B2, B1 and G1 are equally separated. The line between B1 and G1 indicates the English and Arabic blue-green boundary.

The blue-green boundary for both samples was (7.5BG). Adjacent stimuli were paired, giving one within-category pair (B1-B2) and one between category pair. The target for all trials was blue1 and the 11 distractors were randomly switched between within-category (blue2) and across-category (green1). The stimuli were displayed on a 17-inch CRT; a Cambridge Research Instruments ColorCAL was used to obtain the CIE co-coordinates.

3.3.2.3 Procedure

There were twelve circular stimuli displayed in a clock shape (30 mm diameter, ~3.5° viewed from 500 mm) with six set on the right of central fixation cross and the other six on the left. One stimulus, the "target", varied in hue from the rest (11 distractors) appeared randomly in one of the 12 equally separated (30°) locations on a notional circle of 110 mm diameter around the fixation cross at the centre of the monitor. The stimuli were displayed against a grey background on each trial. An example of the task was shown in Figure 13.

The experiment began with a fixation cross which remained for 100 ms to alert the participants that the trial was beginning. Then the stimulus followed and remained on screen for 200 ms. The next trial began when the participants had responded. There were 192 trials made up from 48 trials of each combination of visual field (left or right of fixation) and within- and across-category. There were also 10 practice trials before starting the experiment proper, and they took about ten minutes to complete the task.

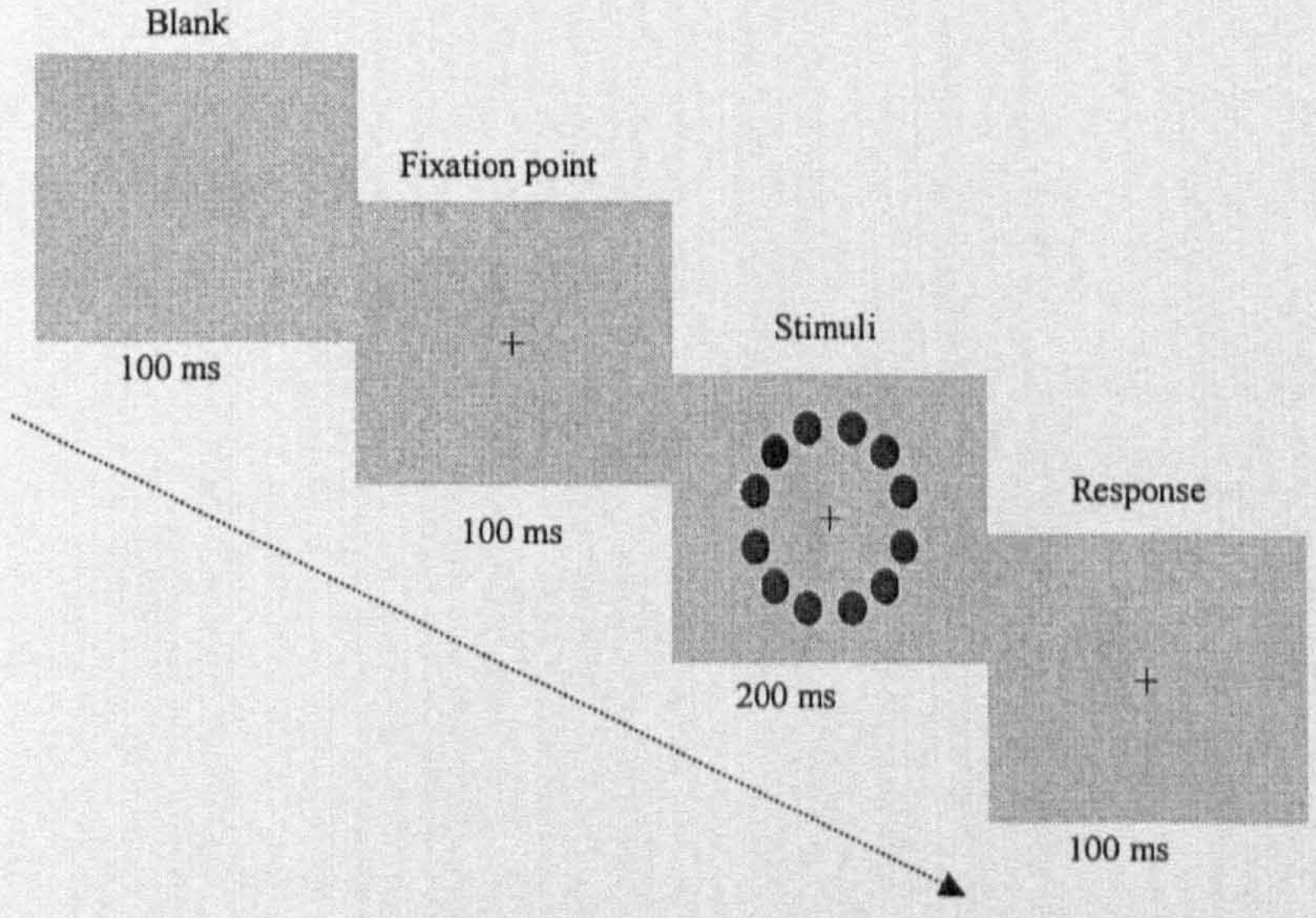


Figure 13. Sample of the visual search task, the green dot shows the target, and the other 11 circles indicate the distractors.

The participants were tested individually in a dark room, and were seated 60 cm away from the monitor and at eye-level to the centre of the monitor, with head restrained using a chin rest. Participants were instructed to click on the right mouse button as quickly as possible when the target appeared in one of the six locations set on the right of central fixation, and click on the left mouse button as quickly as possible when the target appeared in one of the six locations set on the left of central fixation. They were also told that on each trial the target could appear in any one of the twelve locations at random.

3.3.3 Results

The percentage of incorrect trials for each combination of category (within/cross), visual field (left/right) and language (English or Arabic) were calculated for each subject. A three-way ANOVA (Category by Visual Field by Language), with repeated measures on the first two factors, showed that the only significant effect was for Category (all other Fs < 1). Cross-category errors rate (mean = 2.93%, SD = 3.51) were about 1% lower than within-category responses (mean = 4.02, SD = 4.98), $F(1,24) = 0.27$, $MSE = 30.55$, $p < 0.05$.

Median response times (RTs) for each subject were calculated for each combination of visual field and category for correct trials. Although English speakers (mean = 437 ms, SD = 60) responded ~ 25 ms faster than Arabic speakers (mean = 465, SD = 85), this difference was not significant ($F(1,24) = 0.90$, $MSE = 19732.82$, $p = 0.35$). Nor did the language factor interact with any of the other factors: (largest $F = 0.94$, smallest $p = 0.34$). Cross-category responses (mean = 442.81, SD = 75.87) were about 20 ms faster than within-category responses (mean = 463.32, SD = 75.62; $F(1,24) = 9.84$, $MSE = 10481.84$, $p < 0.005$). There was also a significant effect of visual field ($F(1,24) = 6.94$, $MSE = 2000.12$, $p < 0.05$) with the RVF responses (mean = 446.48, SD = 78.86) being about 9 ms faster than LVF responses (mean = 455.36, SD = 73.71). The category effect was about 15 ms larger in the RVF than in the LVF. The Category by Visual Field interaction was also significant, $F(1.24) = 6.42$, MSE = 1378.42, $p < 0.005$. From Figure 14 the interaction appears to be due to the larger category effect in the RVF (~ 25 ms) compared to the LVF (~10 ms).

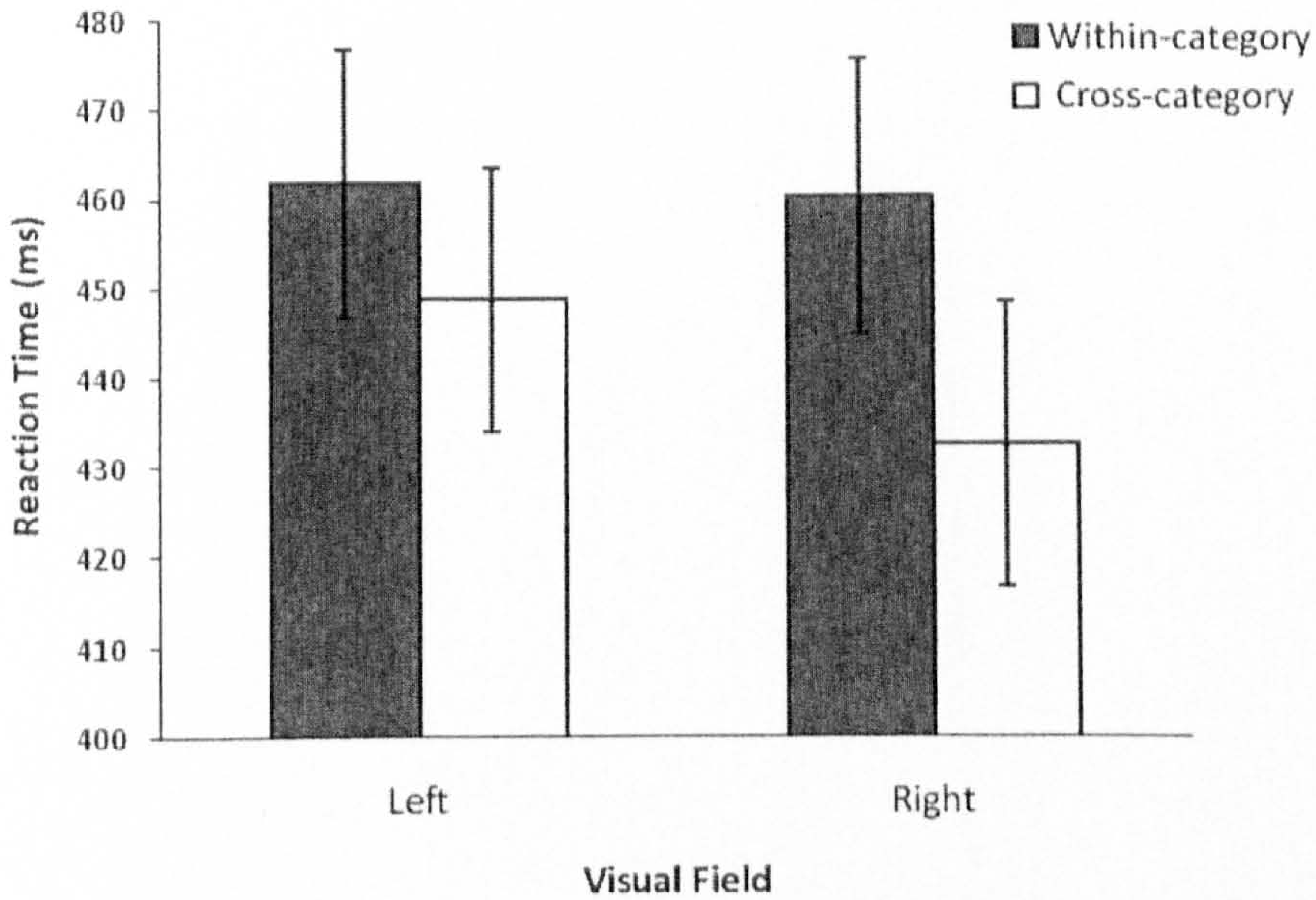


Figure 14. Mean response times (+/-1se) with standard error bars for correct trials for Arabic and English speakers for identification of the left/right location of chromatic target among distractors from either a different or same category.

This impression was supported by paired samples *t*-tests (2-tailed) used to investigate the interaction. There was a significant category effect for the RVF ($t(25) = 3.98$, $p < 0.001$), but not for the LVF ($t(25) = 1.96$, $p = 0.062$). Moreover, for cross-category trials, RVF responses were faster than LVF responses ($t(25) = 3.42$, $p < 0.005$) but there was no effect of visual field for within-category responses ($t(25) = 0.28$, $p = 0.78$).

3.3.4 Discussion

Discrimination of target and distractors was faster when they were categorically different than when they were just perceptually different. However, this category effect was stronger for RVF targets than LVF targets thus replicating Gilbert et al. (2006). Crucially, there was no suggestion that this pattern differed between the two groups with different habitual reading directions.

3.4 Experiment 5: Hemispheric Asymmetries on a Target Detection Task with an eye-movement measure.

3.4.1 Introduction

Experiment 4 used a version of Gilbert et al.'s visual search task to investigate the lateralisation of colour CP to the LH in two samples varying in their scanning habit testing Arabic (right-to-left) and English (left-to-right). The result of this experiment replicated the findings of Gilbert *et al.* and Drivonikou *et al.* A hemispheric asymmetry in CP was shown with a significant CP effect for RVF but not LVF targets. The current experiment checks whether the LH bias in colour CP for Arabic speakers is also found when using an eye-movement measure. Franklin *et al.* (2008) measured the time to initiate an eye-movement to the target in their study of lateralised colour CP in infants. In the current study, the same eye-movement measure was used with readers of a right-to-left script to test whether habitual scanning direction could influence the LH category effect. If so, then the Arabic participants, who have right-left reading and writing habits, could show a different pattern than that shown by the English Adults reading left-to-right Roman script in the Franklin et al. (2007) study.

3.4.2 Method

3.4.2.1 Participants

There were two groups of subjects, 'English' and 'Arabic' all from the University of Surrey. Based on self-report, all were right-handed and reported normal colour vision, as indicated by *the City University Test* (Fletcher, 1981). Twenty of them were native Arabic speakers, 8 females and 12 males aged between 18 and 30 years old with a mean age of 27.05 years (SD = 4.50). None had lived in the UK for more than two years, and none of them had taken part in the previous study. Eighteen were native speakers of English, 11 females and 7 males, aged between 18 and 30 years old with a mean age of 21.83 years (SD = 3.85).

3.4.2.2 Apparatus and Experimental Set Up

The apparatus was the same as in the previous experiment with the addition of an ASL 504 pan/tilt eye-tracking camera mounted directly below the monitor. This camera is sensitive to near-infrared light, enabling a participant's eye movements to be recorded in the dark. An analogue digital video converter (Canopus ADVALUE AND CHROMA-300) digitised the eye-movement output and I-movie 2.1.2 software analysed the digital video.

3.4.2.3 Stimuli

As shown in Figure 15, three stimuli were used varying only in Munsell Hue with Value and Chroma constant at 6/8. The separation between adjacent stimuli was 2.5 Munsell hue steps ($\Delta E \sim 9$). Two stimuli were green (3.75BG and 6.25BG) and the third was blue (8.75BG). The CIE (1931) Y, x, y chromaticity coordinates of the colours and of the grey and white point of the monitor were: 19.47, 0.228, 0.342; 19.47, 0.220, 0.322; 19.47, 0.214, 0.304; 19.47, 0.336, 0.344; 64.80. 0.326. 0.335.

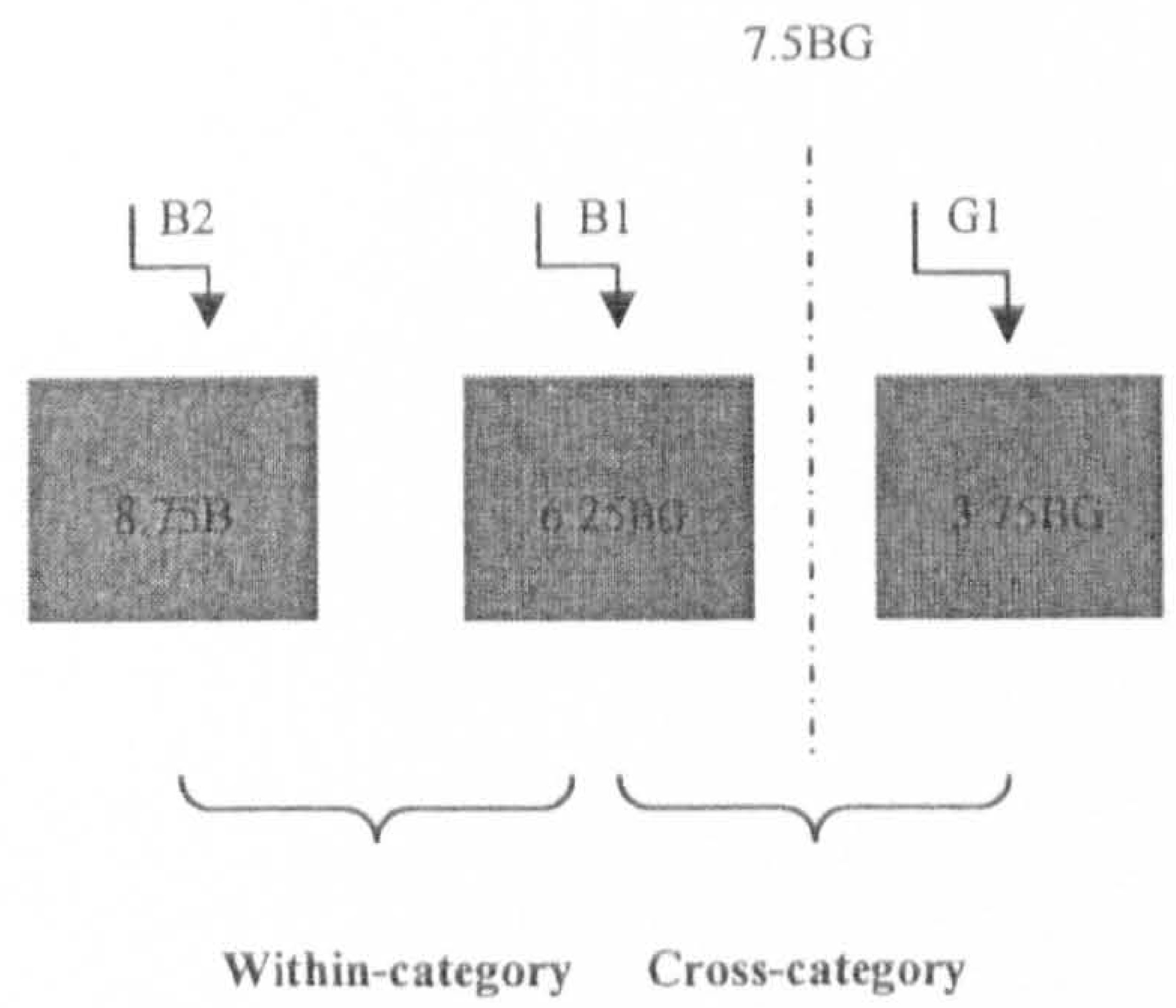


Figure 15. Illustration of the Munsell codes of the three stimuli used. Stimuli B2 and B1 are from the same category, while stimulus G1 belongs to a different category. Adjacent pairs were separated by 2.5 Hue steps. The line between B1 and G1 indicates the English and Arabic blue-green boundary.

3.4.2.4 Procedure

Adjacent stimuli were paired, to give one within-category pair (green1-green2) and one between-category pair (green1-blue1). For each pair, on a given trial, one stimulus was used as the target and one stimulus as the background. However, across trials, each stimulus within a pair was used as the target half of the time and half of the time as the background.

A circular target (3 cm diameter, visual angle = 3.22°) appeared on a coloured background (40 × 30 cm) at one of twelve locations arranged radially around a central point, half of them located in the left visual field (right hemisphere) and half in the right visual field (left hemisphere) with a fixation cross in the centre (Figure 16).

