CHAPTER 1

Overview I: Colour and Recognition Memory

Color and light are major factors in man-made environments; their impact influences man's psychological reactions and physiological well-being...It is no longer valid to assume that the only role of light and color is to provide adequate illumination and a pleasant visual environment. F. Mahnke & R. Mahnke, 1987.

Colour is an integral part of our everyday life and as such may affect many aspects of our life culturally, psychologically and physiologically. As an example, colour commonly enters into our language and contributes to the human ability to communicate meaning. The English language has many familiar sayings derived from colour symbolism (Walker, 1990). "Seeing the world and viewing our past through rose-coloured glasses", "once in a blue moon" and "green with envy" are just a few examples of the ways we have infused colour into our language and related them to our emotional state of mind.

Colour also has an influence on our everyday personal and professional decisions by affecting our spending habits, buying decisions, or even our general personal well-being (Birren, 1961). Scientifically, the effect of colour on human behaviour has been widely investigated in the domains of perceptual and cognitive processes. The following series of experiments primarily concern the influence of colour on the human memory system. Specifically, the current thesis aims to explore the role of colour in recognition memory for emotional information. To my knowledge, there are no particular investigations specifically aimed at studying the above area of interest. Thus, this work is mostly motivated by, and theoretically leans on, the numerous studies which have thoroughly investigated the role of colour in recognition memory of objects.

1.1 The Role of Colour in Object Recognition:

1.1.1 Edge-based model for object recognition

Whether colour plays any role in recognition memory has been the subject of much debate for the last decade. Early investigations have included objects as the most common stimulus type (e.g. Biederman, 1987; Livingstone & Hubel, 1987; Lowe, 1985; Marr, 1982; Ostergard & Davidoff, 1985), and thus much of the theoretical modelling and experimental work has focused specifically on the role of colour in object recognition. Studies that have examined the role of colour in object recognition memory have typically used an assortment of tasks for assessing recognition including classification (e.g. Price & Humphreys, 1989), verification (e.g. Biederman & Ju, 1988; Joseph, 1997; Tanaka & Presenell, 1999), naming (e.g. Ostergard &

Davidoff, 1985), recognition memory (e.g. Wurm, Legge, Isenberg & Luebker, 1993), sequential-matching (e.g. Hayward, Zhou, Gauthier & Harris, 2000) and even object-Stroop tasks (e.g. Kline, 1964; Naor-Raz, Tarr & Kersten, 2003). Many of the foregoing studies revealed equivocal results. The majority support an effect of colour on naming but not on classification or verification performance (Biederman & Ju, 1988; Brodie, Wallace, & Sharrat, 1991; Davidoff & Ostergaard, 1988; Ostergaard & Davidoff, 1985; Price & Humphreys, 1989; Wurm, Legge, Isenberg & Luebker, 1993). For example, in their influential experiment, Biederman and Ju (1988) asked participants to verify whether a word followed by a picture referred to the same object, where the picture was either a black-and-white line drawing or a full-color photograph. No advantage for colour photographs was found and this made the authors conclude that surface color was not a factor in recognition performance relative to the influence of shape. Clearly, when the colour of an object is displayed out of context, identifying a specific object from several different object categories would be regarded as a difficult if not an impossible task. For example, seeing a red patch is not sufficient for identifying a certain object. Similarly, 'red' is not a beneficial cue for selecting apples from cherries. For this reason, previous attempts to explain colour effects on object recognition postulated that object recognition can operate directly from the boundary contours of objects (Biederman, 1987; Grossberg & Mingolla, 1985; Pentland, 1986). These investigations have formed a route of influence which led to the formation of the *edge-based model* or *recognition-by-component* model of object recognition (Biederman, 1987). Biederman specifically pointed to the fact that objects are represented in terms of geons, basic geometric building blocks and special terms that define relations among them (e.g. geon G is beneath geon H, geon F is to the left of geon E). According to this model, in order to name or identify an object the perceptual system computes a structural decision, based on the object's geons and the relations among them, which will eventually result in naming the object. This process is deprived of any colour information and is solely based on lower level processes such as edge and shape detection.

From an edge-based point of view, an evolutionary advantage could ensue from allowing only the fast pathways to play a central role in object-recognition computations (Davidoff 1991). However, it can equally be argued that in situations where the viewing conditions are imperfect, multidimensional objects will benefit more than objects that are coded by a single dimension (Price & Humphreys, 1989). Tanaka, Weiskopf & Williams (2001), accordingly argued:

"…in the real word, recognition-under-occlusion is more the rule than the exception, and hence, color might play a critical role in everyday object recognition." (p. 212)

A methodological argument made recently by Uttl, Graf & Santacruz (2006), argued against the edge-based accounts. The authors reviewed 35 studies that previously investigated the effect of colour on object identification and priming processes and highlighted the flaws in methodology that led these studies to fail to show significant evidence of colour-specific priming (e.g Cave et al., 1996; Biederman & Ju, 1988; Brodie, et al., 1991). These flaws, according to Uttl et al., were mainly a lack of power and weak manipulations of object and colour displays as a result of using line-patterns only. Thus, in their attempt to replicate the foregoing findings, they applied the same basic methodology used before with the exception of increasing the study's power (one hundred and forty participants as opposed to an average of 40 participants in the previous studies) and including object photos that varied in their level of colouring (as measured by a colour complexity rating scale). They found that objects were indeed easier to identify from colour than from black and white photos and that the level of an object's colour complexity significantly affected the magnitude of priming (large priming effect for colour-complex objects, but minimal for colour-simple objects). In summary, the arguments made above against the edge-based model (Price & Humphreys, 1989; Tanaka, et al, 2001) for object recognition, together with the recent findings of Uttl et al., emphasise the need for a different explanation for colour's role in recognition memory.

1.1.2 Surface-plus-edge-based model for object recognition

At about the same time that Beiderman et al. proposed the theory of edge-based representations during object recognition, a series of studies revealed a different pattern of results and all proposed that 'surface-coded' descriptions such as colour, depth and texture, provide a necessary step in the recognition process (Humphreys, Riddoch, & Quinlan, 1988; Marr, 1982; Price & Humphreys, 1989). Thus, a new, but not less dominant, account for the role of colour on recognition memory was opened for further investigation - the *surface-plus-edge-based* position (Bruner, 1957; Gibson, 1969; Marr, 1982).