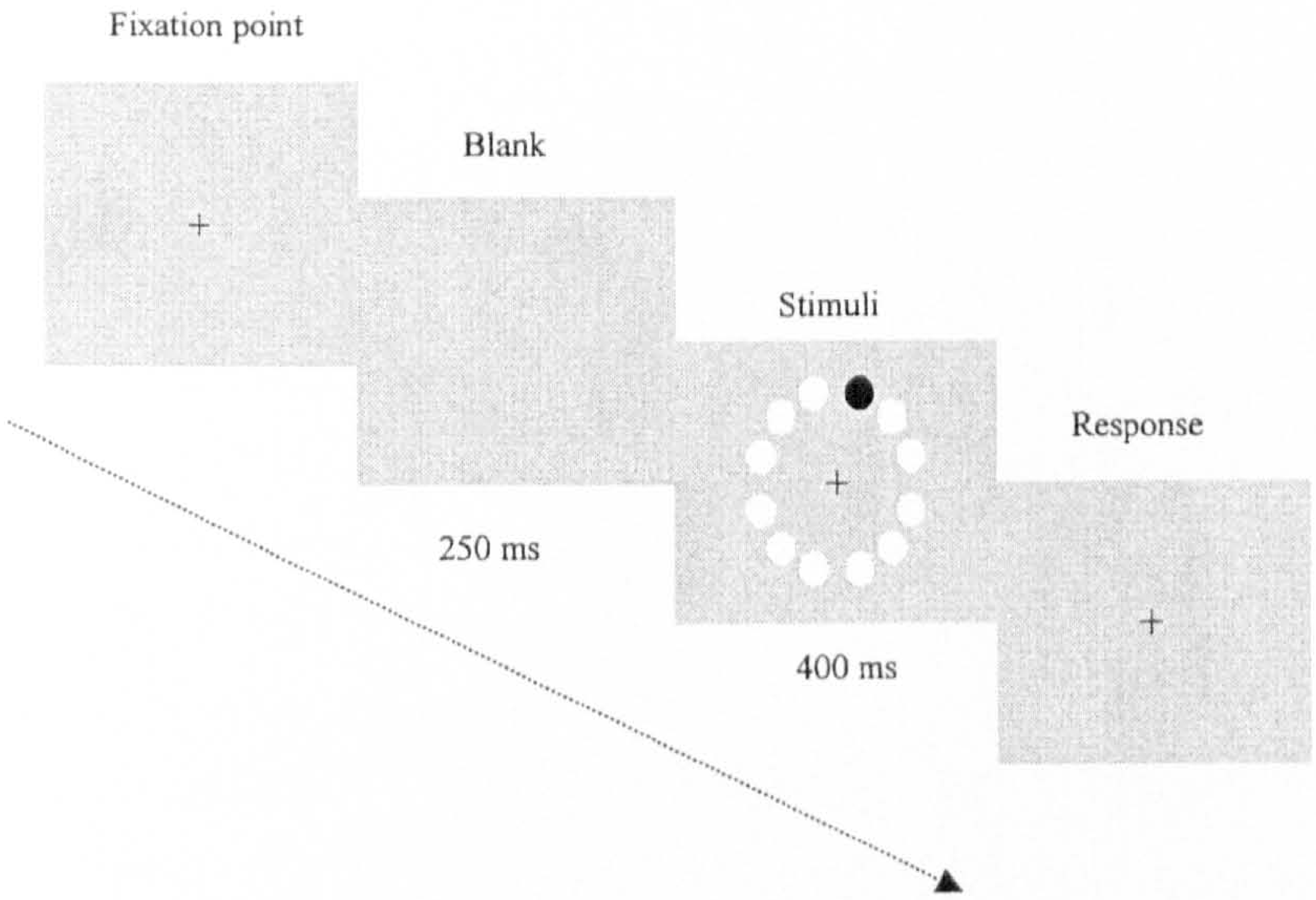


Figure 16. Example of the target detection task, the black dot shows the target, and the other 11 white circles indicate the possible target locations.

Participants were seated in front of the monitor, and were instructed to keep their eyes on the centre of the screen and to hold their head up and in a stable position throughout the calibration and experimental phases. The pan/tilt eye-tracking camera was angled by a remote control to capture the participant's eye, so that the eye was put into focus, and the crosshairs for the pupil signal and corneal reflection were found and appeared on the image of the eye on the video monitor.

The calibration procedure (see Franklin, Pilling & Davies, 2005) preceded the main data collection phase. Nine numbers displayed in a grid shape appeared on the CRT, and the participant was asked to look at the nine numbers as requested by the experimenter. The nine points were given to each participant in a different order, after all nine points had been hit by the corneal reflection and pupil signal crosshair, the calibration phase was accurate and achieved. The calibration procedure was repeated when the crosshair failed to hit one of the nine points.

After calibration, the main data collection phase started. To ensure central fixation, each trial began with a black and white looming and expanding 'attention-getter' on a grey background. Following fixation, a blank grey background of the same luminance as the target appeared for 250 ms, followed by a 4-second presentation of the target and background. The target location was randomised across trials, with the constraint that it appeared to the left and right of fixation equally often. The experiment was run in two blocks, each consisting of 16 trials.

3.4.3 Results

Initiation time data were derived using point of gaze (POG) coordinates and the videotaped output. The initiation time was calculated as the time from onset of the target until the start of an eye-movement to the target. Trials were excluded from the analysis for two reasons: when the eye-movement signal was lost (Arabic: mean = 3.4, SD 6.8; English mean = 2.39, SD 3.16); when multiple eye-movements were made before the eye movement to the target (Arabic mean = 6.9, SD 5.3; English mean = 5.11, SD 3.5). The average number of trials analysed were 48.95 for Arabic and 56.5 for English. There were at least 10 trials analysed for each participant in both samples.

As the language factor did not interact whit any other factor, Figure 17 shows the mean initiation time (ms) across participants for correct trials for each combination of visual field (left or right) and category (within- across) collapsed across the language factor. Three way mixed ANOVA was performed on the initiation time data for the three factors: (Category: cross-category within- category), (Visual Field: Left Right) and (Language: Arabic English).

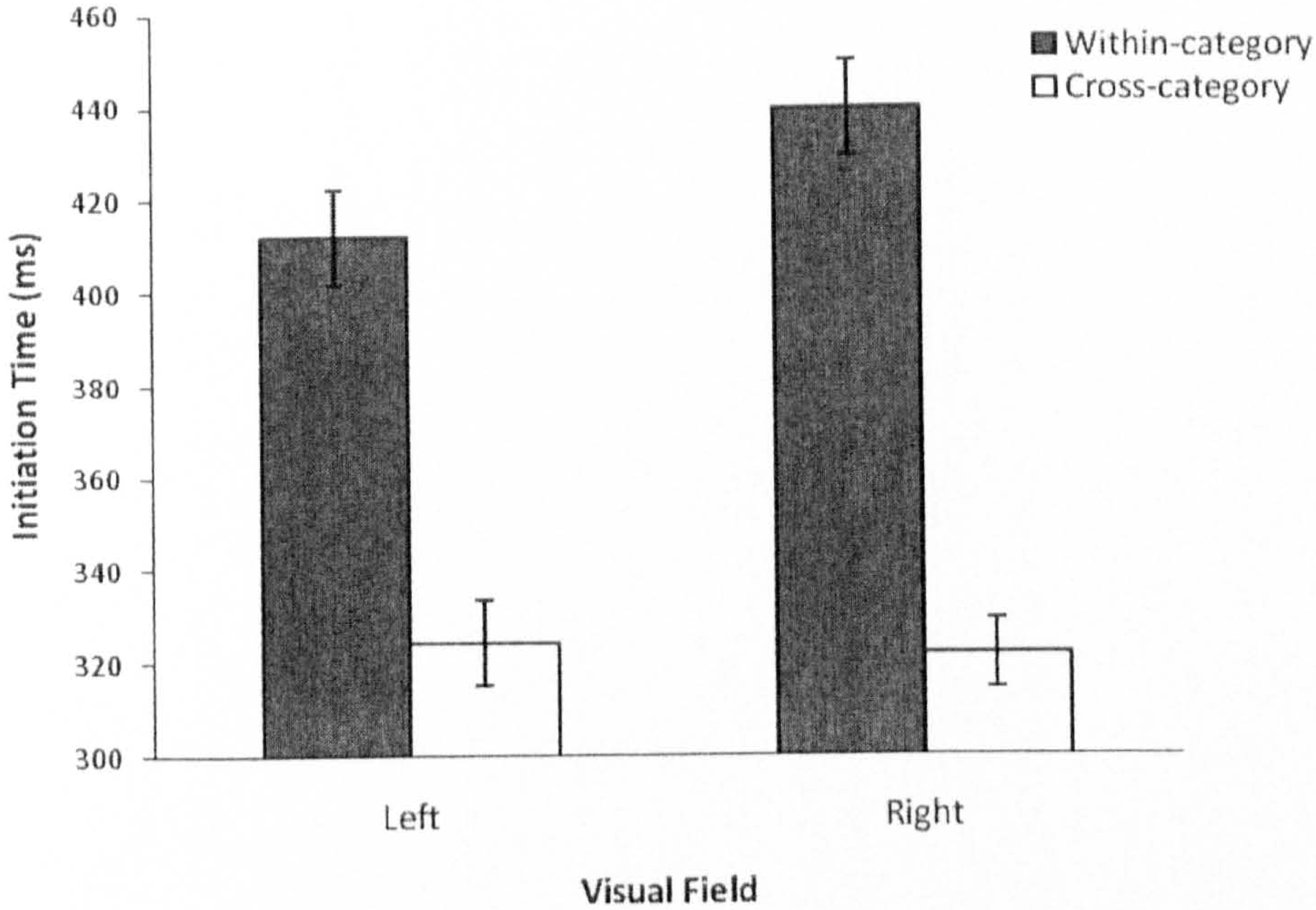


Figure 17. Mean response times (+/-1se) with standard error bars for correct trials for Arabic and English speakers for identification of the left/right location of chromatic target among distractors from either a different or same category.

The Arabic group (mean = 357.25 ms, SD = 74) initiated eye movements about 30 ms faster than the English group (mean = 391.95 ms, SD = 82; $F(1,36) = 5.06$, MSE= 45614.06, $p < 0.05$). There was also a very strong category effect ($F(1,36)$= 248.34, MSE= 400076.05, $p < 0.001$). Initiation time was about 100 ms faster for the cross-category condition (mean = 323.59 ms, SD = 51.59) than the within-category condition (mean = 420.76 ms, SD = 73.76). The effect of Visual Field was not significant, but there was trend for initiation time to be faster for the RVF condition (mean = 367.30 ms, SD = 75.45) than the LVF condition (mean = 377.05 ms, SD = 84.53; $F(1,36) = 3.47$, MSE= 5842.37, p = 0.071). Crucially, the interaction between Category and Visual Field was also significant ($F(1,36) = 7.86$, $p < 0.005$) and this interaction is explored below. There was no significant interaction of Language with the other factors, however, the Language by Category interaction approached significance ($F(1,36) = 3.53$, MSE= 5686.57, p= 0.068; for the remaining interactions, largest $F = .38$).

From Figure 17 there appear to be two reasons for the category by field interaction. First, the size of the category effect is larger in the RVF (11 ms) than in the LFV (88 ms). And second, the within-category condition appears to be faster in the LVF than in the RVF by about 25 ms, whereas there seems to be no effect of visual field on the between category condition. A series of post hoc paired sample *t*-tests supported these impressions. While the category effect was present in both visual fields (RVF, $t(37)$, 13.99, $p < 0.001$; LVF $t(37)$, 9.89, $p < 0.001$) the effect was larger in the RVF than in the LVF ($t(37)$, 2.86, $p < 0.05$). Comparing visual fields, confirmed that for within-category conditions, the LVF was faster than for the RVF ($t(37)$, 2.73, $p < 0.01$) whereas there was no field effect for between category conditions ($t(37)$, 0.42, $p = 0.68$).

3.4.4 Discussion

For both Arabic and English participants, discrimination of pairs of colours from different lexical categories (blue and green) was faster than pairs from the same lexical categories (different shades of blue). While, this categorical effect was present in both visual fields, it was stronger in the RFV than in the LVF. Yet again, the pattern of lateralisation first reported by Gilbert et al. (2006) has been replicated, but this time, it has also been shown that the effect is independent of habitual reading direction. All of the research on lateralisation of colour CP before this thesis was conducted with participants reading left-to-right Roman script (Gilbert *et al*, 2006; Drivonnikou *et al*, 2007; Roberson, 2008; Franklin *et al*, 2008). In this experiment, we show that as in Experiment 4, but this time using an eye-movement measure, that readers of right-to-left scripts, such as Arabic, show essentially the same pattern as the current English sample, and the adult English sample in Franklin et al. (2007). It appears that reading direction has no effect on how colour CP is lateralised.

3.5 Experiment 6: Hemispheric Asymmetries and 'Popout': the effect of number of distractors

3.5.1 Introduction

The previous experiments in this chapter investigated whether the LH bias in colour CP was independent of reading direction. The results showed that lateralised CP was independent of habitual reading direction and broadly replicated previous results (e.g., Gilbert et al., 2006; Drivonnikou et al., 2007 and Franklin et al., 2008). Most tests of lateralised CP have used one or other of these tasks, and it is important to establish that the effect is independent of the detailed methods used. Here, I investigate first varying the number of distractors affects lateralised CP (Experiment 6) and then whether removing the spatial decision (left or right of fixation) affects lateralised CP (Experiment 7).

Most of the studies that tested the lateralised CP effect used tasks similar in design to the original study by Gilbert et al. (2006). In the next experiment (Experiment 6), the number of distractors was varied to test whether search time was independent of the number of distractors, indicating 'pop-out' (Treisman & Gelade, 1980), or that search was 'efficient' (Wolfe, 1994). If search was not efficient, then the pattern of lateralisation might interact with the number of distractors. In Experiment 7, targets were only present in half the trials, and the task was to decide whether there was a target or not. Thus, this Experiment tested whether the same pattern of lateralisation was found as in Gilbert et al. (2006) when the explicit spatial component of the decision was removed. As the results from the previous experiments of this chapter showed that the pattern of lateralisation was independent of reading direction, the following experiments only tested an English-speaking sample.

3.5.2 Method

3.5.2.1 Participants

Sixteen native-English-speaking undergraduates from the University of Surrey participated in this experiment. There were 4 males, with a mean age of 24 years (SD=8), and 12 females, with a mean age of 20 years (SD=6). Their ages ranged from 18 to 24 years. Based on self-report, all were right-handed and had normal colour vision as indicated by the City University Test (Fletcher, 1981). Most of the participants participated for course credit and a few volunteered.

3.5.2.2 Stimuli and apparatus

As shown in Figure 18, three colour stimuli were used in this experiment; one green (5BG) and two blues (10BG and 5B; Value and Chroma = 6/8). The separation between adjacent stimuli was 5 Munsell hue steps (AE ~ 15). Their CIELUV coordinates (u* v*) were -45.65, -2.73; -44.83, -18.68; -39.62, -32.97; all at L* = 61.70; a Cambridge Research Systems, ColorCal colorimeter was used to measure the CIE co-coordinates and they were displayed on a 17-inch CRT model GDM-F520.

3.5.2.3 Procedure

Adjacent stimuli were paired, to form one within-category pair (blue1-blue2) and one between-category pair (blue1-green1). For each pair, one stimulus was the target and the other stimulus was used for the distractors, with both stimuli in a pair appearing equally often as distractors. The target for all trials was always blue and the distractors were randomly switched between 'within' (blue) and 'across' (green). There were equal numbers of trials for each combination of category (within- or between-) and visual field (LVF or RVF) and the order of trials was randomised across these four conditions. In addition, target location was randomised across trials with the constraint that the target appeared equally often to the left and right of fixation. Stimuli were shown as 2.5 cm squares with 5 mm gaps between adjacent locations, appearing in locations specified by a 6×6 square grid on the display (Figure 19). The target appeared amongst either 3, 15 or 35 distractors on a grey background (19.47 cd/m², 0.336, 0.344). For the 4 and 16 set sizes (distractors plus target) stimulus locations within the grid were randomly selected, but for the 36 set size, all locations were occupied (see Figure 19).

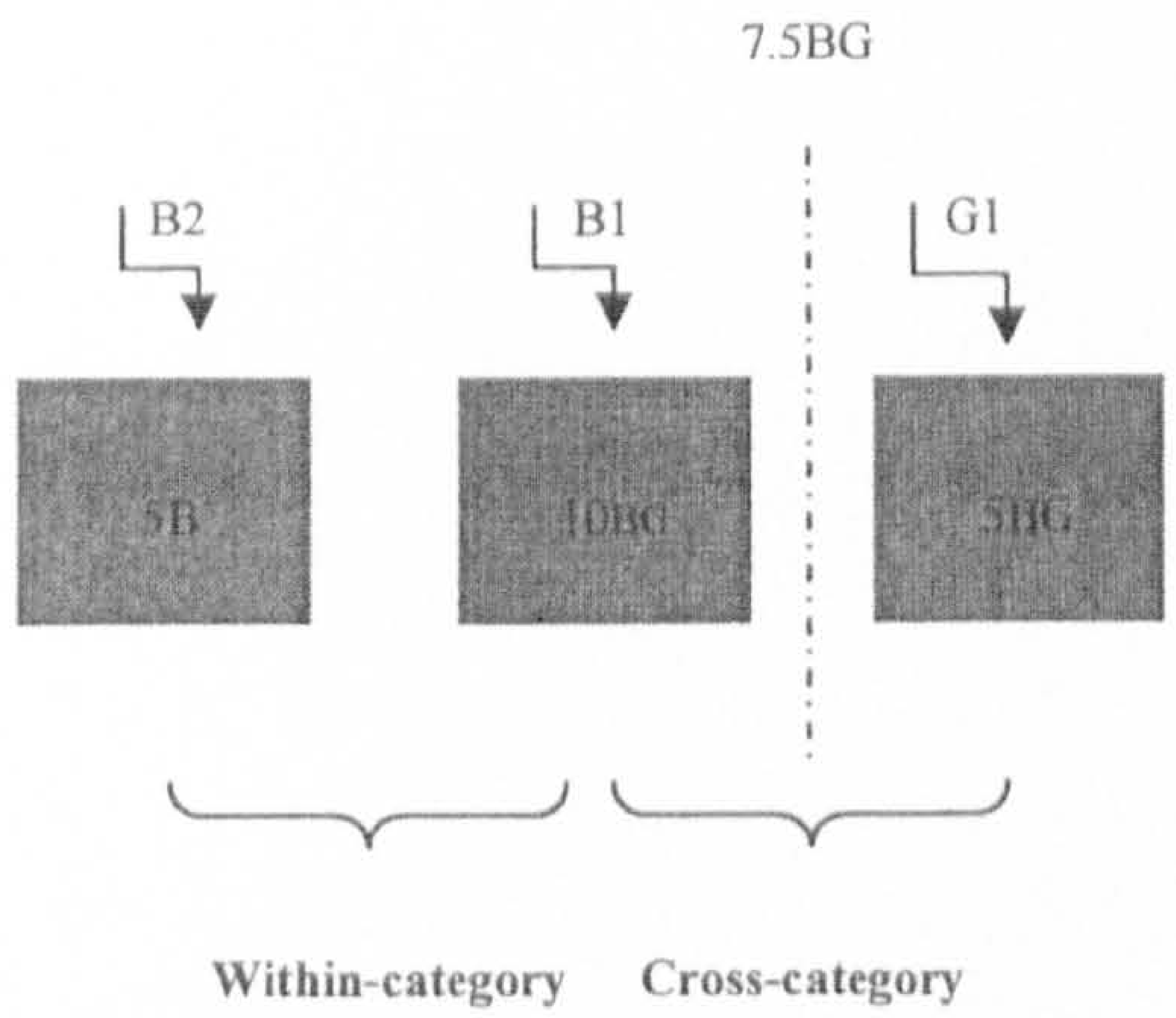


Figure 18. Illustration of the Munsell codes of the three stimuli used. Stimuli B1 and B2 are from the same category, while stimulus G1 belongs to a different category. B1-B2 and B1-G1 differ by 5 Munsell Hue steps. The line between B1 and G1 indicates the English and Arabic blue-green boundary.

The experiment began with a fixation cross which remained for 100 ms to alert the participants that the trial was beginning. Then the test display followed and remained on screen for 200 ms. The next trial began when the participants had responded. There were 192 trials, 16 for each combination of category and visual field, repeated three times, once for each set size. Participants were given 10 practice trials before starting the experiment, and they took about ten minutes to complete the task.

The participants were tested individually in a dark room and sat with their head position constrained by a chin-rest, so that eye-level was at the centre of the monitor, with a viewing distance of 60 cm. Participants were informed that they would be presented with a target stimulus among a varied number of distractors and their task was to decide whether the target was to the right or to the left of fixation. Responses were made by clicking the appropriate mouse button.