Unlike the edge-based model, the surface-plus-edge-based account allows for object representations to comprise information not only about an object's shape but also about its surface characteristics including colour, brightness, depth, motion and texture. Price and Humphreys (1989), for example, predicted that when shape information is not sufficient for distinguishing among category members, surface colour becomes significant and can influence both object naming and categorisation. Results were exactly as predicted: controlling for the level of structural similarities among their objects, it was shown that congruent surface colour not only helped recognition but that incongruent colour interfered with both naming and categorisation tasks. This led the authors to speculate whether studies (Biederman & Ju, 1988; Davidoff & Ostergaard, 1988; Ostergaard & Davidoff, 1985) that obtained no advantage in recognition and naming paradigms did so by using a rather restricted number of objects. As an example, they presumed that the reason Davidoff & Ostergaard, 1988, did not find that colour sped performance on living versus nonliving categorisation was because their objects were specifically disparate in shape and relied on judgments that mostly concerned function (rather than structure) details. Similarly, in the following series of studies, Humphreys and his colleagues (Humphreys Riddoch, & Quinlan, 1988; Humphreys, Lloyd-Jones, Fias, 1995; Riddoch and Humphreys, 1987b; Vitkovich et al., 1993) have shown that objects from structurally similar categories (e.g. fruits or birds) take longer to name than items from structurally dissimilar categories (e.g. furniture or tools) because structurally similar objects' representations are more likely to be co-activated, resulting in more competition within the object recognition system.

1.1.3 Colour contributes to recognition memory at a low level of vision

Although it has been well documented that surface properties such as colour and contour information help the visual system to recognise images both quickly and more efficiently, this does not prove in itself that colour is part of the memory representation. Rather, the possible advantage of colour in recognition memory has been interpreted as a sensory facilitation in which surface properties are processed in parallel and contribute together, at an early processing stage, to the internal visual representation of the world. These properties may relate to some sensory attributes that include both edge and surface information cues such as luminance, shading, form, depth and motion of a certain item and which suggest that the recognition advantage of coloured stimuli is not a result of a memory of the colour but is more due to sensory attributes such as improved image segmentation or increased distinctiveness of features highlighted by colour. In support, one line of studies has demonstrated that such factors (other than the colour *per se)* are the main source of the colour recognition superiority (Aginsky & Tarr, 2000; Chainay & Humphreys, 2001; Hanna & Remington 1996; Treisman & Gelade, 1980; Triesman & Gormican, 1988; Wolf, Cave & Franzel, 1989; Wurm, Legge, Isenberg & Luebker, 1993; Wichman, Sharpe, Gegenfurtner; 2003; Yip & Sinha, 2002). For example, in Hanna & Remington's (1996) study improved image segmentation of the stimuli has been shown to elicit a colour's sensory contribution to recognition memory. Gegenfurtner & Rieger (2000) further showed that colour information result in a coding advantage rather than representation advantage since coloured stimuli were recognised equally well (and better than non coloured stimuli) when they were tested in black and white or colour. This advantage of recognition memory was evident in very brief presentations roles out the possibility that colour aids the recognition of stimuli both through coding and representation since colour was not always available in retrieval (stimuli coloured in black and white). In line with this reasoning, Mollon and Jordan, (1988) and Polyak, 1975 and Walls, (1972) pointed toward a low-level contribution effect of colour to recognition memory. They found that colour plays a highly specialized role in some image segmentation tasks such as detecting ripe fruit or nutritious leaves among mature foliage. Finally, Wurm et al (1993) demonstrate that the advantage of coloured images was independent of whether the colour is linked to the identity of an object or not (e.g. carrot and lemon did not benefit more from colour than foods like apple and pepper). This result suggests that the influence of colour has failed to occur at a cognitive (high) level of visual analysis, but reflects a lower visual process where the knowledge of object properties is not yet perceived.

The above evidence indicates that colour is involved in a rapid, automatic sensory facilitation that does not necessarily participate in memory representation. This lead to the question of whether the effect of colour operates independently of other sensory attributes such as shape, depth or motion (Hanna & Remington, 1996; Livingstone & Hubel, 1987; Ostergaard & Davidoff, 1985). Two lines of experimental evidence support the view that colour is processed independently of other sensory attributes. The first is indirect in showing a superiority effect of colour from outline stimuli with very little surface details (Homa, Haver & Schwartz, 1976; Davidoff & Donnelly, 1990). The second is direct investigation of the separate role of colour and form in recognition memory. If colour and form are bound together, recognition improvement should be revealed in a condition where colour and form details are matched to objects, but not in a condition where the colour details only are matched to objects. This counterintuitive prediction has been refuted by Hanna and Remington (1996). Their findings revealed that performance in the congruent colour condition was not different to performance in the colour-form matched condition, and hence ruled out the idea that colour and form details are necessarily encoded together. The authors further concluded that the binding of colour and form requires deliberate focal attention and thus is not a natural consequence of processing visual stimuli. Likewise, in the Ostergaard and Davidoff (1985) study, although colour congruence facilitates object naming, shape (geometrical) information failed to reveal the same effect. These two lines of study point toward a higher level of colour processing or, as referred to by Wichmann, Sharpe and Gegenfurtner (2002), a cognitive facilitation of colour to recognition memory, where colours conceivably take part in the memory representation.

1.1.4 Colour contributes to recognition memory at a high level of vision

Several studies support a high level contribution of colour to memory. Most have aimed at investigating the difference in memory facilitation between the typical or neutral colours of objects and non-typical or non-neutral colours. The limited role for colour in recognition, and hence its absence at the memory representation, had been initially disputed by Price and Humphreys (1989). First, they argued that surface colour is significant to recognition and can influence both object naming and categorization, especially when shape information is not sufficient for distinguishing among category members and when the decision at stake mostly involves judgments relating to the object's structure rather than its function.