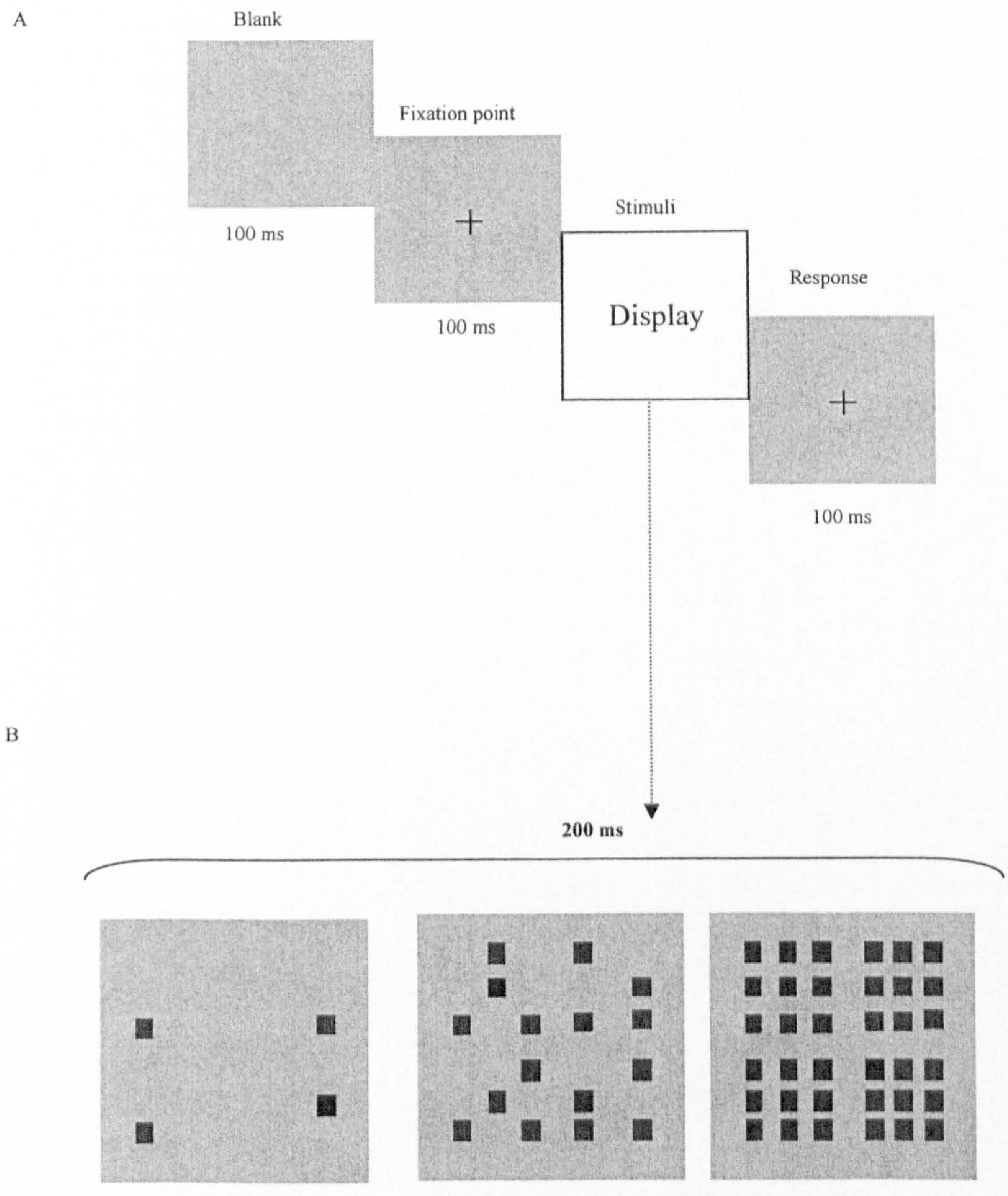


Figure 19. (a) Example of the grid task. The blue square shows the target, and the other green squares indicate the distractors. (b) Illustration of the three set of distractors (3, 15 and 35) for the 3 and 15 stimulus locations within the grid were randomly selected, but for the 36 set, all locations were occupied.

3.5.3 Results

The percentage of incorrect trials was calculated for each subject, for each combination of category (within/cross) and visual field (left/right) and number of distractors (3, 15 or 35). A three-way repeated measures ANOVA on the error rates showed that there were no significant effects. However, the number of distractors was almost significant, $F(2, 28) = 3.13$, $p = 0.059$. (means (3D) = 1.133, (15D) = 0.733, (35) = 0.917).

Then, for each participant, median RTs for correct trials for each combination of category visual field and number of distractors were calculated. A three-way repeated measures ANOVA showed that there was no effect of the number of distractors nor did it interact with any other factor (maximum $F = 1.01$). Figure 20 shows the mean RTs for each combination of category and visual field collapsed across the number of distractors.

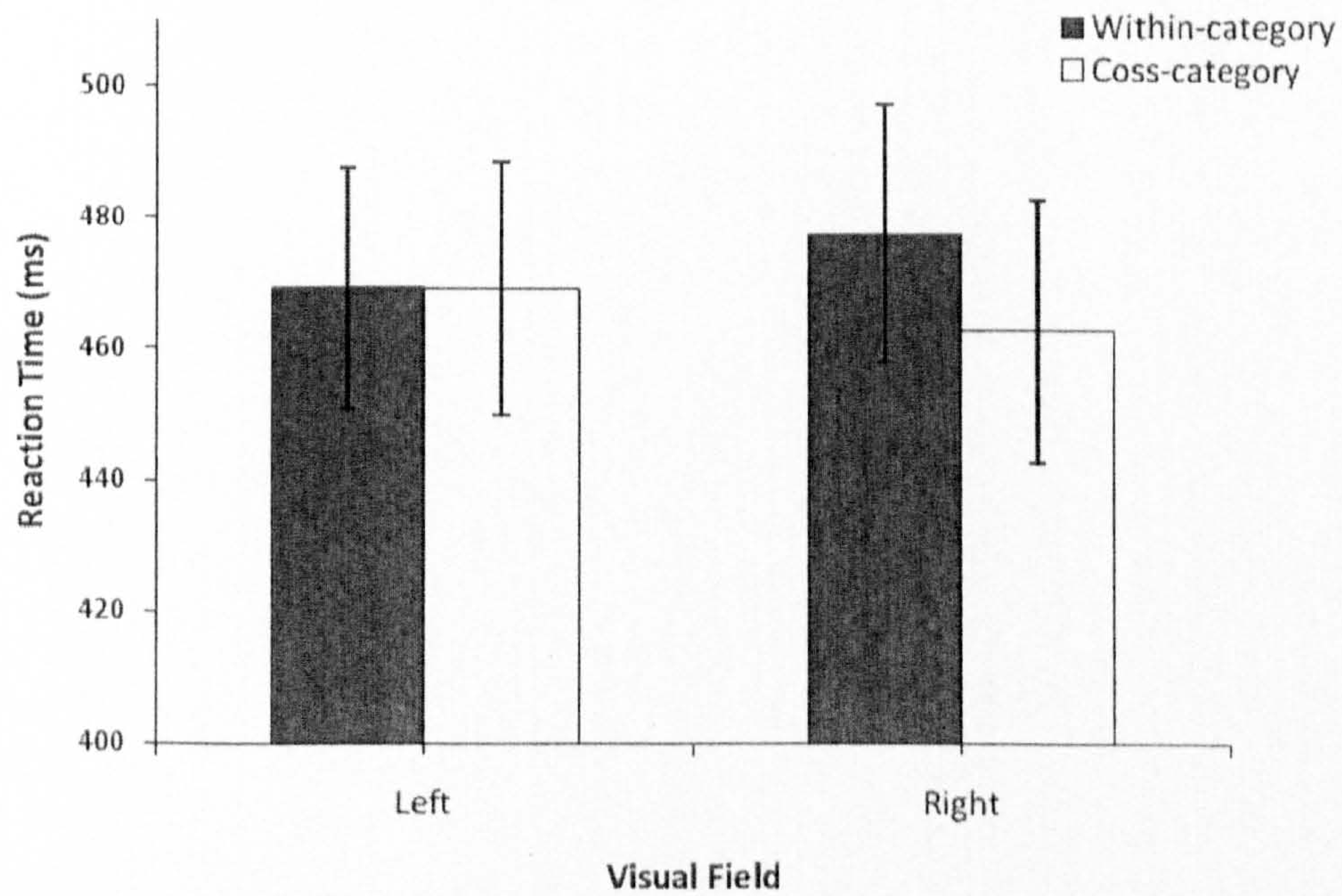


Figure 20. Mean response times (+/-1se) for each combination of category and visual field.

Although between category RTs were only about 6 ms faster than within-category RTs, this difference was significant (Means (SD) = 468.98 (73.75) ms, 474.89 (77.01) ms; $F(1,14) = 4.73, p < 0.05$). The effect of Visual Field was clearly not significant ($F < 1$), but the category by visual field interaction approached significance $F(1,14) = 3.68, p = 0.076$.

The impression of an almost significant interaction was supported by paired samples *t*-tests (2-tailed) used to investigate the interaction. There was a significant category effect for the RVF ($t(14) = 2.97, p < 0.05$), but not for the LVF ($t(14) = 0.41, p = 0.69$). There was no significant difference across visual fields for cross-category responses ($t(14) = 0.21, p = 0.84$) or within-category responses ($t(14) = 1.21, p= 0.26$.

3.5.4 Discussion

The characteristic pattern of lateralisation of CP was found again in this study, although the crucial category by visual field interaction did not quite reach significance. There was clearly no category effect in the LVF, but between-category was about 15 ms faster than within-category in the RVF.

In addition, there was no suggestion that the number of distractors affected RTs, indicative of pop-out or efficient search, nor any suggestion that the number of distractors affected the pattern of lateralisation. Thus with the caveat that the category by visual field interaction was not quite significant, these data provide further support for the LH bias in colour CP.

3.6 Experiment 7: Hemispheric Asymmetries in Colour CP in a Present-Absent Target Detection Task.

3.6.1 Introduction

In Experiment 6, lateralisation of colour CP was investigated using a visual search task where the number of distractors varied. The findings showed a trend towards the LH bias in colour CP found in previous research requiring a left-right target location decision as in Gilbert et al.'s search task, and Drivonikou et al.'s target detection task. The results showed that the pattern of lateralisation was independent of the number of distractors, confirming that, detecting a target colour amongst differently coloured distractors is a 'pop-out' task, and confirming that the LH bias is invariant across basic changes in the nature of the task.

As a further extension of the range of tasks used to test the robustness of the LH bias, Experiment 7 used a target detection task, as in Experiments 5, but with the modification that the decision required did not involve an explicit spatial component, as in Experiments 5 (see also, Gilbert et al., 2006; Drivonikou et al., 2007). Instead, a target was only present on half the trials, and the decision required was 'target-present' versus 'target-absent'.

3.6.2 Method

3.6.2.1 Participants

Participants were twenty-four native English-speaking undergraduates recruited from the student population of the University of Surrey. There were 5 males with a mean age of 19.00 years (SD=0.71), and 19 females, with a mean age of 18.90 years (SD = 1.59), with an age range from 18 to 24 years old. Based on self-report, all were right-handed and had normal colour vision, as indicated by the City University Test (Fletcher, 1981); all participated for course credit, and none of them were aware of the predictions of the experiment at the time of testing.

3.6.2.2 Stimuli, Design and apparatus

Four colours were selected for this experiment as shown in Figure 21. Two stimuli were blue and two were green. They varied only in Munsell hue: 10G, 5BG, 10BG and 5B, with value and chroma kept constant (6/7). The separation between stimuli was 5 hue steps ($\Delta E \sim 15$). Their CIELUV coordinates (u* v*) were: -43.64, 12.12; -45.65, -2.73; -44.83, -18.68; 39.62, 32.97. A Cambridge Research Instruments ColorCal was used to measure CIE co-ordinates. The colour stimuli were displayed on calibrated 17 inch CRT Sony Trinitron monitor.

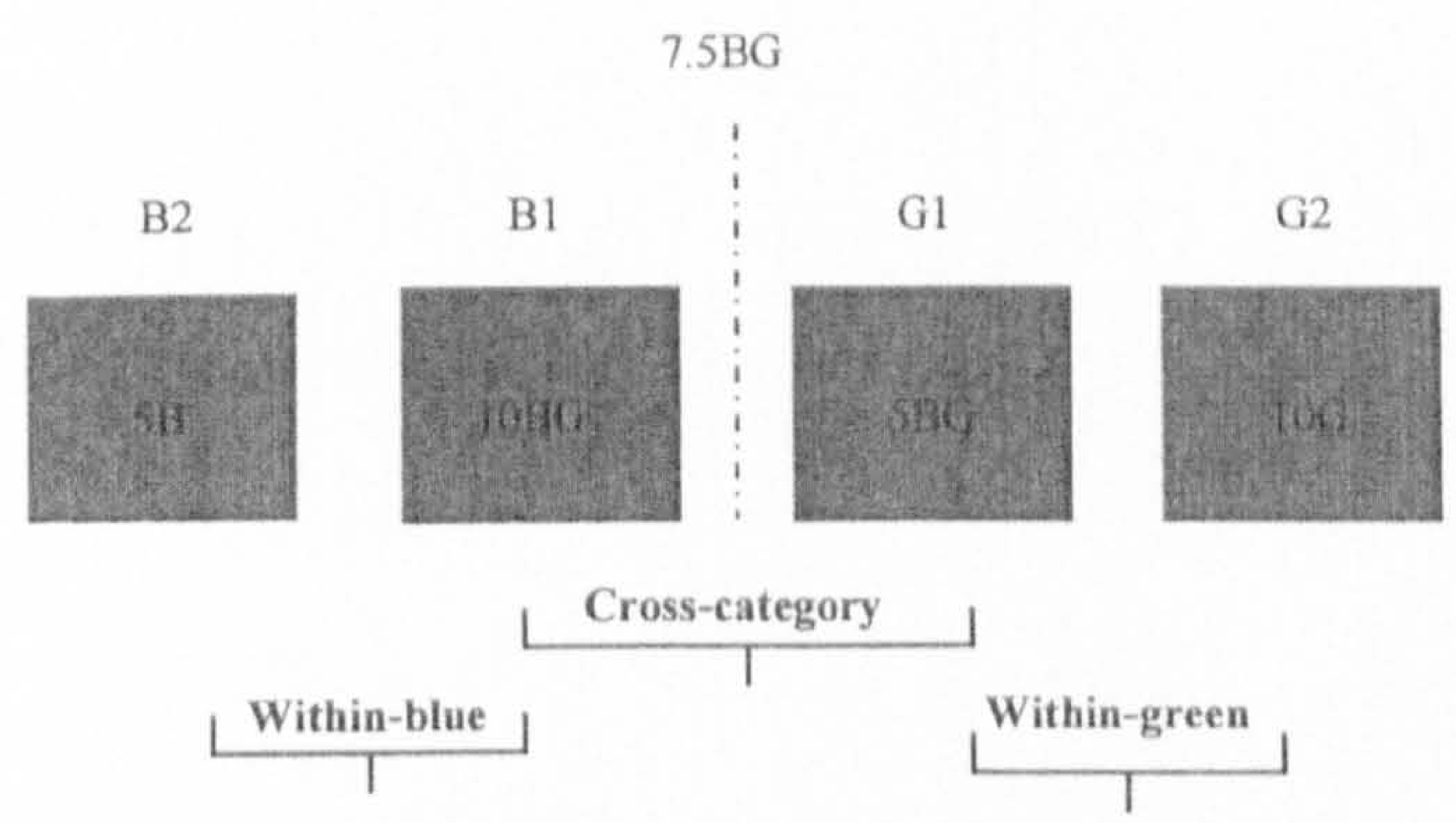


Figure 21. Illustration of the Munsell codes of the four stimuli used. B2 and B1 are blue and G1 and G2 are green. Adjacent colours are 5 hue steps apart. The line between B1 and G1 indicates the English blue-green boundary.

3.6.2.3 Procedure

The target was a circle of 3 cm diameter (visual angle = 3.22°) that appeared on a differently coloured background (40 × 30 cm) at one of twelve locations around a central fixation point, with half of to the right of fixation and half to the left of fixation (see Figure 22). There were three target-background pairs: two within-category (blue1-blue2 and green1-green2) and one between category (blue1-green1). Within each pair, half the time, one was the target and the other the background, and on the other half of the trials, the relationship was reversed. There were 192 trials in total, half target present and half target absent. The 96 target present trials consisted of 24 trials for each of the combinations of visual field (LVF RVF) and category (within- between-). Trial order was randomised subject to the above constraints.

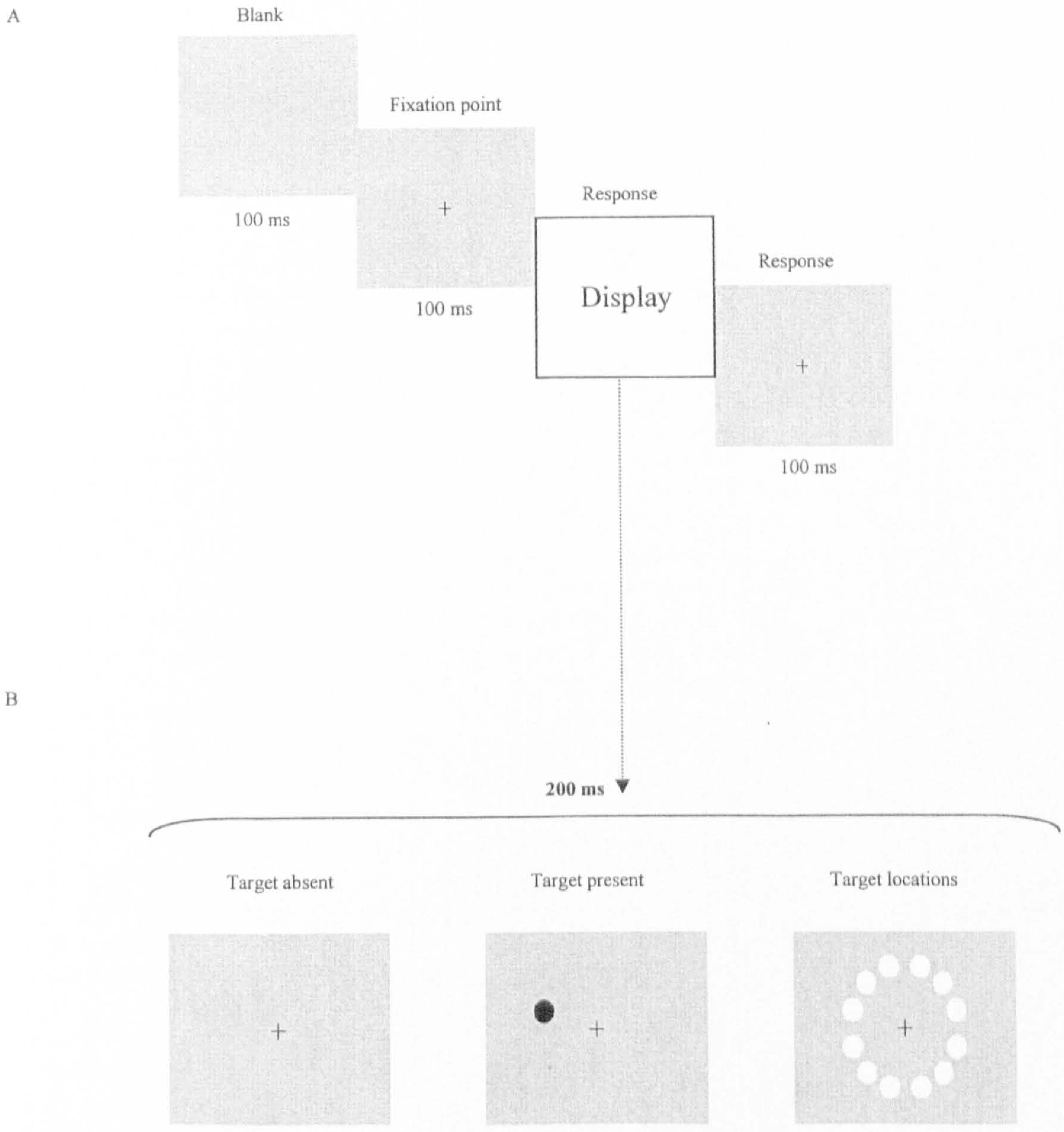


Figure 22. (a) Example display of the target detection task. (b) First left indicates the display when the target absent, display in the middle indicates the target present and first right showed 12 white circles indicates the place that the target could appear.

The experiment was conducted in a dark room. Participants viewed the display at a distance of 60 cm, and their head was restrained by using a chin rest. They were instructed that on approximately half the trials there would be a coloured target on a coloured background. On the remaining trials, there would be no target. When there was a target, it could occur, at random, in any one of 12 locations arranged on a notional circle around the fixation cross. Their task was to decide on each trial whether the target was present or absent and to respond by pressing the left or right mouse button, as appropriate. For half the subjects, the left button indicated target present and for the other half, the right button indicated target present.

3.6.3 Results

As the main interest is in lateralised CP, I only report the analysis of target present trials; the within-between category and the visual field variables only apply to target present trials.

Overall, there were only 2.3% errors; too small a rate to be usefully analysed. For each participant, the median RT for correct trials, for each combination of visual field and category was calculated. Figure 23 shows the mean RT across participants for each combination of category (within/cross) and visual field (left/right). A repeated-measures two-way ANOVA showed that between-category (mean (SD) = 558 (65.13) ms) was about 21 ms faster than within-category (mean (SD) = 579 (73.71) ms; $F(1.23) = 27.83$, $p < 0.001$).