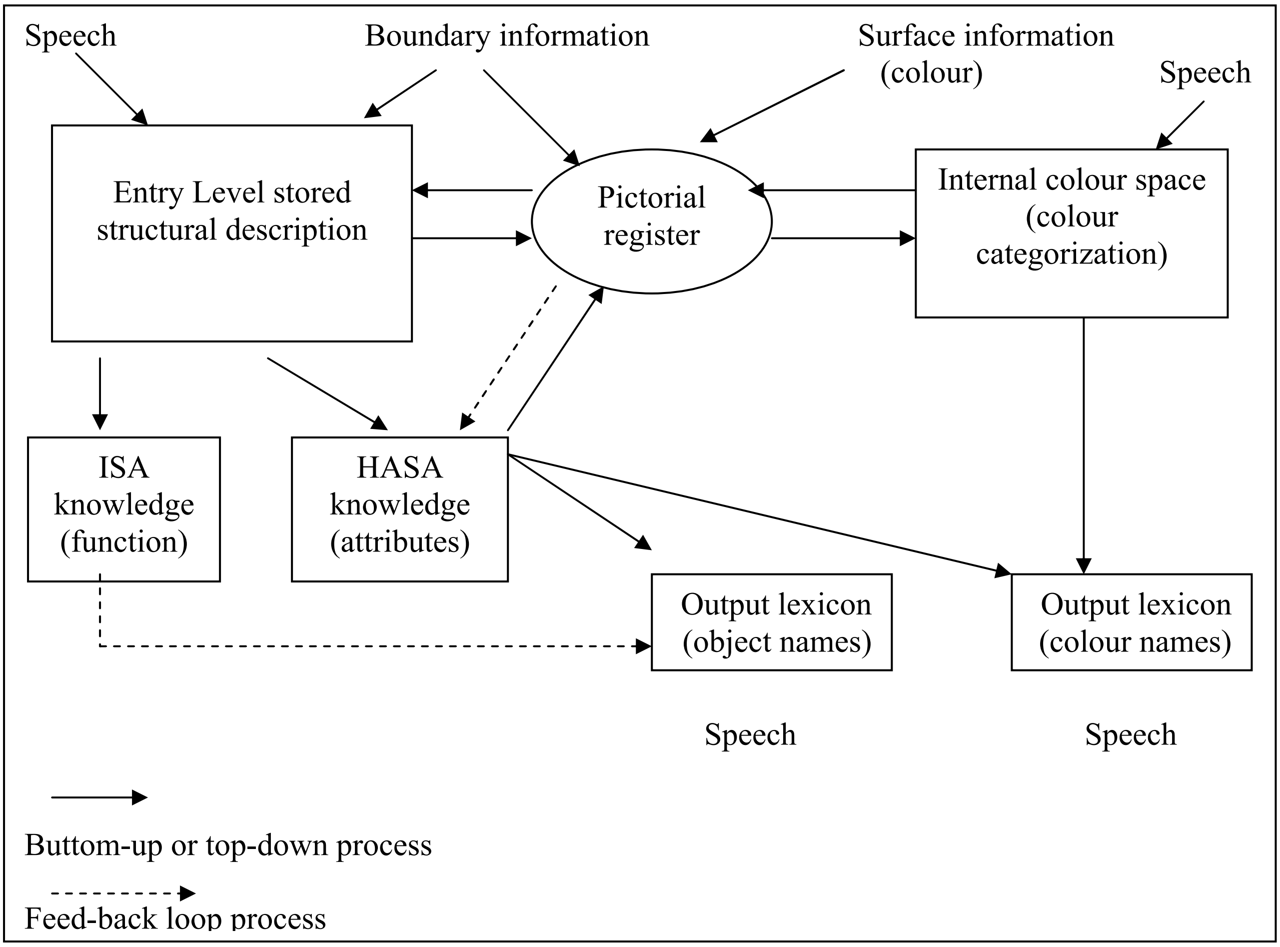


Figure 1.1: A model for object and colour naming (Davidoff, 1991)

Second, congruent surface colour specifically benefited classification speed, whereas incongruent colour interfered with both naming and categorisation tasks. The existence of two separate memory representations for object structure versus function information is in accordance with Davidoff's (1991) model of object recognition (Figure 1.1) in which they were termed as *hasa* and *isa* representations, respectively. Object colour, according to this model, is specifically part of the associated *hasa* properties, so that recognition of an object's colour takes place after the initial visual representation (representations at the *entry level*) has accessed the *hasa* colour knowledge. Since only appropriate or congruent colour information is stored in these representations, recognition memory will be faster and better for objects coloured appropriately than for objects coloured inappropriately.

Support for a separate route of colour processing in object recognition was also obtained from studies of brain-damaged populations. Patients with visual form agnosia (who exhibit a profound impairment in shape perception) also benefit from colour information (Hanna & Humphreys, 2001; Humphrey et al., 1994; Milner & Heywood, 1989; Milner et al., 1991; Mapelli & Behrmann, 1997; Steeves, Humphrey, Culham, Menon, Milner, & Goodale, 2004; Wurm et al., 1993). Humphrey et al. (1994) showed, for example, that colour facilitated object recognition in a patient with visual form agnosia and that normal observers benefited from coloured stimuli (on explicit memory tasks) only when objects were presented in their natural colour. The patient showed a profound deficit in object recognition on the basis of shape, size and orientation, but a relatively spared ability to recognise objects on the basis of colour and texture.

Case studies on colour agnosic patients reveal that, like controls, these patients show a recognition improvement with the use of colour in general, but unlike controls, do not benefit from the colour congruency. Colour agnosia is a type of associative agnosia (rather than apperceptive), in which patients typically have intact perception (low-level processing), but a profound impairment in associating their percepts with stored memories of objects (e.g. lost colour association and semantic representations). The inability of these patients to benefit from appropriate colouring is attributed to the inability to process colour at a high level of processing, thus failing to activate memory representations of object colours (Nijboer, van Zandvoort, & de Haan, 2006, 2007). A recent case study (Nijboer et al., 2006) has reported a patient with visual agnosia who was unable to explicitly use colour information (e.g. to categorise colours) but continued to process colour information implicitly (e.g. to match coloured patches on hue) despite the absence of explicit recognition. Furthermore, the patient showed recognition facilitation from congruent colours in priming tasks at about the same level as demonstrated in age-matched control subjects.

Several studies provide evidence to the claim that congruent colour information is stored in memory representations and thus correspondingly affects recognition memory performance (which is known also as the effect of colour diagnosticity). Appropriate coloured objects are generally recognised faster than monochrome objects (Davidoff & Ostergaard, 1998; Humphreys et al., 1994; Price & Humphreys, 1989; Wurm et al., 1993; Yip & Sinha, 2002; Uttl et al., 2006), and inappropriately coloured objects (Humphrey et al., 1997; Joseph & Proffitt, 1996; Joseph, 1997; Price & Humphreys, 1989; Vernon & Lloyd-Jones, 2003; Nagai & Yokosawa, 2003; Naor-Raz, Tarr & Kersten 2003). Proponents of the high-level facilitation effect of colour on recognition memory have been able to generalise the above findings to a broad range of stimuli types including photographs, simple line drawings, textures, faces, graphs, symbols and animals (Home & Viera, 1988; Denis, 1976; Holt, 1977; Yip & Sinha, 2002; Latimer, Palethorpe, Mezey, Ellwood, Raju, & Hicks, 2002; Intraub & Nicklos 1985; Park & Mason, 1982; Suzuki & Takahashi, 1997). More recently, a substantial body of research has generalised this superiority effect of colours to stimuli other than objects, namely, natural scenes (Wichmann, Sharpe & Gegenfurtner, 2002; Gegenfurtner & Rieger, 2000; Olivia & Schyns, 2000; Olivia & Schyns, 2005). I will return to this pattern of findings for a more thorough review later in this chapter.