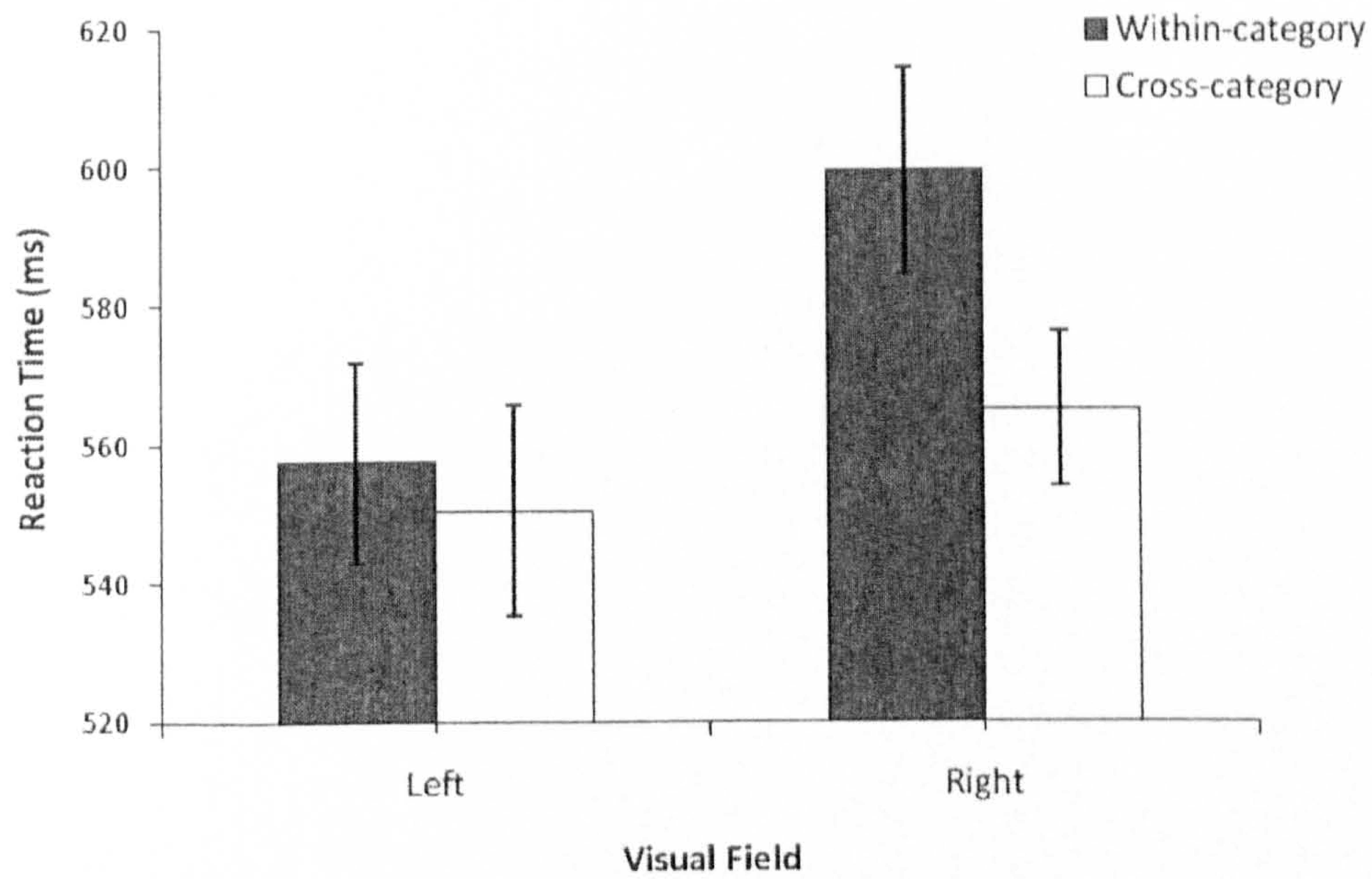


Figure 23. Median response times (ms +/-1se) for correct trials for detecting of chromatic target on colour background. The data were averaged over each combination of category (within/across) and visual fields (LVF/RVF).

RVF RTs (mean (SD) = 582 (65.58) ms) were about 28 ms slower than LVF RTs (mean (SD) = 554 (72.0); $F(1,23) = 27.83$, $p < 0.001$). And, crucially, there was also an interaction between Category and Visual Field ($F(1, 23) = 4.72$, $p < 0.05$). From Figure 24, it appears that the interaction probably reflects a category effect in the RVF while there is probably no LVF category effect. Paired sample *t*-tests supported this impression: RVF, $t(25) = 3.85$, $p < 0.001$; LVF, $t(25) = 0.82$, $p = 0.42$. Additionally, the main reason for the difference in the CP in the two visual fields seems to be due to the particularly high LVF RTs: there was no significant visual field effect for between-category, ($t(25) = 1.63$, $p = 0.12$) whereas there was for within-category ($t(25) = 5.62$, $p < 0.001$).

3.6.4 Discussion

The resuls mirrored the finding of previous experiments where discrimination of pairs of colour from different lexical categories (blue and green) was faster than pairs from the same lexical category (different shades of blue), particularly when the two colours were presented to the RVF (LH).

The aim of the experiment was to replicate the original finding of LH lateralised colour CP using a task that varied in design and instructions to the tasks used in previous research. Participants were asked to decide if there was a target on a different coloured background, without taking into account the target location, when there was a target on just half of the trials. Response times showed the size of the category effect was significantly larger for the RVF than for the LVF suggesting that LH bias for CP still occurs when no explicit spatial decision is required. This result provides converging evidence that colour CP is lateralised to the RVF (LH).

3.7 General Discussion of the chapter

The overall aim of the experiments presented in this chapter was to assess whether previous findings of LH lateralised colour CP are independent of reading direction, the number of distractors and the nature of the target-decision. In brief, the 'robustness' of the effect. The previous studies that found LH colour CP (e.g., Gilbert et al. 2006; Drivonikou et al. 2007; Franklin et al. 2007; Roberson et al. 2008 and 2008; Siok et al., 2009; and Liu et al., 2009) have all tested participants who read left-to-right scripts (or top to bottom scripts), but participants who read from right-to-left had not been tested. Reading direction affects the pattern of lateralisation on a range of perceptual tasks (Eviatar, 1995 and 1997; Farid, and Grainger 1996; Prunet et al. 2000; Berent 2002; Eviatar, 1995, 1997; Schwalm, 2003), so it was plausible that reading direction could affect the lateralisation of colour CP. This hypothesis was tested by testing the lateralisation of blue-green colour CP in Arabic participants. First, Experiment 3 identified the location of the Arabic blue-green category boundary. The findings suggested that the blue-green category boundary for an Arabic speaker is around 7.5BG – corresponding to the English blue-green category boundary reported by Bornstein and Monroe (1980). Then the lateralisation of colour CP then was investigated in experiments 4 and 5 for English and Arabic speakers – two groups of participants who differ in their reading direction. Experiment 4 used a visual search task with an RT measure whilst Experiment 5 used a target detection task with an initiation time eye-movement measure. It was found that both groups had colour CP that was stronger in the LH than the RH. This confirms the robust nature of the lateralisation of colour CP to the LH.

Lateralised colour CP was also tested in Experiments 6 and 7 using two types of task that were different to the tasks used in previous research (e. g., Gilbert et al 2006; Drivonikou et al. 2007; Franklin et al. 2007 and 2008; Roberson et al 2008 and Siok et al., 2009). This allowed a further check on the robustness of the LH category bias. There was a significant LH bias in colour CP on a present/absent target detection task. However, on a visual search task where stimuli were shown in a grid array with a varying number of distractors, there was only a trend for a LH bias. This may suggest that some tasks are better than others at eliciting LH colour CP bias. However, the overall impression from this set of experiments is that LH colour CP is a robust effect that generalises across participants with different reading directions and across different types of visual search and target detection tasks.

In summary, the present results of this chapter revealed LH lateralisation of colour CP. The LH bias in colour CP appears not to be affected by reading direction and the effect is found (or there is a trend for the bias) on a range of different visual search and target detection tasks.

Chapter four

Cultural Variation in Biological Components of Sex Differences in Hue Preference

4.1 Introduction

Chapter 2 investigated colour language in Arabic. Chapter 3 investigated whether Arabic colour categories affect colour discrimination in the LH to the same extent as English colour categories, whilst also presenting evidence that the LH colour CP generalises across other tasks. This chapter investigates whether there is a difference between Arabic and English participants in another aspect of colour perception by investigating cross-cultural variation in colour preference. The influence of both culture and sex on colour preference is considered. The key questions asked were the extent to which Arabic and English colour preference differs and the extent to which sex differences in English colour preference are also found for Arabic speakers. These questions address debates about whether culture and gender influence colour preference or whether colour preference is in part driven by biological processes.

4.1.1 Origin and Nature of colour preference

Walton, Guilford, and Guilford (1933) investigated colour preference among 1279 university students. Eighteen colours were used in the study with a parried comparisons method. Results showed significant differences between males and females in colour preference. Males had a preference for yellow to orange colours, while females showed a different pattern, their preference peak appears was in the purple region. There was great agreement for each sex in their response and this was interpreted as providing evidence for a universal biologically driven order of colour preference. An evolutionary and universal pattern has also been suggested by Guildford and Smith (1959) who tested 20 males and 20 females. Participants were asked to judge the pleasantness of 316 Munsell colours using a 10 point rating scale. Considerable consistency was found in the participants' answers with preference highest in the green to blue region and lowest in the region of yellow and yellow-green. Eysenck (1941), also claimed that there was a stable universal order of colour preference.s. He tested 42 university students who were asked to rank 10 colours (6 fully saturated 3 tints and shades) in order of preference. There was high agreement in the order of preference, and the average ranking in order of preference was: blue, red, green, purple, orange and yellow. The existence of a general order of preference or a universal pattern in hue preference has been also been supported by other studies (Garth, 1922; George, 1938; Granger, 1955; Helson, and Lansford, 1970; Ou, Luo, Woodcock and Wright, 2003; Hulbert & Ling, 2007).

4.1.2 Gender Differences in Colour Preference

The debate about whether gender plays a role in hue preference has raged since as long ago as 1800 (Chandler, 1934). Eysenck (1941) found gender differences only for orange and yellow, while Granger (1955) concluded from his controlled ranking study of more than 400 Munsell colours covering the entire colour solid, that there was no evidence of any marked difference between the preference ranking of men and women. A child hue preference study by Zentner (2001) tested 127 Swiss preschool children (mean age = 54 months) with nine colour patches (black, light blue, dark blue, brown, light green, dark green, pink, red and yellow), and children handed the experimenter the colours in order of their preference. Results showed no significant effect of gender on colour preference. Also, studies by Child, Hansen and Hornbeck (1968), Camgoz, Yener and Guvenc (2002), Ou et al. (2004), and Rosenbloom (2006) have shown no significant gender difference in hue preference

On the other hand, other studies report substantial gender differences, and have shown that males and females differ when it comes to their favourite colours. An early major finding was that females showed a greater preference for warm colours than males and males showed a greater preference for cool colours than females (Helson and Lansford's, 1970). McManus, Jones and Cottrell (1981) have also concluded from a controlled paired comparison task, that males and females differ significantly in their hue preference, as females showed a greater preference for red and less preference for yellow compared to males. Further evidence comes from a developmental study by Burkitt, Barrett and Davies

(2003) who tested the colour preference of 330 UK children, aged between 4-11 years old. Children were asked to point to their preferred colour from a set of 10 colours (black, blue, brown, green, orange, pink, purple, red, white, and yellow), and continued pointing until all colours were chosen. It was found that girls significantly preferred pink, purple, and red more than boys. In contrast boys showed a greater preference than girls for black, blue, brown, green, and white. More recent work by Ling and Hurlbert (2007), tested 94 males and females from China and England, aged between 20-26, and they were asked as quickly as possible to choose their preferred colour from each of a series of paired coloured rectangles. The findings from this study showed that females prefer reddish hues and dislike greenish-yellowish hues significantly more than males. These sex differences in hue preference could be due to culture (Langenbeck, 1913). For example, Paoletti (1983, 1987, and 1997) documented that sex difference in colour preference is culturally influenced and noted that general acceptance of pink for girls and blue for boys was inverted since 1920 in the North American culture. Cultural colour stereotypes which influence colour preference are found in Eichstedt's (1997) study where the awareness of gender incongruity led 24 months old to look longer at a pink hue than blue hue when it was preceded by a male than a female voice. Sex differences in colour preference could also be due to biological factors (Humphrey, 1976) or due to sex differences in the evolution of colour vision (e.g., Hurlbert & Ling, 2007). This issue is returned to later on.

4.1.3 Cultural differences in colour preference

Colours have different meanings in different cultures. For instant, red symbolises good luck in China, Denmark and Argentina, while it means bad luck in Germany, Nigeria and Chad (Schmitt, 1995; Neal, Quester & Hawkins, 2002). White is a colour of happiness and purity in the USA, Australia and New Zealand, but symbolises death in East Asia (Ricks, 1983; Neal et al, 2002). Green represents envy in the USA and Belgium, while in Malaysia it represents danger or disease (Ricks, 1983; Hupka, Zaleski, Otto, Reidl & Tarabrina, 1997). This variation in the symbolism of colour could lead to variation on colour preference between cultures. Choungourian, (1969) compared 148 American and Lebanese children age between 5 and 10 using 8 coloured stimuli (red, orange, yellow, yellow-green,

green, turquoise, blue and purple) and the 8 colours were paired against each other. Colour preference varied between the two samples, American children showed a significant preference for red and lack of preference for green, whereas Lebanese children showed preference for blue and lack of preference for green, and their (top and bottom of preference did not differ significantly from each other.

A previous comparative adult study by Choungourian, (1968) which compared 160 male and female American, Lebanese, Iranian and Kuwaiti university students, also found cultural variation in colour preference. By using the same stimuli and method, results showed variation in the over-all order of colour preference across the four cultures. Saito (1994) compared Japanese, Korean and Taipei samples. Participants were asked to select from a colour chart the three colours they preferred most and the three they disliked the mostand, to give their reasons for their choices. Results of these studies showed that although a high preference for white was common to all three samples, each sample had a specific preference for colours not shown by the others. Saito (1996) also expanded their study using the same stimuli and procedure but testing 175 Japanese, 158 Chinese and 157 Indonesian participants. The finding of this study confirmed the conclusion of the previous study that culture influenced colour preference. More recently, Ling, Hurlbert & Robinson (2006) and Hurlbert and Ling (2007) reported that cultural factors played a role in differences in the colour preference of English and Chinese participants. The Chinese sample had a stronger preference for reddish hues than the English sample, and it was argued that this variation is due to a red symbolising good luck in the Chinese culture.

4.1.4 Developmental studies in colour preference

Studies on the development of colour preference have revealed that hue preferences develop and shift through the phases of development from early childhood to adulthood. Several researchers have indicated a tendency to move from warm to cool colours with increasing age. Beebe-center (1932) tested 3-15-year-olds on their colour preference. Results showed that preference for warm over cool colours disappeared gradually with increasing age. In a related study of age differences in colour preference, Child et al.

(1968) tested more than 1100 students drawn from primary and high school. Participants were shown 35 pairs of colours and were asked to indicate the colour they liked the most from each pair. Their results also showed a shift in preference from warm toward cool colours with development. This has also been found in subsequent studies (Ward, Holden & Boss, 1900; Bjersted, 1960; Burnham, Hanes, & Bartleson, 1963; Milne & Greenway, 1999; Zentner, 2001; Beke, Kutas, Kwak, Young Sung, Park, & Bodrogi, 2008). Preference for particular colours has also been shown to change with age. For instance, red was the favourite colour in children under 3 years old whereas in older children there was a change in preference towards blue over red (Ward, Holden & Bosse, 1900). Ward et al. (1900) tested 200 children between the age 6 months and 13 years. Children below 3 years selected red first and blue last, but by four years the order of selection was reversed and blue was chosen first and red last. In another study, Staples (1932) found that red was the favourite colour for 2 year olds, then at school age there was a shift in preference to blue. Similar results were found in other studies (Sharp, 1974; Katz & Breed, 1922; and Choungourian, 1968).

Even infants appear to have 'preferences' for certain colours. Infants, when shown pairs of colours, will look significantly longer at some hues than other hues. For example, Bornstein (1975) found that 4-month olds looked longer at blue and red than green and yellow (see also Zemach, Chang & Teller, 2007). Franklin, Pitchford, Clausse, Mahony and Davies (2008) found that infants looked longest at red and least at brown out of the focal colours for the 8 basic colour categories. Franklin, Bevis, Ling and Hurlbert, (2009) tested 39 4-5 months old and found infants looked longer at hues that were redder then the background and less at hues that were greener than the background. Looking longer at a colour does not necessarily indicate an affective state – that infants like the colour more. However, these studies of infant colour 'preference' do indicate that perceptual biases to different colours occur at a very early age.

4.1.5 Biological Components in Colour Preference

Inspection of previous studies of colour preference reveals that many of these studies (but not all) have poor control over the colours that are shown – the chromatic co-ordinates of colours are either not noted or the illuminant that colours are shown under is not controlled. This means that conclusions about colour preference are made using subjective terms for hue with little knowledge about the precise colours that were shown. Differences in order of preference from study to study therefore may be explained by differences in the colours shown (for example, the rank order of preference may change for hues of different saturation or lightness).

However, recently, a new quantitative approach to investigating colour preference has been proposed, where there is no need to summarise colour preference using subjective terms for hue (Ling et al., 2007; Hurlbert & Ling, 2007). This approach aims to quantitatively summarise hue preference in terms of weights on the two channels or 'cardinal axes' underlying colour vision, and to map hue preference onto these biologically meaningful constructs (Derrington, Krauskopf & Lennie, 1984).

Human vision is trichromatic, meaning that the human eye has three types of colour sensitive receptors, the short wavelength-sensitive bluish (S) cone, the middle wavelength-sensitive greenish (M) cone and the long wavelength-sensitive reddish (L) cone. The two cone-opponent channels underlying colour vision are formed by differential activation of the three wavelength-sensitive cones: the L-M red-green channel results from comparison of L and M wavelength-sensitive cone signals, and the S-(L+M) blue-yellow channel results from cooperation of S wavelength-sensitive cone signal and the combined L- & M-wavelength-sensitive cone signals. Ling et al. (2007) and Hurlbert and Ling (2007) summarise preference in terms of weights on these channels.

In their studies they tested samples of Chinese and British aged between 20-26 on their colour preference task using 8 hues at various levels of saturation and lightness. The participants' task was to choose as quickly as possible their preferred colour from a series of paired, coloured rectangles shown on a computer monitor. The percentage of times a given hue was chosen as the preferred one was recorded and used to form preference curves across the hue spectrum.

A Principal Components Analysis on these preference curves revealed two components that had close resemblance to how the stimuli varied in L-M and S-(L+M) stimulus-background cone-contrast. Regression analysis was also used to determine what percentage of the variation in preference curve could be accounted for by variation in stimulus-background cone-contrast. A large percentage of the variance in preference could be explained by cone-contrast: 22.5% for L-M and 44.5% for S-(L+M). It was found that Chinese and English male and female preference curves weighted these two types of cone-contrast differently.

Chinese and English males and females weighted S-(L+M) positively, indicating a bias towards hues bluer than the background. For English participants, females weighted S-(L+M) more strongly than males, but there was no sex difference for Chinese participants. In terms of the L-M weight, males in both samples weighted it negatively, indicating a bias for hues greener than the background. For females, both samples weighted L-M cone-contrast positively showing a bias for hues redder than the background.

Both Chinese and English samples showed a sex difference in how preference curves mapped onto L-M cone-contrast. They (Hurlbert and Ling) argued that this sex difference in how L-M cone-contrast was weighted might be invariant across cultures and that it could be explained by an evolutionary model of colour vision, linked to hunter-gatherer theory (Silverman and Eals, 1992). It was conjectured that as part of differentiation of gender-roles, females foraged for ripe, red fruit, and a survival advantage was conferred by increased sensitivity to red. In association with this, preference for red may also have been enhanced more than in males. However, in addition to this claimed 'universal' sex difference, they also emphasised the potential for cultural influence on colour preference as there were also cultural differences in the preference curves of the two groups. For example, the groups differed in whether there was a sex difference in the weighting of S-(L+M) cone-contrast. In addition, the preference curves for the Chinese sample were shifted more towards reddish hues than in the English sample, which was argued could be due to the symbolism that red has in Chinese culture.

4.1.6 Aims of the study

The main aim of this study was to extend Ling et al. (2007) and Hulbert and Ling's (2007) work, by replicating their study with Arabic participants. One aim was to investigate whether the sex difference in the weighting of the L-M channel found for English and Chinese samples would also be found in a Saudi Arabian Arab sample. If so, this would be support for sex difference in the weighting of this biological component being universal and possibly linked to evolutionary processes. In addition, the study aimed to see to what extent S-(L+M) cone-contrast is weighted similarly by an Arab as by an English sample. The study aimed to contribute to the debate about how colour preference is constrained, whilst also testing whether differential weighting of the cardinal axes of colour vision could explain variation in colour preference for cultures other than English and Chinese.

4.2 Method

4.2.1 Participants

Seventy one native Arabic-speaking undergraduates from King Saud University in Riyadh and 38 native English-speaking undergraduates from Surrey University participated in this experiment. All their ages ranged from 18 to 29 years. For the Arabic sample, there were 32 males with a mean age of 21.35 years (SD = 1.47), and 36 females with a mean age of 20.28 years (SD = .54). For the English sample, there were 17 males with a mean age of 21.35 years (SD = 3.32), and 31 females with a mean age of 19.32 years (SD = 2.06). All participants had normal red-green colour vision as assessed by Ishihara's Tests for Colour Vision Deficiency (Ishihara, 1987). Most of the participants participated for course credit and a few volunteered. No participant was aware of the predictions of the experiment at the time of testing.