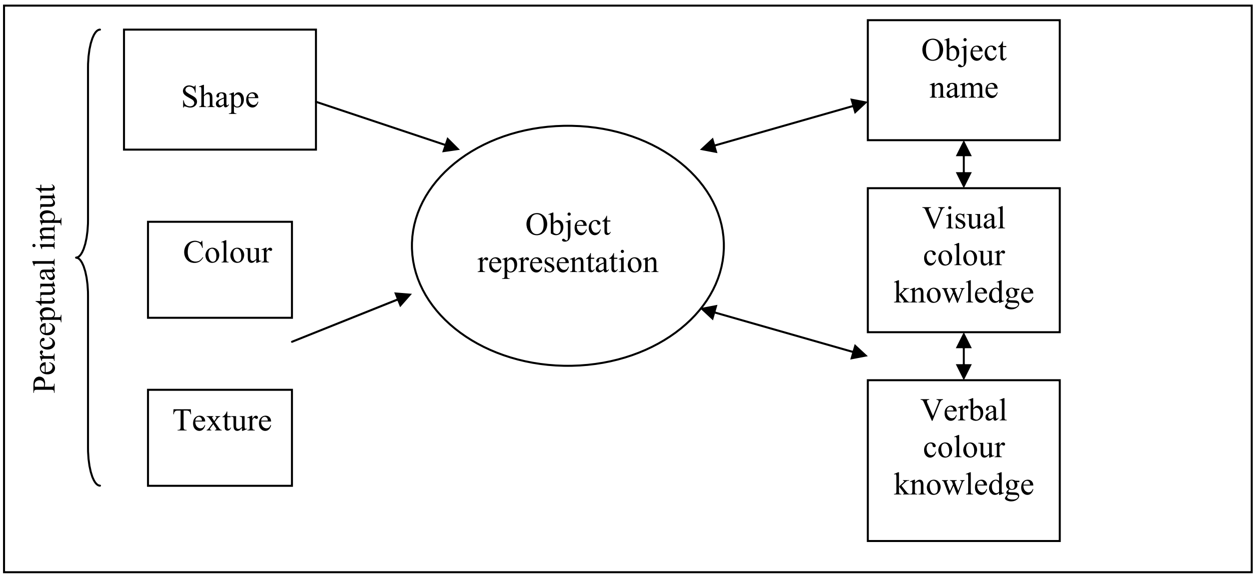


Figure 1.2: The 'Shape + Surface' model of object recognition (Tanaka, et al. 2001)

Based on these recent conclusive findings of a colour congruency effect (or, as will be discussed later, *colour-diagnosticity* effect) on recognition memory, Tanaka et al., (2001) recently presented a revised model (Figure 1.2) of the shape-plus-surface account of object recognition, similar to Davidoff's (1991) model, in which a high level of visual processing of colour is involved. The model allows for objects to be represented in terms of both their shape and colour (and possibly other surface input, such as texture). Visual colour knowledge can be triggered during object recognition either by the perceptual bottom-up process (input depicted on the left side) or by its lexical label during verbal or imagery processes (input depicted in the right side). Easy access to the knowledge of an object's colour and hence to the loci of their memory representations, through verbal labels rather than a pictorial form, was similarly suggested by both Paivio and Linde, (1980), and Davidoff and Ostergaard, (1988). As depicted by the two sided arrows, the model allows for a top-down effect on the perceptual processes involved in recognition. This may include the effect of prior associations between the object's identity and its colour, thus incorporating not only the importance of colour in general, or the surface colour itself, but also the congruent colour - the particular colour that a particular object may have in everyday life (Joseph & Proffitt, 1996; Joseph, 1997). The model suggests that the process of object recognition is a result of both the bottom-up influence of perceptual colour and the top-down influence of colour knowledge (Rumelhart, 1986).

The significance of the specific top-down influence of colour knowledge on recognition memory beyond any other bottom-up or top-down effects of colour on memory was investigated in two experiments by Joseph et al., (1996) and Joseph (1997). Joseph et al. were interested in which of the two types of facilitation bottom-up or top-down, is more influential? It was argued that many of the previous studies concentrated solely on the effect of surface colour on recognition memory, leaving the effect of the 'prototypical' colours (or congruent colours) still unresolved. The studies measured reaction times using a verification task in which subjects were asked to indicate whether the pictorial and word stimuli referred to the same object. Two colour manipulations were used: stimuli coloured in the object's surface colour and stimuli coloured in the object's typical colour. Unlike typical colours, surface colours were chosen arbitrarily (e.g. purple tomato). The effects of colour as a surface feature or colour as stored knowledge were assessed separately for objects that could and could not be easily discriminated on the basis of shape. The findings revealed a dominant influence of stored colour knowledge over the surface colours. Stronger interference effects were produced by inconsistent semantic colour associations than by inconsistent perceptual colour associations. For example, when a picture of an apple was followed by the label cherry, interference was always greater than when a picture of an apple was followed by the label blueberry. This interference occurred regardless of the surface colour of the apple so that even when a purple apple was presented, the label blueberry did not produce more interference than the label cherry did. These findings were replicated and generalised a year later to verification tasks that included pictorial stimuli only (Joseph, 1997). The author therefore proposed that the activation of stored colour knowledge during object processing may have special status as an identifying attribute of objects during an automatic conceptual process. A few other studies can support this proposal. Firstly, it has already been mentioned that object colour knowledge, such as associative or functional object knowledge, is stored separately from information about its structure and possibly with other sensory object attributes (see above Davidoff's model for object recognition, and also Luzzatti and Davidoff, 1994). Secondly, a few studies show that children choose different grouping criteria - colour, for unfamiliar objects that they thought may taste similar (Macario, 1991), and shape, for unfamiliar objects that reminded them of some kind of toys (Humphrey et al., 1994) thus perhaps reflecting the separate processing of colour and shape information within the visual recognition system.

To conclude, various types of investigations using different methodologies as well as stimuli are indicating that colour plays a prominent role at high levels of visual processing as a result of memory representations directly linked to the knowledge of the object's colour.