4.2.2 Stimuli and apparatus

As in Ling and Hurlbert (2007), there were eight stimuli that varied only in hue angle (saturation = 0.5 and lightness = 80 in CIE Lu'v' HSL space). Table 6 shows the coordinates in CIE (1931) Y,x,y space for the eight stimuli, and Figures 24 and 25 show the variation in S-(L+M) and L-M cone-opponent contrast against the uniform grey background (Y = 50 cd/m², x = 0.321, y = 0.337).

The L, M and S cone excitation values are calculated using the Smith-Pokorny cone fundamentals[2] (Smith and Pokorny, 1975). The L-cone contrast value, ΔL, is computed as $(L_s-L_b)/L_b$, the M-cone contrast ΔM, is computed as $(M_s-M_b)/M_b$ and $\Delta S=(S_s-S_b)/S_b$, where the subscript 's' denotes the stimulus, and 'b' the background colour. The LM components cone contrast LM_c is therefore computed as $LM_c = 0.7*\Delta L-0.72\Delta M+0.02*\Delta S$, and the S component cone contrast S_c equal to $0.8\Delta S-0.55\Delta L-0.25\Delta M$ (Eskew, McLellan and Guilianini, 1999). A Cambridge Research Instruments ColorCal was used to obtain CIE co-ordinates. The colour stimuli were displayed on a calibrated 17 inch CRT Sony Trinitron monitor.

Table 6. CIE (1931), Y,x,y co-ordinates of the eight stimuli and the hue angle and the Hue Labels for all the stimuli: *Y* 'yellow-red', *R* 'red' *RP* 'red-pink', *P* 'pink', *BG* 'blue-green', *G* 'green', *GY* 'green-yellow'. Stimuli were constant saturation (S = 0.5) and constant lightness (L = 80).

Stimulus	Y	x	y	Hue angle	Hue Label
1	28.29	0.376	0.342	1.29	YR
2	28.28	0.362	0.316	1.69	R
3	28.32	0.346	0.299	2.03	RP
4	28.29	0.295	0.278	3.01	P
5	28.32	0.264	0.332	4.42	BG
6	28.32	0.274	0.360	4.84	G
7	28.29	0.291	0.382	5.17	G
8	28.32	0.353	0.410	6.15	GY

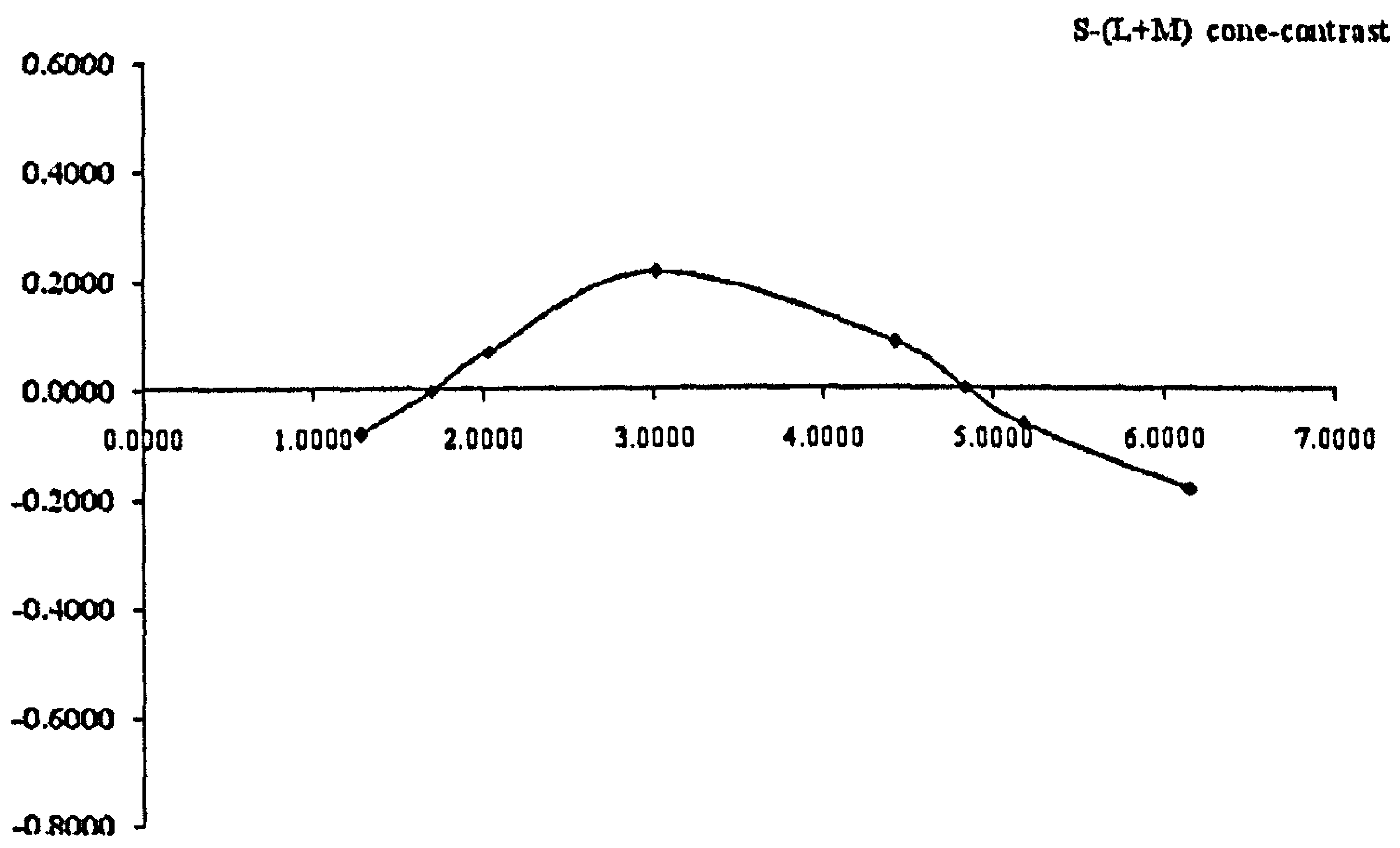


Figure 24. S-(L+M) Cone-contrast between the uniform gray background and each of the eight stimuli as a function of hue angle (Radians).

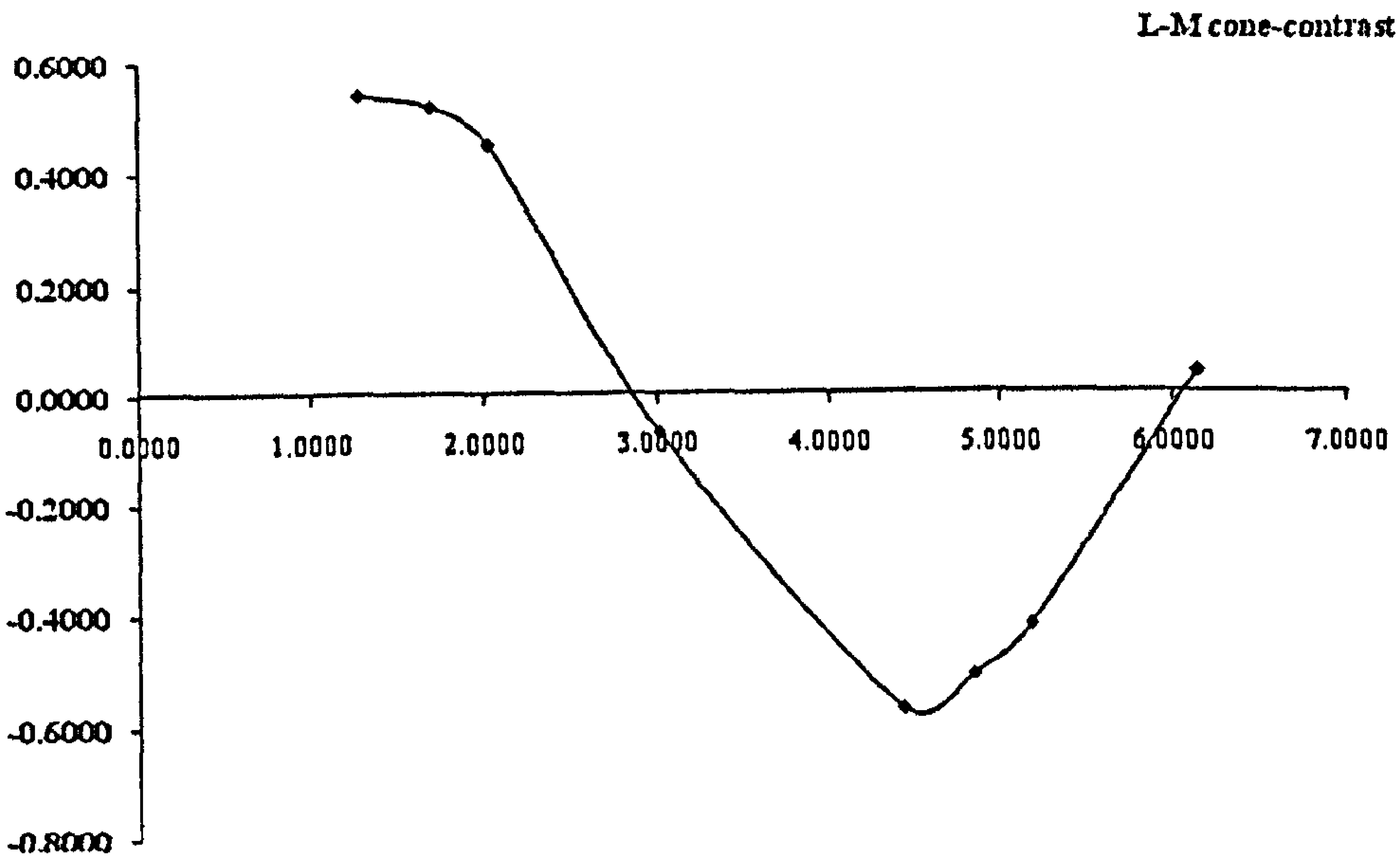


Figure 25. L-M Cone-contrast to the uniform gray background for the eight stimuli as a function of hue angle (Radians).

4.2.3 Design

The stimuli were presented as pairs of rectangular patches (3 cm × 2 cm) above and below central fixation (4 cm between the two patches) on the grey background. Each possible pair was shown twice, in random order, with the position of each colour reversed on the second occurrence.

4.2.4 Procedure

The experiment was conducted in a dark room. Participants were seated at a distance of 57 cm from the monitor, at eye-level to the centre of the monitor, with head restrained using a chin rest. Participants were instructed to move the cursor as quickly as possible to select their preferred colour in each pair. The next pair appeared immediately after each response until the end of task. Participants were told that, there was no time limit for their responding, and not to think about possible uses of the colour.

4.3 Results

The number of times each hue chosen as the preferred colour across all the 56 trials was calculated for each participants and the mean across participants percentage preference scores for each colour are shown in Figure 26 which gives the hue preference curves for the Arabic and English samples. It can be seen that there appear to be differences in the preference curves for Arabic and English samples. For the Arabic sample, the preference peak is in the red-pink region, with a preference minimum in the green-yellow region. For the English sample, peak preference is in the purple/blue-green region, with a preference minimum in the yellow-red region. The preference peak differs across the two samples, but the samples share a dislike of yellowish colours.

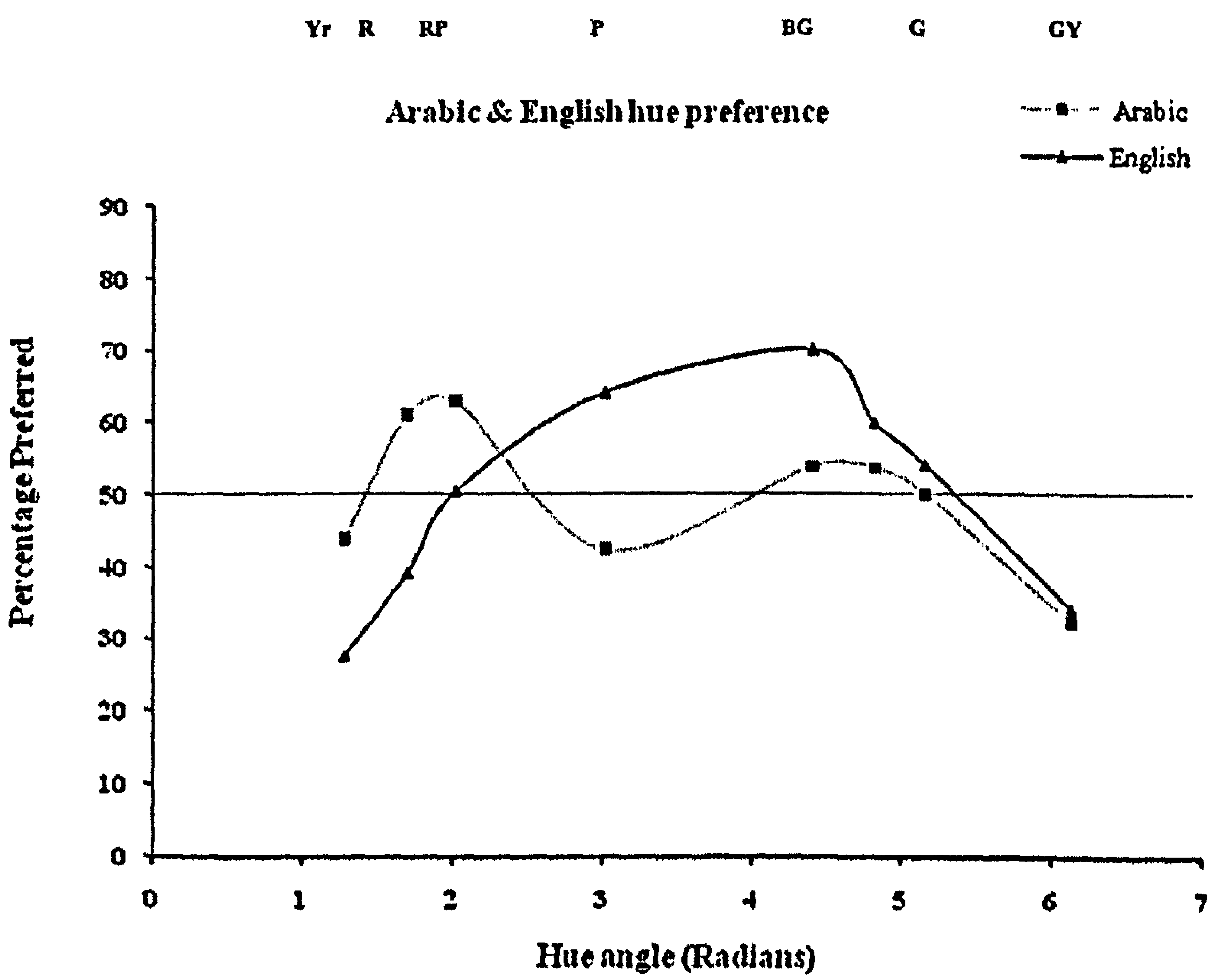


Figure 26. The hue preference curve (% preferred for each stimulus) for Arabic and English samples. The Munsell hue labels for the stimulus range are given. The dashed line at 50% indicates no preference.

Figures 27 and 28 illustrate the hue preference curves by plotting the percentage preferred, for the 8 stimuli for males vs. females for each of the Arabic and English samples.

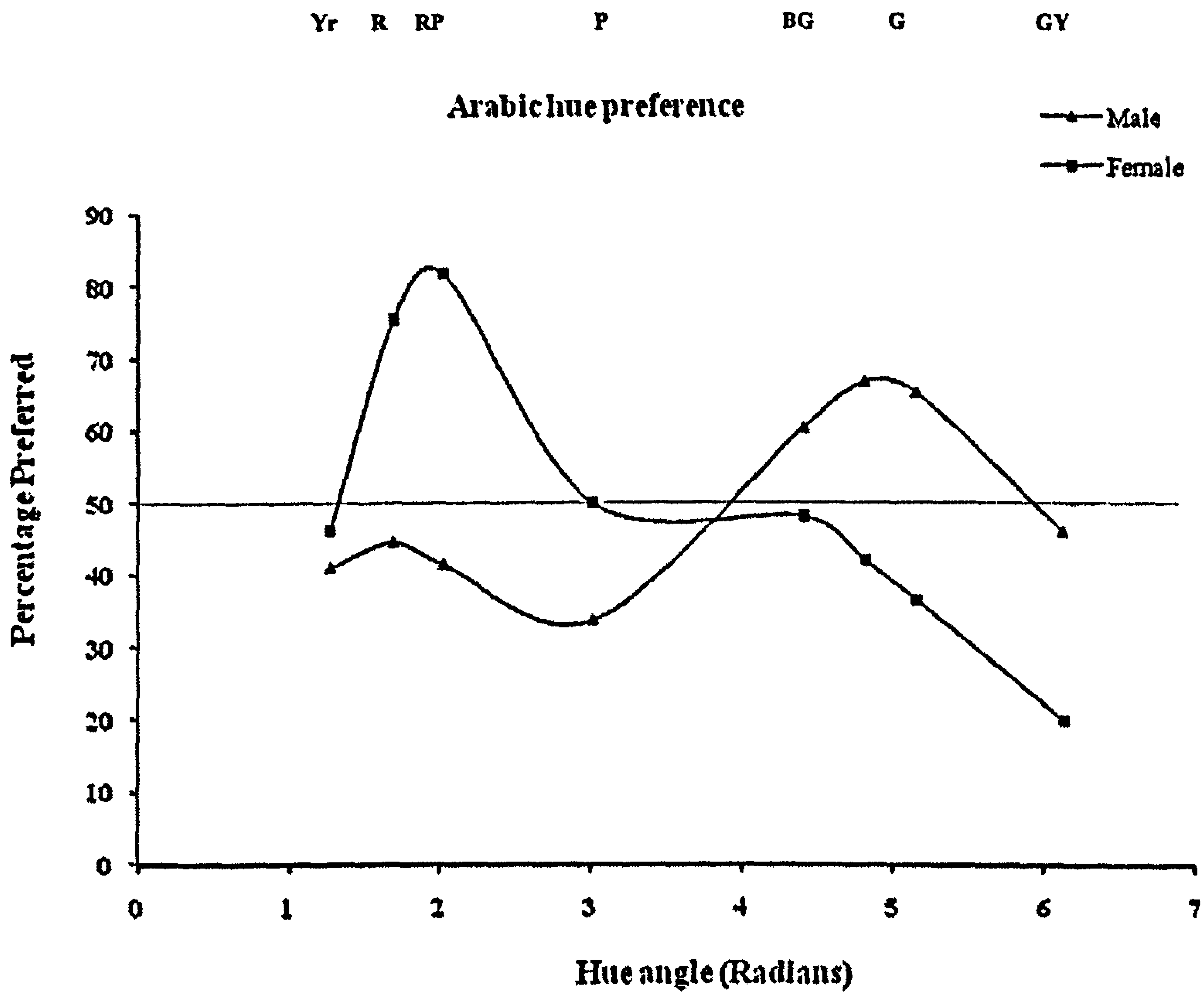


Figure 27. The hue preference curve (% preferred for each stimulus) for males and females, for the Arabic sample. The Munsell hue labels for the stimulus range are given. The dashed line at 50% indicates no preference.