1.1.5 A multiple memory systems framework of object recognition

The studies reviewed above demonstrate that the role of colour in recognition memory involves both low-and high-level processing. At the lower level, colour helps the visual system to segment (complex) images faster and more efficiently, thereby separating images in the visual field into identifiable objects. At the higher level, colour may be stored as part of the semantic representations of an object knowledge, which may be activated in cases where it resembles the perceptual input (surface colour) presented to the visual system and in turn result in memory facilitation. There is still considerable debate about the level of visual analysis at which colour influences recognition of objects. However, given evidence for both sensory and cognitive contribution, it has been argued that the question that ought to be asked is how can these findings be reconciled theoretically? Schacter & Cooper's (1992) distinction between two components of multiple memory system - *a structural description system* and *an episodic memory system*, may offer a reasonable solution. The first processes and represents structural information of images in the visual field and is responsible for mediating priming on implicit memory tasks, but not for representing visual properties like object size and colour. The second codes and represents the semantic and visual information that comprise the distinctive representation of a specific object (e.g. colour, function) and is associated with explicit memory tasks. Schacter & Cooper (1992) suggest that these two memory systems normally interact with each other when the task at hand demands the identification of a certain object in the human visual field:

"The picture emerging from our experimental work is of separate aspects of or systems for the representation and retrieval of information about visual objects. These systems act in concert during ordinary perceptual encounters with objects in the word, however, the systems can be dissociated and their distinguishable properties examined more closely by appropriate experimental manipulations with normal subjects and also in individuals with brain injury." (p. 145)

Recently, Wichmann et al., (2003) adopted the idea of a multiple memory systems framework to account for evidence that supports both a *sensory* (low level) *contribution* of colour to recognition memory and *cognitive* (high-level) *facilitation* of colour. Their findings revealed that the addition of colour was found effective in two different colour manipulations: it enhanced recognition memory in image segmentation of natural scenes and removed a memory advantage for falsely coloured images.

It has been well established that colour contributes at high levels of visual processing, and as a surface cue may activate memory representations that link to the knowledge of the *object*'s congruent colour. It may therefore be asked whether a similar high-level of colour processing is also involved in the processing of *emotive* stimuli. Any attempt to scrutinise such investigation necessitates a close examination of the *colour diagnosticity* effect, an effect that concentrates specifically on the role of the object's congruent (diagnostic) colour to recognition memory, (Biederman & Jul, 1988; Wurm et al., 1993; Tanaka & Presnell, 1999).

1.2. Colour Diagnosticity

1.2.1 Colour diagnosticity in object recognition

Just as the research of Biederman et al., (1988) was an important building block of the low level account of colour processing in object recognition theories, Tanaka and Presnell’s (1999) study was the foundation for the high level account of colour processing in object recognition models. Their study was the first to measure colour diagnosticity rigorously, and thus to provide normative data as to whether diagnostic colours of objects benefit recognition memory more than non-diagnostic colours. The basic assumption behind Tanaka and Presnell's (1999) study was that objects may vary in the extent to which colour influences (or can be diagnostic of) recognition. Colour diagnosticity was defined as the degree to which a colour is associated with or symptomatic of a particular object. The authors postulated that colour information would affect recognition of objects high in colour diagnosticity but not those low in colour diagnosticity. They used two different measures of colour diagnosticity: the feature listing task and the typicality task. These two distinctive measurements of colour diagnosticity were first used by Wurm et al. (1993) who, nevertheless, failed to find any superiority effect of high diagnostic colours of objects over low diagnostic colours of objects:

"…from an information-theory perspective, two factors determine whether colour is diagnostic of an object: The colour must be symptomatic of the object (e.g., "green" is a "symptom" of spinach), and not many other objects in the allowable domain should have the same colour." (p. 901)

In both studies (Tanaka & Persenall 1999 and Wurm et al., 1993) an object was rated high in colour diagnosticity if a specific colour was consistently mentioned first in the feature listing task and was also rated as the most typical colour of the object. The failure to show any effect of colour diagnosticity in the earliest study can be attributed, firstly, to a subjectivity bias caused by using a panel of nine judges only (as opposed to 30 in Tanaka and Presenell's study), and, secondly, to their failure to control for differences in size and shape among their objects. When these two shortcomings were accounted for, Tanaka and Presenell reported sweeping findings in favour of the colour diagnosticity theory.

Following Tanaka and Persenall's (1999) study, many other investigations began to emerge with supporting evidence of the colour diagnosticity effect on recognition memory when using a variety of task measurements as well as a wide range of stimuli (Naor-Raz, Tarr & Kersten, 2003; Latimer et al., 2002; Suzuki & Takahashi 1997; Wichmann, Sharpe & Gegenfurtner, 2002; Gegenfurtner & Rieger, 2000; Olivia & Schyns, 2000; Olivia & Schyns, 2005; Nagai & Yokosawa, 2003;1999 ; Vernon & Lloyd-Jones, 2003). For example, Nagai and Yokosawa (2003) have questioned whether the colour diagnosticity advantage was due to the frequent use of natural objects and images in the majority of the above studies. Their results however, revealed that the advantage of colour to recognition memory was obtained regardless of object category (man made versus natural) but only for objects high in colour diagnosticity.

Images of everyday scenes have also often been used as stimuli in recognition memory paradigms that question the colour diagnosticity hypothesis. Although, Suzuki and Takahashi (1997) reported that colour recognition superiority was more due to increased distinctiveness and image segmentation than due to the memory of the colour *per se*, Olivia and Schyns (2000) provided clear evidence that colour diagnosticity is also beneficial to scene recognition. Like other recent studies (Gegenfurtner & Rieger, 2000; Olivia & Schyns, 2005; Wichmann, et al., 2002), they stressed the importance of applying methodological improvements to ground scene recognition on colour information, namely, controlling the diagnosticity of colour and the physical luminance of the neutral stimuli. More specifically, as in the study by Wichmann et al., they used luminance-matched colour and black and white images and excluded the effect of image contrast from the colour contribution to recognition memory. A comparison between diagnostically and non-diagnostically coloured scenes revealed better performance for scenes coloured diagnostically on both accuracy and latency measurements of recognition memory. Similarly, computational models that permit accurate scene classification without the prior recognition of individual objects (Oliva & Torralba, 2001; Vailaya, Jain, & Zhang, 1998) make use of properties such as the spatial complexity of the scene, visual texture and diagnostic colours (Oliva & Schyns, 2000; Oliva & Torralba, 2001; Olivia & Schyns, 2005). Thus, the research succeeded in generalising the colour diagnosticity advantage on recognition memory from isolated objects to everyday scenes.

Although an extensive body of research validates the theory of colour diagnosticity, Naor-Raz, Tarr and Kersten (2003) have recently argued that it is still uncertain whether diagnostic (or natural) colours of certain objects play a substantial part in the conceptual representation of objects and should be tested preferably by using a Stroop paradigm (Menard-Buteau & Cavanagh, 1984; Klein, 1964; Naor-Raz, Tarr & Kersten, 2003). In their paper, Naor et al. made the argument that object recognition tasks recruit both visual and non-visual sources of information and thus impede the ability to establish the specific level or levels of processing (visual, conceptual, or lexical) at which the surface properties of an object affect its recognition. Accordingly, to test whether the visual representation of an object intrinsically includes surface properties such as colour, observers need to make judgments that do not directly invoke object identity - that is to name the colour of the object (rather than to name or identify the object itself). Their results were consistent with Klein's (1964) in showing faster mean response times for objects coloured in typical colours than for objects coloured in atypical colours. Clearly, this support for the colour diagnosticity theory, even when using a completely different task to those used previously in recognition paradigms, further strengthens its reliability.

The idea that colour (and shape) information is stored as part of the long-term memory representations, even for novel objects, was also proposed by Nicholson and Humphrey (2004). Their study manipulated colour congruency across study and test phases and used an old versus new shape-identification task to explore the role of colour in the recognition of novel 3-D objects. Correct identification was faster when stimuli were coloured congruently across study and test phases than when presented in different colours. This colour congruency effect on novel objects was shown to be significant when object colour was incongruent across study and test, but not when background colour was incongruent across study and test. It was concluded that congruent colour was a significant cue for correct identification of objects and as such takes part in the long term conceptual representation of objects.

1.2.2 Colour diagnosticity in the brain

The studies reviewed above indicate that colour is a powerful tool for recognition enhancement, particularly if it is a diagnostic colour of the stimuli to be remembered. Various different test paradigms were employed to provide evidence supporting the notion that colour is stored in the conceptual representation of objects and natural scenes. The scientific evidence provided above mainly involves support on cognitive grounds. Clearly, *perceiving* that a specific object (e.g. banana) appears in a typical (diagnostic) colour (e.g. yellow) and *knowing* that this object is typically coloured in a certain colour (e.g. banana is yellow) are two different cognitive processes (Tanaka et al., 2001). Neuropsychologically, evidence that the two distinct cognitive processes are associated with neural activation in distinct regions may support the colour diagnosticity theory. There are a few studies that concentrated specifically on this task (Chao, & Martin, 1999; Luzzatti & Davidoff, 1994; Martin, Haxby, Lalonde, Wiggs, & Ungerleider, 1995; Ungerleider, L. & Mishkin, M., 1982; Wiggs, Weisberg, Martin, 1999; Howard, Ffytche, Barnes, McKeefry, Ha, Woodruff, Bullmore, Simmons, Williams, David & Brammer, 1998; Zeki & Marini, 1998). Firstly, neuroimaging findings suggest a link between colour knowledge and object recognition processes, as evidenced by the common activation regions (left inferior temporal, frontal and posterior parietal area) triggered by both object-recognition and object-colour association tasks (Chao, & Martin, 1999; Martin et al., 1995). Secondly, Howard, et al. 1998 also discovered that there are separate neural areas that are activated by colour knowledge tasks and colour perception tasks. The left inferior temporal regions, specifically, were found highly activated by the retrieval of object colour knowledge (e.g. responding 'red' to a picture of an achromatic fire engine) but not by colour perception tasks (e.g. responding 'red' to a picture of a fire engine coloured in red; passively viewing a red fire engine). Thirdly, patient studies showed an intact ability to process perceptual colour and shape information (e.g. name the object or its colour) but an impairment in discriminating between appropriately and inappropriately coloured objects (Luzzatti & Davidoff, 1994).

More direct neural correlates of the colour diagnosticity effect on recognition memory come from the study by Zeki and Marini (1998). Participants were asked to observe normally coloured objects, abnormally coloured objects and achromatic Mondrian displays (arrays of different coloured patches). The two types of coloured stimuli, not surprisingly, activated V1 and V4 - both are cortical areas known to be involved in colour processing. The unexpected finding, however, was that different neural pathways were activated by the normally and abnormally coloured objects. Naturally coloured objects (e.g. red strawberries) activated the same brain areas that were found activated by different object colour-knowledge tasks - the fusiform gyrus, hippocampus and ventrolateral portion of the frontal cortex. Abnormally coloured objects (e.g. purple strawberries) on the other hand, activated the dorsolateral region of the frontal cortex. Although the above neuropsychological research provides evidence for separate neural correlates for congruently versus incongruently coloured objects, and also supports a separate neural mechanism for colour-perception processes and colour-knowledge processes in object recognition tasks, none have yet linked these separate neural mechanisms have not yet been linked with recognition memory processes. Thus it is still uncertain whether these neural correlates also reflect a neural network for the colour diagnosticity effects or merely show neural evidence for colour congruency.

1.3. Study Rationale I

As comprehensive as the above studies regarding the investigation of colour and memory may be, none have addressed the question of whether recognition memory will benefit particularly from colour cues when the stimuli are emotional. This is surprising given that colour and emotion have long been known as two dimensions that can be easily associated with each other, within and across cultures (Eysenck 1941; Wexner, 1954; Choungourian 1968; Valdez & Mehrabian 1994; Terwogt & Hoeksma, 1995; Boyatzis & Varghese 1996; Hemphill 1996; Hupka, Zaleski & Tarabrina, 1997; Zenter, 2000; Burkitt, Barrett & Davis 2003; Leichsernring 2004; Ou, Luo, Woodcock & Wright, 2004) and at different developmental stages (even for children as young as three years old**,** Zenter, 2000; Burkitt, Barrett & Davis 2003). These associations are often used in clinical settings as a therapeutic tool to enhance the ability to express deep traumatic feelings. If found beneficial to recognition memory, colour may also be valuable as a memory tool for the retrieval of suppressed emotional information (e.g. traumatic experiences and eyewitness testimonies). The present investigation aims to examine the role of colour in recognition memory of emotional information and specifically the colour diagnosticity effect on recognition memory of six basic emotions, presented both as textual (emotive words) and pictorial stimuli (facial expressions). Since Gohar and Latimer (submitted) demonstrated that colour improved recognition memory of the above emotional stimuli more significantly than grey-scale, luminance-matched stimuli, the present thesis mainly focuses on whether colour can be diagnostic for recognition memory of emotional information conveyed by facial expressions and emotive words. To address this aim, any effects of emotion on memory and of colour on emotions may also need to be considered, as these two additional effects may shape the direction in which diagnostically emotional colours influence memory. Consequently, in the following pages, studies regarding these two additional effects will be reviewed and discussed in light of their contribution to the current investigation.