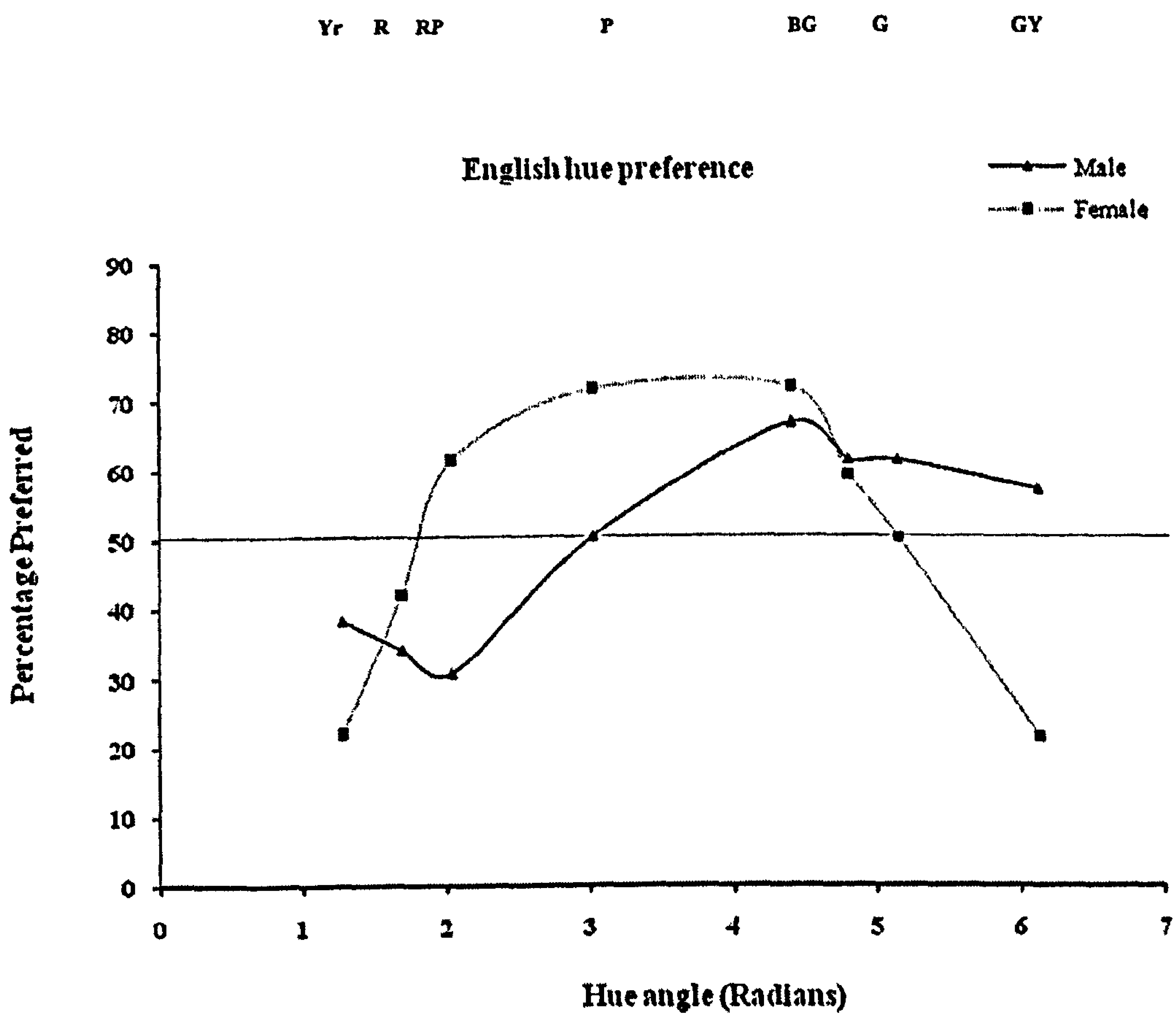


Figure 28. The hue preference curve (% preferred for each stimulus) for males and females, for the English sample. The Munsell hue labels for the stimulus range are given. The dashed line at 50% indicates no preference.

Figure 27 gives male and female preference curves for the Arabic sample while figure 28 gives male and female preference curves for the English sample. From these Figures, it can be seen that there appear to be sex differences in colour preference for both groups. The male curve is fairly similar for both samples: peak-preference is in the blue-green region, and a preference minimum is in the red-pink/purple region. For Arabic females the preference peak appears to be in the red-pink region, whilst for English females it is shifted towards purple/blue-green. Both Arabic and English females however appear to dislike the green-yellow hue.

The variance of each participant's preference curve was calculated. This represents how strong the variation in preference there is across the hues tested – smaller numbers indicate less variation in preference across the spectrum than larger numbers. Figure 29 gives the variance in preference across the spectrum for males and females, for Arabic and English samples.

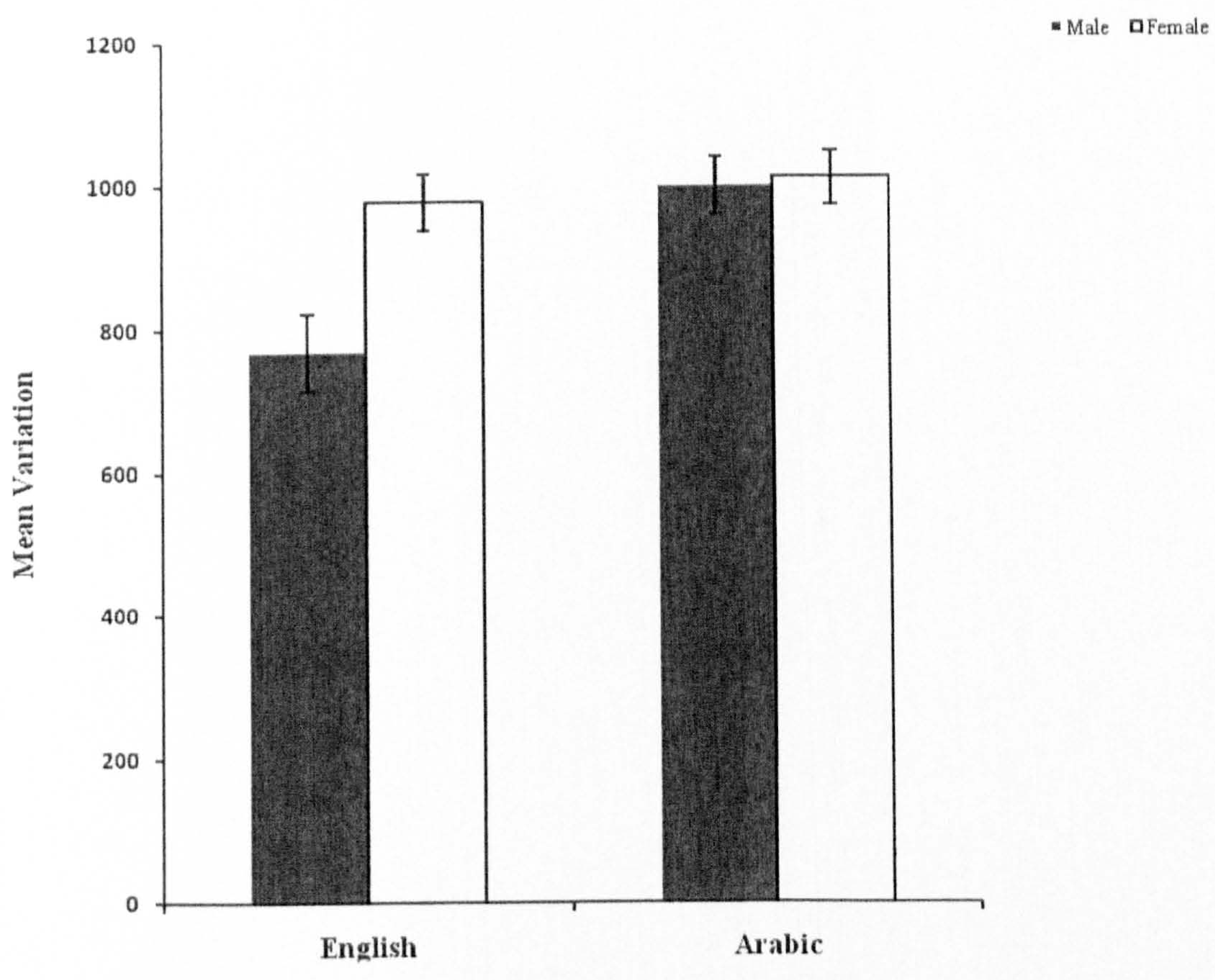


Figure 29. Mean variation (+/-1se) for males and females of Arabic and English samples.

A two-way analysis of variance (ANOVA) with the independent group factors of Gender (Male/female) and Culture (Arabic/English) was conducted on the variance scores to investigate differences in how much variation there is in preference across the spectrum for the different sub-groups. There was a significant difference in the amount of variation in the preference curve of Arabic (mean = 1004.54, SD = 264.91) and English (mean = 903.46, SD = 286.76) samples, $F(1,112) = 9.43$, $MSE=48563$, $p<0.005$. There was also more variation in preference across the spectrum for females (mean = 994.51, SD = 201.30) than males (mean = 919.25, SD = 264.91), $F(1,112) = 6.55$, $MSE=48563$, $p<0.05$. There was also a significant interaction of Culture and Gender, $F(1,112) = 5.35$, $MSE=48563$. The ANOVA was followed by independent *t*-tests (2-tailed) to further investigate the reason for the interaction. For English, there was a significant difference between males and females, $t(24.2) = 2.27$, $p<0.01$, but there was no gender difference for the Arabic sample, $t(66) = 25$, $p=0.81$.

The amount of S-(L-M) and L-M cone-contrast between each hue and the background was calculated. A least squares regression was conducted with S-(L+M) and L-M cone-contrast as predictors, and percentage preference of the 8 stimuli as the variables. Overall, the S-(L-M) cone contrast accounted for 43.22%, the L-M cone contrast accounted for 34.57% of the variance. For the Arabic sample, the S-(L-M) cone contrast accounted for 30.87% and the L-M cone contrast accounting for 31.82% of the variance. For the English sample, the S-(L-M) cone contrast accounted for 39.78% and the L-M cone contrast accounted for 35.43% of the variance.

Figures 30 and 31 give the mean weights to the two cone-opponent channels; S-(L-M) and L-M cone contrast for the male and female from Arabic and English samples. For the S-(L-M) cone contrast, a positive weight indicates a preference for hues bluer than the background, while a negative weight represents a bias for hues yellower than the background. In terms of the L-M cone contrast, a positive weight represents a preference for hues redder than the background, and a negative weight indicates a preference for hues greener than the background.

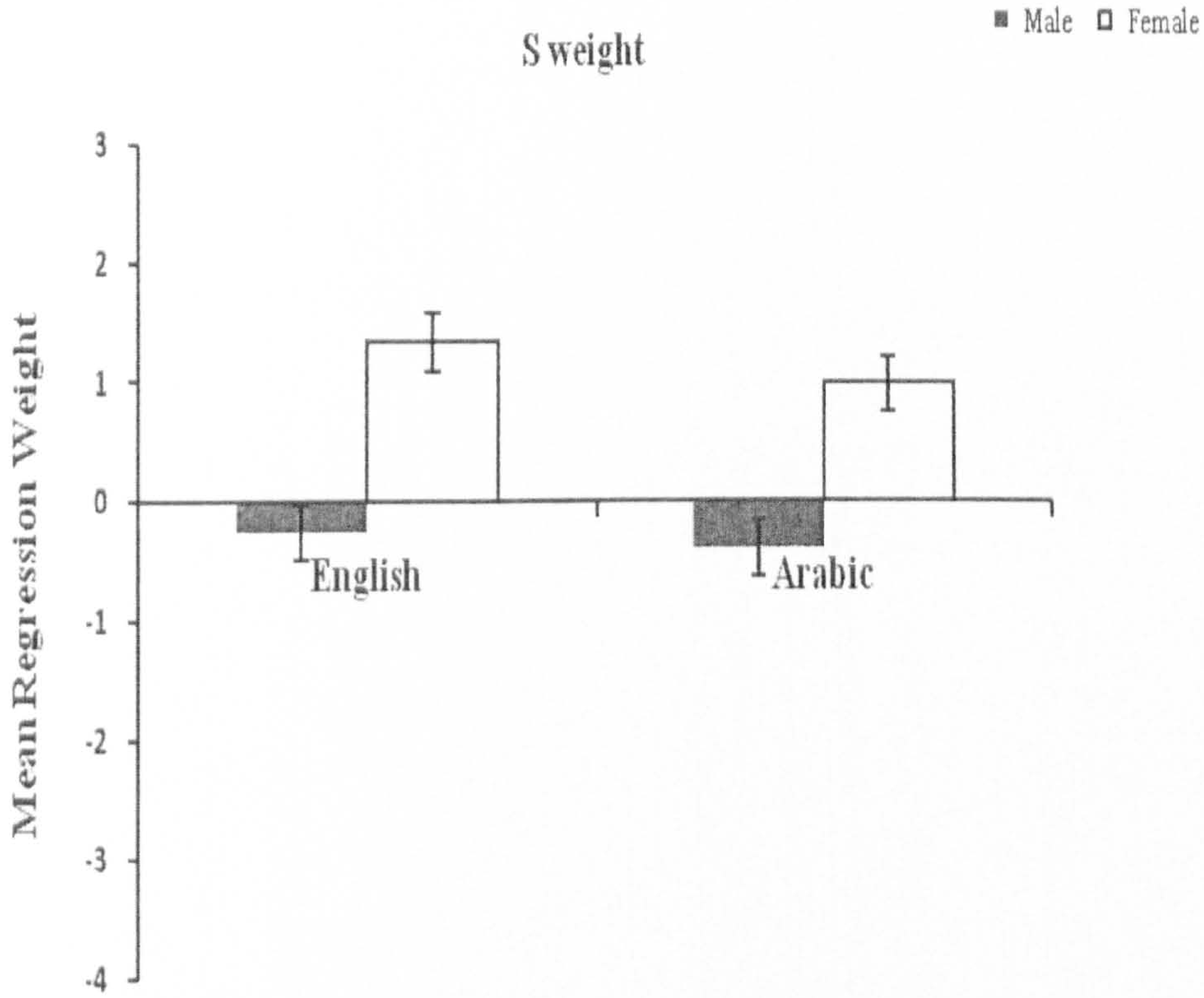


Figure 30. Mean weights on the S-(L+M) cone-contrast, for males and females of Arabic and English samples.

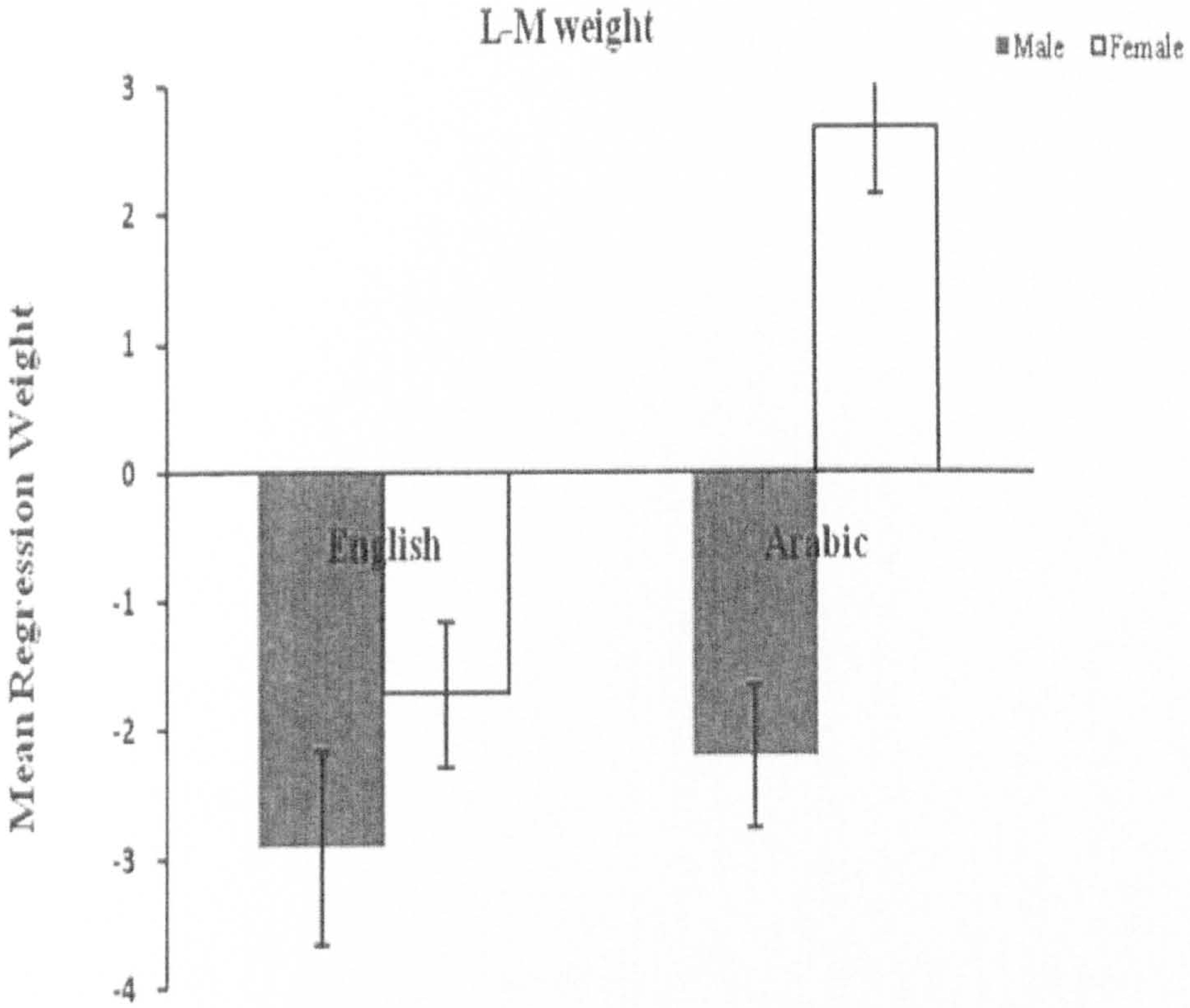


Figure 31. Mean weights on the L-M cone-contrast, for males and females of Arabic and English samples.

As can be seen, both Arabic and English males weight S-(L-M) cone contrast negatively (bias to hues yellower than the background). However, Arabic and English females both weight S-(L-M) cone contrast positively (bias to hues bluer than the background). In terms of the L-M weighting, the males in both groups weight it negatively. This indicates a bias for hues greener than the background, with the average English marginally higher than Arabic. For females, the pattern differs in both Arabic and English samples. The Arabic females weight L-M cone-contrast positively showing a bias for hues redder than the background, while the English females gave a negative weight – the same as the males in both groups.

A two-way analysis of variance (ANOVA) with the factors of Gender (Male/female) and Culture (Arabic/English) was conducted on the weights for S-(L-M) and L-M cone-contrast separately. The results show that for the S-(L-M) cone-contrast weightings, there was no significant difference between Arabic (mean = 0.34, SD = 1.54) and English (mean = 0.78, SD = 1.53), $F(1,112)= 0.85$, $MSE= 1.87$, $p=0.360$. The weight of S-(L-M) cone-contrast was significantly greater for females (mean = 1.15, SD = 1.35) than males (mean = 0.34, SD = 1.38), $F(1,112)= 31.40$, $MSE=1.87$, $p<0.001$. The interaction in Culture and Gender was not significant, $F(1,112)= 0.15$, $MSE=1.87$, $p=0.704$. While for the L-M cone-contrast, there was a significant difference in the weighting of L-M cone-contrast between Arabic (mean = 0.37, SD = 4.12) and English (mean = -2.14, SD = 2.79), $F(1,112)= 17.70$, $MSE= 9.69$, $p<0.001$. The main effect of Gender was also significant: the weight of L-M cone-contrast was greater for females (mean = 0.63, SD = 4.29) than males (mean = -2.45, SD = 3.81), $F(1,112)= 25.24$, $MSE=9.69$, $p<0.001$. There was also a significant interaction of Culture and Gender, $F(1,112)= 9.28$, $MSE=9.69$, $p<0.005$. Independent *t*-test (2-tailed) were conducted to further investigate the interaction of Culture and Gender for the weighting of L-M cone-contrast. For English, there was no gender difference, $t(1.28) = 24.1$, $p=0.21$, but for the Arabic sample, there was a significant difference in how L-M was weighted between males and females $t(5.85) = 51.7$, $p<0.001$.

4.4 Discussion

The main aim of this study was to further extend Ling et al. (2007) and Hurlbert and Ling's (2007) approach to investigating colour preference, by replicating their study but with Arabic participants. The study aimed to answer several questions. First, are there cultural differences in the shape of the overall preference curve for English and Arabic participants? Second, can Arabic colour preference also be summarised in terms of weights on the cone-opponent channels, and are there differences in the weighting of these components? Third, does the sex difference in the weighting of the L-M channel that was previously found for English and Chinese samples extend to an Arabic sample? If so, this would be support for Hurlbert and Ling's claims that the sex difference in the weighting of this biological component is universal and possibly linked to evolutionary processes.

Fourth, is cultural variation across English and Chinese participants, in how S-(L+M) cone-contrast is weighted, also found when English and Arabic are compared? It was hoped that addressing these questions would contribute to debates about how colour preference is constrained, whilst also testing whether a model which summarises colour preference in terms of biological constructs can successfully explain variation in colour preference for cultures other than English and Chinese. Each of these questions is discussed in turn.

4.4.1 Differences in hue preference across the spectrum for English and Arabic

The results indicate that there are differences in hue preference for Arabic and English samples. Collapsing across males and females, the preference curves for the Arabic and English samples have peaks in different locations. For the Arabic sample, preference is highest for the reddish hues, whilst for the English sample, preference is highest for the blue-green region. There are also striking similarities in the preference curves of the two groups. In the green and green-yellow region, the preference ratings are almost identical for Arabic and English, with preference dropping at green-yellow. When males and females are considered separately, it becomes clear that Arabic and English males are more similar in their preference than Arabic and English females. The preference curve for Arabic and English males is highly similar, yet the shape of the curve is dissimilar for Arabic and English females. Arabic females have a strong preference peak for two of the reddish hues – other colours were either at 50% (no preference) or, in the case of greenish hues, were below 50% (an aversion to the colour) on the preference scale. English females on the other hand had a preference curve that had minima at green-yellow and yellow-red, but that gradually peaked in between these hues at purple to blue-green. There therefore appears to be a cultural difference in the colour preference of Arabic and English females.

The Arabic sample overall also had stronger preferences than the English sample as there was more variation in their preference curve than the English sample. The weaker variation in the preference curve for the English sample compared to the Arabic sample, was due to less variation for English males than females. Therefore, English males appear to be less strong in their hue preferences than English females, yet this sex difference is not found for the Arabic sample.

4.4.2 Summarising Arabic colour preference in terms of biological components

One of the aims of the current study was to see whether Arabic colour preference could also be summarised in terms of weights on the cone-opponent channels as for Chinese and English samples in Ling et al. (2007) and Hurlbert and Ling (2007). The amount of S-(L-M) and L-M cone-contrast between each hue and the background was calculated for Arabic and English samples separately. The amount of variance in the preference curve explained by cone-contrast between stimulus and background was similar to the English sample (and to Ling et al. 2007 and Hurlbert & Ling, 2007), suggesting that Arabic colour preference can also be effectively summarised in terms of weights on the cone-opponent channels.

4.4.3 Differences in weighting of biological components

There were both sex differences and cultural differences in how cone-contrast was weighted. We take each of the types of cone-contrast in turn.

4.4.3.1 Weighting of S-(L+M) cone-contrast

There was no significant difference between Arabic and English samples in how S-(L+M) cone-contrast was weighted. For both Arabic and English groups, females weighted S-(L+M) cone-contrast more strongly than males indicating a greater female preference for hues bluer than the background. In the Hurlbert and Ling studies there was also this sex difference in how S-(L+M) cone-contrast was weighted for the English sample, but not for the Chinese sample. The current study therefore replicates the sex difference in the weighting of S-(L+M) cone-contrast for the English sample, and also provides evidence that this extends to Arabic participants also. The lack of this sex difference for the Chinese sample in the previous studies however, prevents any claim about this being a 'universal sex difference.'

4.4.3.2 Weighting of L-M cone-contrast

There was a significant difference between Arabic and English samples in how L-M cone-contrast was weighted. Overall, Arabic participants weighted L-M cone-contrast positively, showing a preference for hues redder than the background. English participants overall weighted L-M cone-contrast negatively, showing a preference for hues greener than the background. There were no sex differences in the weighting of L-M cone-contrast for the English sample. However, for the Arabic sample, there were sex differences in the weighting of this component – females on average weighted it positively, whereas males weighted it negatively.

In the Ling and Hurlbert studies there was a sex difference in the weighting of L-M for both Chinese and English samples, with females in both samples weighting it positively and males in both samples weighting it negatively (the same pattern as Arabic sample in the current study). On the basis of the sex difference for Chinese and English, Ling and Hurlbert argued that there could be a 'universal' sex difference in hue preference where females universally prefer hues that are redder than the background, whilst males show no such preference. It was argued that this 'universal' sex difference could be evolved. For the current study, whilst the sex difference in L-M is found for the Arabic sample, the sex difference for the English sample was not replicated. English females in the current study actually weighted L-M negatively indicating a preference for greener hues than the background. Therefore, the current study indicates that a sex difference in how L-M is weighted for colour preference extends to other cultures, but also appears not to be robust. In light of this, claims for a 'universal' sex difference are not supported and the evolutionary hypothesis of colour preference proposed by Ling and Hurlbert is challenged.

4.4.4 Implications for theories of colour preference

The current study provides evidence for both sex differences and cultural differences in hue preference. As outlined in the introduction, there is a long history of research that has aimed to establish whether colour preference varies across different groups and whether there are any universal patterns of colour preference. Some of the findings of the current study appear similar to previous colour preference studies. For example, McManug et al. (1981) found that females show less preference for yellow than males, and here we also find less preference for yellowish hues for females than males. However, comparisons across colour preference studies that have simply summarised colour preference using the subjective names for colour are difficult to make as colours with the same colour term can vary dramatically. The approach used in the Ling and Hurlbert studies summarises colour preference in terms of how stimulus-background cone-contrast is weighted summarising colour preference quantitatively rather than using subjective colour names. Hurlbert and Ling (2007) and Ling et al (2007) argue that this approach is better as colour preference is identified in terms of biologically meaningful constructs (the cone-opponent mechanisms) whilst also quantifying how well these biological components account for variation in preference. They argue that this method enables comparisons across groups (such as by sex and culture) to be made efficiently with reference to the underlying mechanisms of preference. Here it is shown that their approach can be extended to other cultures and we show that Arabic colour preference can also be identified in terms of the cone-opponent mechanisms and comparisons between Arabic and English can be made by comparing the weights on these mechanisms.

The findings have implications for theories on colour preference. Some have argued that there is a universal order of colour preference (e.g., Eysenck, 1941) and others have argued for universal sex differences in colour preference (e.g., Ling et al., 2007). However, the findings of the current study suggest that colour preference varies with both sex and culture and that sex differences in colour preference also vary culturally. Studies of colour preference need to move away from simply summarising, quantifying and comparing colour preference across cultures, sexes and ages and start to consider the factors that lead to variation. Here we show that colour preference can be identified in terms of the biological components of colour preference. The extent to which colour preferences driven by interactions with the chromatic environment, such as colours being associated with positive or negative objects, also needs to be established. For now, the strongest contribution from the current study to the literature on colour preference, is that Hurlbert and Ling (2007) and Ling et al.'s (2007) suggestion that there are evolutionarily driven universal sex differences in the weighting of L-M for colour preference is not supported.

4.5 Conclusion

The previous experimental chapters considered whether colour language and the effect of colour categories on colour discrimination varies for Arabic and English speakers. The current chapter considered whether there is cultural variation between Arabic and English in colour preference. The study used Ling et al. (2007) and Hurlbert and Ling's (2007) approach which summarises colour preference in terms of weights on the two cone-opponent processes. A substantial amount of variation in colour preference colour be explained for both Arabic and English speakers using this approach. Arabic and English preference curves were found to differ, yet there was greater similarity for Arabic and English males than Arabic and English females. There was also a sex difference that was present for both Arabic and English participants - females weighted S-(L+M) cone-contrast positively, yet males weighted it negatively for both groups. There was also a sex difference that was present only for the Arabic group with Arabic females weighting L-M positively whilst Arabic males weighted it negatively. Support for Ling et al. (2007) and Hurlbert and Ling's (2007) claim for a universal sex difference in the weighting of L-M, meaning that females universally prefer hues redder than the background, was not provided by the findings.

Chapter five

General Discussion

5.1 Summary of aims of research

This thesis reported three sets of investigations into aspects of the 'Psychology of Colour'. These investigations all relate to long standing questions about the origin, nature and interaction of colour language, perception and cognition. The first line of investigation aimed to contribute to the debate about the origin of colour terms by assessing whether Arabic has two basic terms for blue, as suggested by pilot work. The second aimed to contribute to the debate about the relationship between colour language and colour perception by establishing whether hemispheric asymmetries in categorical perception of colour are invariant across tasks, culture and reading direction. The third aimed to contribute to the debate about the origin and nature of colour preferences by assessing whether claimed 'Universal' patterns of colour preference extend to Arab samples. This chapter summarises the findings for each of these investigations, whilst also highlighting the contribution to the debates and identifying the need for further research.

5.2 The basic colour terms of Arabic

The first investigation of this thesis investigated the basic colour terms in Arabic. This allowed a test of Berlin and Kay's theory that there are semantic universals in colour vocabulary (e.g., Berlin & Kay, 1969) and a test of the theory that there is an eighth stage to colour term evolution whereby the language encodes the blue region of colour space with two basic terms. Adult and child Arabic-speaking samples were tested with a list task and a colour naming task. The findings from both samples and both tasks suggest that Arabic has 11 basic colour terms that correspond to Berlin and Kay's eleven universal categories. The findings suggest that *ahmar* 'red', *akhdar* 'green', *asfer*, 'yellow', *azrock* 'blue', *asswed* 'black', *abiyadh* 'white', *banafsagee* 'purple', *boartoogaalee* 'orange', *bonee* 'brown', *wardee* 'pink' and *rassasee*, 'grey" have the strongest claim to basic status. Arabic therefore corresponds perfectly with Berlin and Kay's stage VII of colour term evolution. However, there was no strong evidence to suggest that Arabic had moved to an eighth stage of colour term evolution, as the two blue terms *samawee* 'light blue' and *khuhlie* 'dark blue' were not BCTs. Therefore, the number of BCTs in Arabic is the same as in English, and different to Russian, Turkish and Greek which all have two basic terms for blue (e.g., Davies & Corbett, 1994; Özgen & Davies, 1998; Androulaki et al., 2006).

5.2.1. Implications for the debate

These findings contribute to the theories on the evolution of colour terms by providing further support for Berlin and Kay's hierarchy. The findings also suggest that caution is needed in claiming that languages have two basic terms for blue. Although various languages have two blue terms, such as Italian and Spanish, possibly suggesting an eighth stage in colour term evolution, systematic tests of the way these terms are used, often indicate that they are secondary terms rather than BCTs. The possibility that the secondary terms for blue in Arabic and other languages may eventually become BCTs remains open.

5.2.2. Further research

Further research into Arabic colour terms is warranted. First, the current investigation investigated Arabic colour terms for a sample of educated urban dwellers in Saudi Arabia. It has been suggested that less urbanised samples or other Arabic speaking groups may have fewer BCTs (Borg, 2007). Further research should test other Arabic-speaking samples to establish whether the presence of 11 BCTs in Arabic is general. Moreover, the status of the two secondary blue terms in Arabic should be monitored to see whether their use changes so that they become BCTs. Observing the evolution of BCTs would provide strong support for one of Berlin and Kay's major hypotheses.

5.3 Left hemisphere lateralisation of categorical colour perception

The second investigation in this thesis was into factors affecting the lateralisation of categorical colour perception. Chapter 3 explored the recent finding that colour CP is stronger in the LH than the RH of the adult brain (e.g., Gilbert et al., 2006 a & b; Drivonikou et al., 2007 a & b; Roberson et al., 2008), aiming to establish how universal and robust a LH bias in colour CP is. One aim was to establish whether the LH bias in colour CP was affected by reading direction as the influence of habitual scanning on perception has been shown in several studies (e.g., Eviatar, 1995, 1997; Schwalm et al., 2003; Farid, and Grainger 1996; Prunet et al., 2000; & Berent, 2002). Research on the lateralisation of blue-green colour CP was conducted in Chapter 3 with Arabic-speaking and English-speaking samples. Experiment 3a and 3b aimed to establish the location of the Arabic *azrock* 'blue'- *akhdar*, 'green' category boundary and confirmed that the boundary was at about 7.5BG as for English (Bornstein & Monroe, 1980) Experiments 4 compared Arabic-speaking and English speaking samples using a version of Gilbert et al.'s (2006) search task. Despite the differences in reading direction, both samples showed effectively the same pattern of results. They discriminated pairs of colours from different lexical categories faster than pairs from the same lexical categories (CP). Although, this categorical effect was present in both visual fields, it was significantly stronger in the RVF (LH) than in the LVF (RH). Experiment 5 also investigated the effect of reading direction, but this time used an eye movement latency measure as in Franklin et al. (2008). Again, reading direction did not affect the results, although the LH bias was less clear than in the previous experiment. These experiments confirmed that readers of right-to-left scripts, such as Arabic, show the same pattern of lateralisation as readers of left-to-right scripts, such as English. Habitual scanning direction seems to have no effect on how colour CP is lateralised.

Experiments 6 and 7 further tested the robustness of LH lateralised colour CP by testing an English sample with two new colour tasks. The effect has previously been tested for in adults using visual search or target detection tasks where participants are required to indicate the left/right spatial location of the target (e.g., Gilbert et al, 2006 a and b; Drivonikou et al, 2007; Roberson et al, 2008; Siok et al, 2009 and Liu et al, 2009). Two experiments in this thesis used variants of these tasks. Experiment 6 used a search task that varied the number of distractors and Experiment 7 used a visual search task where the task was to decide whether there was a target present or not rather than to decide the location of the target. The characteristic pattern of LH colour CP was found on both of these tasks, with Experiment 6 showing a trend for a LH bias and Experiment 7 showing a significant lateralised effect.

5.3.1 Implications for the debate

Taken together, Experiments 4, 5, 6 and 7 suggest that lateralised colour CP is a robust effect that is unaffected by factors such as habitual scanning direction and the requirement for a spatial decision. The LH bias in colour CP has implications for the wider debate about the origin and nature of colour categories. For example, if the LH bias is related to language it provides evidence that language contributes to colour CP. Whilst language cannot be the origin of colour CP, as colour CP is found in pre-linguistic infants and toddlers (e.g., Franklin & Davies, 2004), a language related LH bias suggests that at some stage after language learning, the nature of colour CP is changed.

5.3.2 Further research

Now that it has been demonstrated that LH colour CP is robust, further research is needed to investigate the nature of the LH category effect, in particular the contribution of language to the LH bias. As the LH is dominant for most language functions, evidence for a LH bias in colour CP has been taken as evidence that language contributes to colour CP. The developmental research that suggests that the LH bias arises around the time of colour term acquisition (Franklin et al., 2008) supports this assertion. Research using fMRI has also supported this assertion by providing evidence that language regions of the brain are more greatly activated for between-category than within-category colour discriminations (Siok et al., 2009). Now that it has been established that LH colour CP is a solid phenomenon, the next step should be to investigate how language leads to this LH bias.

Interestingly, Siok et al.'s fMRI investigation also found greater activation of between- than within-category colour discriminations in areas of visual cortex. This may suggest that language strengthens the colour category effect in the LH by reinforcing the perceptual distinction between different category colours at early stages of perception. There is some evidence from a recent Event-Related-Potential study, that language may affect pre-attentive stages of colour perception (Thierry, Athanasopoulos, Wiggett, Dering & Kuipers, 2009). That study examined an early pre-attentive ERP component (visual mis-match negativity) elicited in response to the detection of a change in colour (blue 1 – blue 2 or green 1 – green 2) for Greek and English participants. The two blues fall in different lexical categories for Greeks but not for English-speakers and Greeks showed greater visual mis-match negativity to the blue colour change than the English participants did. There were no differences between English and Greek for the green colour change where both languages use only one basic term for both greens. This study raises the possibility that language can actually influence early pre-attentive colour perception and provide strong evidence for Whorf's theory of linguistic relativity (Whorf, 1956). Further research is needed to establish whether colour language actually leads to long term perceptual change or whether colour language merely modulates perception temporarily through the activation of on-line verbal codes (Siok et al., 2009). The recent ERP and fMRI investigations also provide a useful framework for testing linguistic relativity in domains other than colour to establish how language influences perception more generally.

5.4 Universals of colour preference

The third line of investigation in this thesis aimed to test the theory that there are 'Universal' aspects to colour preference. As discussed previously, research into colour preference has a long history (Chandler, 1934) and there have been frequent claims that there is a universal order of colour preference (e.g., Guilford & Smith, 1959), although the lack of rigorous methods and lack of control of stimuli has constrained research until recently. A recent study investigated colour preference in Chinese and English samples using rigorous methods and related the findings to the physiology of colour vision (Hurlbert & Ling, 2008; Ling et al., 2006). As outlined previously, colour preference for Chinese and English samples could be summarised in terms of weights on the cone-opponent channels. Chinese and English males and females all weighted S-(L+M) positively (bias for hues bluer than the background). However, L-M cone-contrast was weighted positively for females (bias for hues redder than the background) but negatively for males (bias for hues greener than the background) for both Chinese and English samples. Ling and colleagues claimed, on the basis of the sex difference in L-M for the two samples, that there could be a 'Universal' sex difference in the weighting of L-M for colour preference and related this to evolutionary theories of colour vision.

The study in Chapter 4 replicated Ling and colleagues' study, but tested English and Arabic samples. One aim was to establish whether Arabic colour preference could also be summarised in terms of weights on the cone-opponent processes. A second aim was to establish whether the sex difference in the weighting of the L-M channel that was previously found by Ling and colleagues for English and Chinese samples would be replicated for another English sample and extend to an Arabic sample. This therefore tests Ling and colleagues theory that there is a 'Universal' sex difference in how L-M is weighted when making judgements of colour preference.

Arabic and English females appeared to have different preference curves with peaks in different regions, yet the preference curves were similar for Arabic and English males. As for Ling et al.'s investigation, the preference curves for the two samples could be summarised in terms of weights on the cone-opponent processes. Analysis of how participants weighted S-(L+M) cone-contrast indicated a significant sex difference that was the same for English and Arabic samples. Arabic and English males weighted S-(L+M) cone-contrast negatively (preference for yellowish hues) and females weighted it positively (preference for bluish hues). This is in contrast to Ling et al.'s investigation where all participants weighted S-(L+M) cone-contrast positively. The current investigation therefore finds a different weighting of S-(L+M) cone-contrast for the English male sample than Ling et al.'s English male sample.

For L-M cone-contrast, for the Arabic sample, there was a sex difference in the weighting as in Ling et al.'s investigation, with females weighting L-M positively and males weighting it negatively. The current investigation suggests that the sex difference in L-M identified by Ling et al. with English and Chinese samples extends to an Arabic sample. However, importantly, the current investigation failed to replicate the sex difference in the weighting of L-M for the English sample – both the English males and females in the current investigation weighted this negatively. The difference between the two, apparently similar, English samples, questions the robustness of Ling et al.'s findings, which may in turn, question the universality of colour preference.

5.4.1. Implications for the debate

These findings have various implications for the debate about the origin of colour preference. Although there have been many suggestions that colour preference is to some extent universal, only a limited number of cultures have been tested. Colour preference for a Saudi sample has never been tested before. The current investigation therefore provides the first data on colour preferences in a Saudi sample. As there was no a sex difference in the weighting of L-M for the English sample in the current investigation, Ling et al.'s theory that there are universal sex differences in L-M that are related to the evolution of colour vision is not supported. It appears that colour preference can vary both across cultures, and from sample to sample within a culture, and that colour preference is more fluid than previous theories suggest.

5.4.2. Further research

Although there is a long history of investigation into colour preference, there is a relatively short history of research that has used appropriate methods. It is evident that, further research into colour preference is needed. First, although there is research on colour preferences in infancy (e.g., Ward et al., 1900; Bornstein, 1975; Zemach et al., 2007;

Franklin et al.,2008 & Franklin et al.,2009), there is a need for research that establishes how these early perceptual biases to colour contribute to colour preferences later on in development. Second, although there have been cross-cultural studies of colour preference, all of these studies have tested urbanised populations in developed countries. Further research is needed which tests a broader range of societies that vary in both culture and the coloured environment. For example, it would be of interest to establish colour preferences in cultures where there are a limited number of artefacts and where the colours available are more restricted to the colours that occur in the natural environment. This would be a stronger test of any 'Universal' aspects of colour preference and may provide evidence to link colour preference to cultural or environmental influences. Third, further research is needed to establish the influence that colour preference has on other aspects of colour perception and cognition, for example, do we attend quicker or search faster for colours that we prefer? Research that investigates questions such as these will contribute to an understanding of the impact of colour preference on perception, cognition and behaviour.

5.5 Conclusions

The contributions of the current thesis which investigated are three-fold. First, Arabic has 11 basic colour terms that correspond to Berlin and Kay's (1969) universal terms. Second, the LH bias in colour CP is independent of reading direction and basic procedural variations. Third, the claim for a 'Universal' sex difference in the weighting of L-M cone-contrast between stimulus and background (Ling, Robinson & Hurlbert, 2006; Hurlbert & Ling, 2007) was not supported.

Closing Remarks

When I started as a PhD student, I thought that Arabic had two, or possibly three, basic colour terms encoding the blue region. I planned to exploit this difference between Arabic and English to explore the relationship between language and CP, and the lateralisation of colour CP first reported by Gilbert et al. (2006). Such studies would have been the first to compare language groups' lateralisation of colour CP.

However, I was advised to first confirm the status of the various Arabic blue terms using empirical methods, rather than to rely on my own impressions. In the event, as reported in Chapter 2, it became clear that Arabic had just one basic blue term, and thus there was no point in doing the Arabic English comparison for the original reason (different category structure). Equivalent cross-cultural studies have now been done by others (Roberson et al. 2009; Drivonikou, 2009) with the results broadly showing that left hemisphere CP only occurs for speakers of languages that mark the colour category distinction.

My choice of alternative routes to take was partly driven pragmatically — I had ready access to Arab and British samples — and partly by the belief that replications and minor extensions, although often undervalued were necessary for science to progress. I think of the studies in Chapter 3 as mainly replications with minor variations on methods; a form of 'good housekeeping'. In general, studies from Chapter 3 support the original findings, and there is nothing groundbreaking about the results. Nevertheless, I believe that my studies have provided converging evidence that colour CP is lateralised to the left hemisphere, and that it is independent of reading direction and the number of distractors. They also confirm that Gilbert et al.'s search task exhibits 'pop-out', but importantly, even such apparently effortless tasks may still be affected by language.

The colour preference study in Chapter 4 is again a replication and extension of a previous study. It is of interest that the sex difference in the weighting of the red-green cone-opponent process extends to Arabic samples. In addition, the lack of replication of this sex difference for the English sample highlights the importance of attempting to replicate previous findings.