CHAPTER 2

Overview II: Memory for Emotional Information

"An impression may be so exciting emotionally as almost to leave a scar upon the cerebral tissue." (James 1890, p. 670)

2.1 The Role of Emotion in Memory

Emotions manifest with some measurable response to a typically acute event. These responses can be overt, such as facial expressions, or covert, such as changes in the autonomic or central nervous systems (Ekman, 1964; Ekman, 1965; Levenson, Ekman & Friesian, 1990, Ekman, 1993). Psychologists have known for a long time that such emotional responses have a strong influence on many cognitive functions, among them is memory. There is evidence from many studies that emotional material is better remembered than neutral material (for review see Reisberg & Hertel, 2004; LeDoux, 2000). This memory enhancement of emotionally laden visual stimuli has been reported for various kinds of stimulus features including film clips (e.g. Cahill et al., 1996), pictures (e.g. Bradley et al., 1992), words (e.g. Kensinger et al., 2002; Nagae & Moscovitch, 2002), sounds (Bradley & Lang, 2000) and autobiographical experiences (Rubin & Schulkind, 1997). Emotional responses (measured behaviourally and physiologically) to these materials were shown to fit reliably with two primary dimensions: valance and arousal (Greenwaild et al., 1989; Lang, Bradley, & Cuthbert, 1998). The dimension of valence typically refers to the direction of an emotional response - that is whether the effect is positive/appetitive or negative/aversive and ranges from highly positive to highly negative. The dimension of arousal, on the other hand, most often refers to the magnitude of an emotional response and ranges from calming to exciting (Russell, 1980; Lang et al., 1992). Physiologically, research has shown that somatic responses are specifically tied to differences in the rated pleasantness of emotive stimuli whereas skin conductance responses reliably covary with changes in rated arousal. For example, Lang, Greenwald, Bradley and Hamm (1993) reported that facial electromyographic responses have the ability to index the affective valence dimension, specifically the corrugator (‘frown’) and zygomatic (‘smile’) muscles, which vary with changes in pleasantness ratings. As the pleasantness of the emotive stimuli decreases, corrugator activity increases and zygomatic activity decreases. Judgments of arousal can be traced by the magnitude of the skin conductance responses. Past research aimed at addressing the question of which of the above dimensions is the most influential on memory has produced mixed results (e.g. Bradley, Greenwald, Petry & Lang 1992; Cahill et al., 1994; Cahill & McGaugh, 1995). Although emotional arousal, in most cases, found to be critical for the emotional enhancement effect in memory, there is evidence that memory can be also enhanced even for positive or negative stimuli that do not elicit arousal (Ochsner, 2000; Kensinger & Corkin, 2003; Kensinger et al., 2003; D'Argembeau & Linden, 2004; Doerksen, & Shimamura, 2001).

2.1.1 The use of six basic emotions as emotional stimuli

This investigation will employ facial expressions and (emotional) words as emotional stimuli representing the six basic emotions – happiness, anger, sadness, surprise, fear, disgust, and a comparable neutral category. The use of six basic emotions has been proven, in the literature, sufficiently reliable and valid to represent the range of human emotional expressions (Ekman, Friesen & Ellsworth, 1982; Ekman, 1973; Ekman & Friesen, 1978, 1986; Plutchik, 1962, 1980; Russell, 1995, 1994). Ekman and Friesen proposed that the basic emotions appear to be universally associated with, and recognisable by, characteristic facial expressions and as such may further serve identifiable biological functions related to the survival needs of the individual and of the species.

"… in my view expression is a central feature of emotion, not simply an outer manifestation of an internal phenomenon." (Ekman, 1993, p. 384)

Silvan Tomkins has also suggested that a face has *"… the greatest importance in producing the feeling of affect."* (Tomkins, 1998: p. 212)

Though it may be argued that facial expressions may represent emotions more reliably than any other emotional stimuli, specifically words, Doerksen and Shimamura (2001) have pointed out that the emotional intensity associated with word stimuli may be less than with pictures. Kensinger and Schacter (2006) found that valence-dependent activation of the prefrontal cortex was much stronger for pictures than for words. Consequently, both stimulus types were employed in the present study, to account for any potential differences in the intensity of emotional responses produced.

Although some basic emotions can be seen as representing either an arousal or a valence dimension (happiness has a positive valence whereas surprise has high arousal) most of the six basic emotions, like other more complex emotions, reflect an orthogonal relationship between the two dimensions (Russell, 1980; Lang, 1995; Bradley et al., 1992) depending on the degree of intensity and the magnitude of the emotional state experienced at a certain time (e.g. anger can be highly negative but also highly arousing). Clearly, with the exception of surprise (which can be interpreted as either negative or positive) it may be argued that the valence (the direction of positive versus negative) of the six basic emotions is less prone to subjectivity (fear, anger, sadness and disgust are mostly referred to as negative emotions, and happiness as positive). However, studies investigating the dimension of arousal provide a basic understanding of the general role of emotions in memory (Kensinger & Corkin, 2004; Kensinger & Schacter, 2006; Lewis, Critchley, Rotshtein, & Dolan, 2007). Consequently, theories and possible cognitive mechanisms of how emotions affect memory will be discussed first with regard to the arousal dimension. Focus will be then given to the more specific effect of valence on memory for emotional versus neutral information.

2.1.2 Effect of arousal on memory

The experimental literature paradigms has tended to assess memory for stressful or high arousal material (mostly negative), often compared to neutral stimuli (Christianson & Lofttus, 1991; Christianson & Nilsson, 1984; Brown & Kulik, 1977; Clifford & Hollin, 1981; Neisser & Harsch, 1990). The findings are diverse. Some studies have found that arousal has an adverse effect on memory and may disrupt certain aspects of memory. Kihlstrom (1995) suggested that severe emotional trauma can cause amnesia for the traumatic event. According to the Freudian repression hypothesis, unpleasant emotional or traumatic events are repressed from the conscious state to avoid confrontation with psychological pain (Freud, 1915, 1957). On the other hand, a wide variety of studies also demonstrate that memories for negative emotional events are retained quite well (e.g. Bohannon, 1992, for a review see Christianson, 1992). The common explanation for the enhancement effect of arousal on memory is that, over time, the unpleasant events are less threatening and thus become more accessible to conscious memory