Finally, I hope that my work has helped established the robustness of the lateralisation of colour CP as well as establishing that the recent interest in colour preference using rigorous methods requires further work, and I hope to be able to encourage others in Saudi Arabia to join in this research programme.

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Appendix

Appendix 1. The Stimuli of experiment two

The Color-aid system

Color-aid Corporation produces the Color-aid system of coloured papers. The full developed set contains the complete range of 314 matt-finished colours. The colours are divided into 34 hues, 100 tints, 47 shades, 114 pastels and 17 greys from dark to light plus black and white. In the 220 Color-aid designs that we used in this study, there are six main Hues: Y (yellow), O (orange), R (red), V (violet), B (blue) and G (green). And three intermediate Hues for each main Hue, such as YOY (yellow, orange, yellow). Each of the 24 hues has four tints (T1-T4) with lightness increasing from T1 to T4, and three shades (S1-S3) with increasing blackness from S1 to S3. For more information, please see (www.coloraid.com).

The CIE (Committee International D'Eclairage)

In 1931 the CIE: Commission Internationale de l'Eclairage (International Commission on Illumination) produced the well-known colour space that represents all possible colours in a chromaticity diagram. This model has been developed in several versions. One of them is the 1976 uniform chromaticity CIE (u' v') that was used in experiment two. This version is designed to be perceptually uniform. A given change in value corresponds nearly to the same perceptual difference over any part of the space. Table A. shows the Colour-aid codes and CIE co-ordinates for the 65 tile colours.

Table A. Colour-Aid codes and CIE co-ordinates for the 65 tile colours.

Colour-aid code		CIE co-ordinates					
		Y	x	y	L*	u'	v'
Y	HUE	64.77	0.47	0.48	91.49	0.24	0.55
	S2	16.99	0.41	0.44	52.81	0.22	0.53
YOY	HUE	47.48	0.50	0.43	80.92	0.28	0.54
	T4	55.63	0.45	0.41	86.18	0.26	0.53
	S2	22.08	0.36	0.38	59.09	0.21	0.50
YO	HUE	39.52	0.51	0.41	75.17	0.30	0.53
	T3	47.02	0.48	0.41	80.61	0.28	0.53
	S3	10.72	0.36	0.41	43.02	0.20	0.51
OYO	HUE	26.51	0.54	0.37	63.81	0.34	0.52
O	HUE	25.00	0.54	0.37	62.26	0.34	0.52
	S1	14.34	0.50	0.37	49.03	0.31	0.52
	S3	09.15	0.42	0.36	39.98	0.26	0.50
ORO	HUE	18.87	0.57	0.34	55.26	0.38	0.52
	T3	36.88	0.46	0.35	73.09	0.29	0.50
	S3	26.51	0.33	0.32	63.81	0.21	0.47
RO	HUE	16.22	0.58	0.33	51.75	0.40	0.51
	T3	32.66	0.45	0.32	69.56	0.30	0.48
	S3	04.19	0.37	0.34	27.15	0.23	0.48
ROR	HUE	15.23	0.53	0.31	50.35	0.37	0.49
	T3	29.82	0.42	0.30	67.00	0.29	0.47
	S3	20.71	0.34	0.28	57.50	0.24	0.44
R	HUE	11.71	0.50	0.29	44.78	0.36	0.48
	T4	24.34	0.40	0.27	61.57	0.29	0.45
	S3	04.81	0.33	0.30	29.18	0.22	0.45
RVR	HUE	09.11	0.42	0.24	39.90	0.33	0.43
	S1	12.79	0.35	0.25	46.60	0.26	0.42
	S3	28.43	0.36	0.28	65.69	0.26	0.45
RV	HUE	06.97	0.33	0.19	35.13	0.29	0.37
	T2	14.51	0.31	0.19	49.28	0.27	0.37
VRV	HUE	06.71	0.30	0.19	34.48	0.26	0.37
	S3	08.42	0.36	0.28	65.68	0.26	0.45
V-	HUE	04.67	0.26	0.17	28.74	0.23	0.34

Table A. (continued)

Colour-aid code		CIE co-ordinates					
		Y	x	y	L*	u'	v'
VBV	HUE	04.13	0.24	0.17	26.94	0.21	0.34
	T4	19.05	0.25	0.20	55.49	0.20	0.37
BV	HUE	04.21	0.22	0.19	27.22	0.18	0.35
	S2	07.88	0.25	0.26	37.26	0.18	0.42
BVB	HUE	04.80	0.19	0.13	29.15	0.18	0.28
	S3	26.65	0.26	0.23	63.95	0.20	0.40
B	HUE	09.51	0.18	0.16	40.71	0.16	0.32
	T1	19.02	0.20	0.19	55.45	0.16	0.35
BGB	HUE	09.62	0.19	0.19	40.93	0.16	0.35
	T3	23.08	0.20	0.23	60.21	0.15	0.39
BG	HUE	08.93	0.20	0.25	39.53	0.14	0.40
	T1	16.57	0.19	0.25	52.24	0.14	0.40
	S2	07.42	0.21	0.26	36.21	0.15	0.41
GBG	HUE	10.69	0.23	0.37	42.96	0.13	0.48
	S2	20.79	0.20	0.25	57.60	0.14	0.40
G	HUE	11.99	0.24	0.42	45.26	0.13	0.50
	S3	06.10	0.26	0.33	32.91	0.16	0.46
GYG	HUE	12.89	0.25	0.44	46.76	0.13	0.51
	T4	31.14	0.26	0.41	68.21	0.14	0.50
	S1	15.59	0.26	0.31	50.86	0.17	0.45
YG	HUE	14.66	0.28	0.48	49.51	0.14	0.53
	S3	05.78	0.30	0.34	32.04	0.19	0.47
YGY	HUE	18.92	0.30	0.51	55.32	0.14	0.54
YGY	S3	35.87	0.35	0.43	72.27	0.19	0.52
ROSE RED		17.63	0.41	0.24	53.66	0.32	0.43
SIENNA		13.31	0.44	0.36	47.43	0.27	0.50
WHITE		81.40	0.32	0.33	100.00	0.20	0.47
GRAY 1		47.55	0.32	0.33	80.97	0.20	0.47
GRAY 2		30.59	0.32	0.33	67.71	0.20	0.47
GRAY 4		18.88	0.31	0.31	55.27	0.20	0.46
GRAY 6		11.20	0.31	0.31	43.89	0.20	0.46
GRAY 8		04.53	0.31	0.32	28.89	0.20	0.46
BLACK		03.59	0.34	0.33	24.98	0.22	0.47

Appendix 2. Detailed results of the colour-naming task

Table A. Child tile-naming summary (N = 61). Terms used to name each tile with a frequency of use of at least 10% of the sample. (Code = Colour-Aid code, % = percentage of respondents who used a term for a given tile).

Code	Terms	%	Code	Terms	%	Code	Terms	%
Y-HUE	Yellow	100.00	Y-S2	Oil green	55.7			
				Brown	27.9			
YOY-HUE	Yellow	70.5	YOY-T4	Yellow	60.7	YOY-S2	Oil green	39.9
	Orange	24.6		Beige	18.0		Green	14.8
							Brown	14.8
YO-HUE	Orange	78.7	YO-T3	Yellow	59.0	YO-S3	Brown	75.4
	Yellow	18.0		Orange	19.7		Oil green	14.8
OYO-HUE	Orange	98.4						
O-HUE	Orange	98.4	O-S1	Orange	54.1	O-S3	Brown	95.1
				Brown	36.1			
ORO-HUE	Red	78.7	ORO-T3	Pink	37.7	ORO-S3	Orange	62.3
	Orange	21.3		Meat	21.3		Beige	14.8
RO-HUE	Orange	60.7	RO-T3	Orange	55.7	RO-S3	Brown	91.8
	Red	37.7		Pink	27.9			
ROR-HUE	Red	100.0	ROR-T3	Pink	67.2	ROR-S3	Pink	59.0
							Grey	14.8
R-HUE	Pink	49.2	R-T4	Pink	85.2	R-S3	Brown	63.9
	Red	36.1					Black	32.8
RVR-HUE	Purple	31.1	RVR-S1	Purple	41.0	RVR-S3	Pink	63.9
	Pink	21.3		Pink	41.0		Purple	19.7
	Red	18.0						
	D red	18.0						
RV-HUE	Purple	75.4	RV-T2	Pink	70.5			
				Purple	24.6			
VRV-HUE	Purple	80.3	VRV-S3	Pink	82.0			
	Blue	16.4						
V-HUE	Purple	80.3						
	Blue	16.4						
VBV-HUE	Purple	80.3	VBV-T4	Purple	77.0			
	Blue	18.0		Pink	11.5			
BV-HUE	Blue	63.9	BV-S2	Blue	42.6			
	Dblue.6	24.6		Purple	31.1			
				D blue	24.6			

Table A. (continued)

Code	Terms	%	Code	Terms	%	Code	Terms	%
BVB-HUE	Blue	83.6	BVB-S3	Grey	77.0			
B-HUE	Blue	90.2	B-T1	Blue	85.2			
				L blue	13.1			
BGB-HUE	Blue	82.0	BGB-T3	Blue	49.2			
	L blue	14.8		L blue	44.3			
BG-HUE	Blue	70.5	BG-T1	L blue	49.2	BG-S2	Green	70.5
	Green	16.4		Blue	34.4		Blue	21.3
				Green	34.4			
GBG-HUE	Green	100.00	GBG-S2	Blue	42.6			
				L blue	23.0			
G-HUE	Green	98.4	G-S3	Green	91.8			
GYG-HUE	Green	100.00	GYG-T4	Green	83.6	GYG-S1	Green	93.4
YG-HUE	Green	93.4	YG-S3	Green	54.1			
				Oil green	44.3			
YGY-HUE	Green	95.1	YGY-S3	Green	72.1			
ROSE RED	Pink	59.0	SIENNA	Brown	55.7	WHITE	White	100.00
	Purple	19.7		Orange	26.2			
GRAY 1	White	68.9	GRAY 2	Grey	73.8	GRAY 4	Grey	91.8
	Grey	31.1						
GRAY 6	Grey	88.5	GRAY 8	Grey	91.8	Black	Black	

Table B. Adult tile-naming summary (N = 60): Terms used to name each tile with a frequency of use of at least 10% of the sample. (Code = Colour-Aid code, % = percentage of respondents who used a term for a given tile.

Code	Terms	%	Code	Terms	%	Code	Terms	%
Y-HUE	Yellow	100.00	Y-S2	Oil green	48.3			
				Green	25.0			
YOY-HUE	Yellow	60.0	YOY-T4	Yellow	78.3	YOY-S2	Green	40.0
	Orange	33.3		Beige	11.7		Oil green	28.3
YO-HUE	Orange	83.3	YO-T3	Yellow	66.7	YO-S3	Brown	83.3
	Yellow	15.5	Beige	13.3				
			Orange	11.7				
OYO-HUE	Orange	100.00						
O-HUE	Orange	100.00	O-S1	Brown	61.7	O-S3	Brown	100.00
				Orange	33.3			
ORO-HUE	Red	63.3	ORO-T3	Brown	26.7	ORO-S3	Orange	53.3
	Orange	35.0		Pink	21.7		Yellow	15.0
				Beige	20.0		Kurbazee	11.7
				Kurbazee	11.7			
RO-HUE	Orange	88.3	RO-T3	Orange	56.7	RO-S3	Brown	100.00
	Red	10.0		Pink	15.0			
				Kurbazee	15.0			
ROR-HUE	Red	98.3	ROR-T3	Orange	40.0	ROR-S3	Pink	70.0
				Pink	33.3			
R-HUE	Red	48.3	R-T4	Pink	96.7	R-S3	Brown	90.0
	Pink	25.0						
	Fuoshee	23.3						
RVR-HUE	D red	48.3	RVR-S1	Pink	63.3	RVR-S3	Pink	93.3
	Pink	20.0		Purple	23.3			
RV-HUE	Purple	100.00	RV-T2	Pink	78.3			
VRV-HUE	Purple	98.3	VRV-S3	Pink	90.0			
V-HUE	Purple	100.00						
VBV-HUE	Purple	95.0	VBV-T4	Purple	81.7			
BV-HUE	Purple	41.7	BV-S2	Purple	65.0			
	D Blue	28.3		D Blue	23.3			
	Blue	25.0						
BVB-HUE	Blue	51.7	BVB-S3	Grey	91.7			
	Purple	28.3						
	D blue	20.0						
B-HUE	Blue	76.7	B-T1	Blue	80.0			
	L blue	20.0		L blue	20.0			

Table B. (continued)

Code	Terms	%	Code	Terms	%	Code	Terms	%
BGB-HUE	Blue	81.7	BGB-T3	L blue	66.7			
	L blue	13.3		Blue	33.3			
BG-HUE	Blue	61.7	BG-T1	Blue	41.7	BG-S2	Green	40.0
	Turquoise	15.0		L Blue	26.7		Blue	26.7
				Tarquazee	20.0			
GBG-HUE	Green	88.3	GBG-S2	Green	40.0			
				L blue	30.0			
				Blue	16.0			
G-HUE	Green	96.7	G-S3	Green	75.0			
				Oil green	20.0			
GYG-HUE	Green	100.00	GYG-T4	Green	80.0	GYG-S1	Green	96.7
YG-HUE	Green	96.7	YG-S3	Green	55.0			
				Oil green	33.3			
YGY-HUE	Green	96.7	YGY-S3	Green	81.7			
ROSE RED	Pink	73.3	SIENNA	Brown	71.7	WHITE	White	100.00
	Fuoshee	21.7		Orange	23.3			
GRAY 1	White	71.7	GRAY 2	Grey	93.3	GRAY 4	Grey	100.00
	Grey	26.7						
GRAY 6	GRAY	98.3	GRAY 8	Black	98.3	Black	Black	100.00

Table: C. Child highest percentage of tile-naming: Colour-Aid codes, terms used, their English glosses, the percentage of highest total usage, the average CIE co-ordinates for the 11 basic colour terms along with the loci of the 11 universal colour foci (Heider, 1971).

Colour-aid Code			Term	Gloss	%	Average CIE co-ordinates	
1	2	3				u'	v'
WHITE	-	-	Abiyadh	White	100.00	0.20	0.47
BLACK	-	-	Asswed	Black	100.00	0.22	0.47
ROR-HUE	-	-	Ahmar	Red	100.00	0.37	0.49
GBG-HUE	GYG-HUE	-	Akhdar	Green	100.00	0.13	0.49
Y-HUE	-	-	Asfer	Yellow	100.00	0.24	0.55
O-HUE	-	-	Boartoogaalee	Orange	098.40	0.34	0.52
RO-S3	-	-	Bonee	Brown	091.80	0.23	0.48
GRAY 4	GRAY 8	-	Rassasee	Grey	091.80	0.20	0.46
B-HUE	-	-	Azrock	Blue	090.20	0.16	0.32
R-T4	-	-	Wardee	Pink	085.20	0.29	0.45
VRV-HUE	V-HUE	VBV-HUE	Banafsagee	Purple	080.30	0.23	0.35

Table: D. Adult highest percentage of tile-naming: Colour-Aid codes, terms used, their English glosses, the percentage of highest total usage, and the average CIE co-ordinates for the 11 basic colour terms.

Colour-aid Code			Term	Gloss	%	Average CIE co-ordinates	
1	2	3				u'	v'
WHITE	-	-	Abiyadh	White	100.00	0.20	0.47
BLACK	-	-	Asswed	Black	100.00	0.22	0.47
GYG-HUE	-	-	Akhdar	Green	100.00	0.13	0.51
Y-HUE	-	-	Asfer	Yellow	100.00	0.24	0.55
OYO-HUE	O-HUE	-	Boartoogaalee	Orange	100.00	0.34	0.52
RO-S3	-	-	Bonee	Brown	100.00	0.23	0.48
RV-HUE	V-HUE	-	Banafsagee	Purple	100.00	0.26	0.35
ROR-HUE	-	-	Ahmar	Red	098.30	0.37	0.49
R-T4	-	-	Wardee	Pink	096.70	0.29	0.45
GRAY 8	-		Rassasee	Grey	091.80	0.20	0.46
B-T1	-	-	Azrock	Blue	080.00	0.16	0.35

Appendix 3. The Munsell Colour-order System

The Munsell Colour-order System developed by an American artist Albert H. Munsell in 1905, was designed to provide an orderly system for accurately identifying every perceptible colour. The system specifies colour in term of three attributes: hue, value and chroma (see figure 3A).

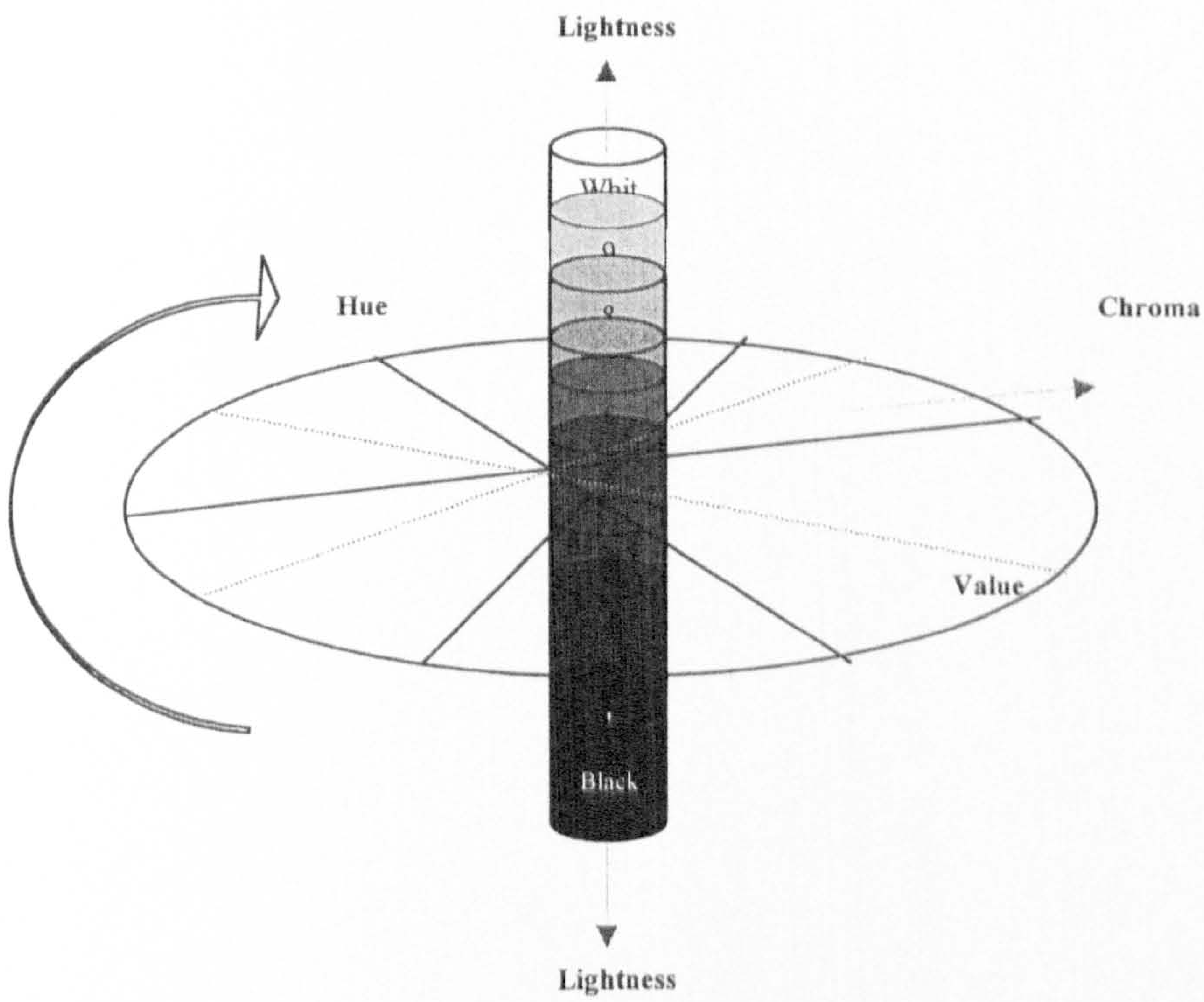

Figure 3A. Schematic representation of Munsell colour space.

The system has five principal hues on the horizontal plane: Red (R), Yellow (Y), Green (G), Blue (B) and Purple (P), and five intermediate hues: Yellow-red (YR), Green-yellow (GY), Blue-green (BG), Purple-blue (PB) and Red-purple (RP), making 10 hues in all. The vertical plane gives the value, which indicates the lightness of colour, and distinguishes light colours form dark ones. The value scale ranges from 0 for pure black to 10 for pure white with different shades of greys between them. The horizontal plane represents the chroma, which indicates the saturation of colours. The Munsell Colour-order System is standardised so that each of the three Munsell dimensions is intended to be perceptually uniform (Newhall, Nickerson and Judd, 1943).