Yerkes & Dodson (1908) proposed an *inverted-U-form relation* between arousal and cognitive performance to consolidate the diversity in the emotion and memory literature. According to this model, moderate levels of emotional arousal are assumed to facilitate learning and memory performance. Successive increase in emotional arousal beyond the optimal arousal level correlated with a lower degree of performance. Such an argument assumes a single dimension of arousal that ranges from low to high and as such will predict a very low memory performance at extreme levels of negative arousal. This assumption was challenged later by numerous contemporary studies which showed evidence to the contrary - a general increase in the arousal or intensity of affect promotes memory for a broad spectrum of details. In the eyewitness literature for example, it was demonstrated that some critical information of traumatic events (e.g. rape cases) was retained quite well (e.g. Christianson & Nilsson, 1989) and is also manifested in the common phenomena of *flashbulb memories* (coined by Brown & Kulik, 1997). Flashbulb memories are highly vivid and detail-oriented memories for emotional events that seem to remain stable over long periods of time. A photograph-like memory for the circumstances in which one learned of the attacks on the Word Trade Center would be an example of a flashbulb memory. Studies examining the specific phenomenon of 'flashbulb' memory have further claimed that the more intense the emotional reaction to the discovery of the shocking event, the better the retention of attendant circumstances over time (Bohannon, 1988, 1992; Pillemer, 1984). Others have recently suggested that these highly emotional memories are usually associated with vivid details of the event and high confidence that the memory is accurate which, however, do not necessarily accurately reflect the facts (Neisser & Harsh, 1992; Talarico & Rubin, 2003; Schmolck et al., 2000). Taken together, these flashbulb memories suggest an important role for emotion in memory processes - an independent enhancement of the subjective sense of remembering (Phelps, 2006). Thus, high levels of emotional arousal (which are mostly negative) tend to be associated with the persistence of a broad spectrum of detailed information, both central and peripheral although not always with high accuracy.

Easterbrook's (1959) *cue-utilization hypothesis* suggests that subjects in intense states of stress and emotion attend to only a few details using a limited availability of attentional resources and at the expense of attention for irrelevant cues (such as contextual or source information). The contemporary variation of Easterbrook's (1959) theory is the *attentional narrowing hypothesis*. It also states that heightened emotion directs attentional focus toward the emotion-eliciting stimulus at the expense of attention (and subsequent memory) for peripheral information (Reisberg & Heetel, 2004; Loftus et al., 1987; Schmidt, 2002). Touryan, Marian & Shimamura (2007) have recently assessed memory for central item (emotional arousal versus neutral) information, peripheral information (object), and the association between item and peripheral information. Their findings show better memory for negative arousal center items than for neutral center items. In line with the attentional narrowing theory, performance worsened for associative memory between item and peripheral information when the central items were negative compared to neutral. Nevertheless, memory for the peripheral objects themselves was equal for the negative emotional arousal items and the neutral items. The authors concluded that negative arousal information particularly disrupts the associative links between peripheral information and central emotional events. Thus, it seems that attention plays a major role in mediating the effect of emotional arousal stimuli on memory and tends to be the reason for an increased likelihood that emotional aspects of experiences are remembered. Emotional items also appear more likely to be processed when attention is limited, suggesting a facilitated processing of emotional information (Dolan & Vuilleumier, 2003). For example, Kensinger & Corkin, (2004) reported that processing of arousal items is less likely to suffer from demands on attention. Their study participants were asked to encode words either as the sole task or while concurrently performing an auditory discrimination task. Results showed that memory performance for the neutral items was significantly affected by the performance of the secondary task, whereas memory performance for emotional items was not. Other studies revealed similar results using a phenomenon known as 'attentional blink' (Raymond et al., 1992; Chun & Potter, 1995; Keil, Ihssen & Heim, 2006) which demonstrates that when items are presented in close proximity within a stream of rapid presentations, participants are less likely to miss an emotionally targeted item than a neutral item.

Different distributions of attention to different stimuli dependent on the level of emotionality are certainly central to explaining the effect of emotional material on memory. However, other mechanisms that are more automatic in fashion and that involve *preattentive* (perceptual) processes are also suggested in the literature. Christianson et al., (1991) proposed that certain characteristics of emotional information are processed in an automatic fashion that uses preattentive mechanisms which do not involve consciously controlled memory processes either at acquisition or retrieval. Their study, like some others (Christianson & Loftus, 1991; Christianson & Fallman, 1990), revealed congruence in memory performance at short and long exposure durations for emotional material but not for neutral material. Subjects presented with emotional stimuli at short exposures (180 ms) performed equally well as when the same stimuli were presented at a longer exposure. Thus, it was concluded that preattentive or automatic information processing took place when stimuli were presented at the short exposures. Such preattentive processing is assumed to be fast, non-conscious, independent of context and dependent on limited processing resources (Öhman, 1991; Tulving & Schacter, 1990). According to this model of processing, being faced with emotional circumstances will therefore result in a process that promotes memory for central detail information, but impair memory for peripheral information of the emotional event. This can be demonstrated again by the eyewitness testimony effect called 'weapon-focus' (Loftus, 1979; Loftus, Loftus & Messo, 1987). Witnesses to a crime often will remember the weapon from the crime but not other details such as the perpetrator's clothing or vehicle.

In addition to aspects of attentional selectivity that are part of the encoding phase, emotional arousal items also seem to uniquely influence retrieval and storage stages. There are indications that memories of personal experiences associated with very intense feeling (regardless of their valence) are stored more accessibly (as evidenced by their being quick to be retrieved) than those associated with mildly intense feeling (Christianson & Nilsson, 1984; Robinson, 1980; Wagenaar, 1986). Pertinent to this discussion of retrieval facilitation in memory for emotional information are the *mood-congruency* and *mood-dependent* retrieval effects, originally demonstrated by Bower (1981). A variety of mood and memory investigations, which often used the strategy of mood induction, have made the general point that people will store more information consistent, rather than inconsistent, with their mood - an effect called mood selectivity or mood congruency (Blaney, 1986; Bower, 1981; Bower, Monterio & Gilligan, 1978; Clark, Milberg & Ross, 1983; Eich, 1980). For example, a person who feels excited is more likely to notice and later remember positive information (e.g. being praised for doing good work) than negative information (e.g. forgetting someone's birthday). Similarly, a depressed person is more likely to notice and later remember negative rather than positive information. On the other hand, research focused on the effects of mood states on the *retrieval* of previously learned material (*mood-state-dependent*) has revealled more equivocal results. In most of these studies, the main hypothesis generally tested was whether mood induced at the time of recall selectivity influences what is remembered from previously learned material. That is, will people remember better if they are in the same mood when they recall an experience as they were in when they originally had the experience? Some experiments investigating mood only at recall succeeded in finding the mood selectivity effect (Laird, Wagener, Halal & Szegda, 1982; Teasdale & Russell, 1983; Forgas, Bower & Krantz, 1984; Fiedler & Stroehm, 1986) while others have failed to show the effect (Bower & Mayer, 1985, 1989; Bower et al., 1981). To consolidate the differences in these findings, Bower has suggested the causal belonging hypothesis (Bower, 1987) which attributes the failure to show a mood selectivity effect during retrieval to the fact that the subject's mood has been induced externally to the to-be-remembered items. In line with this postulation, memory enhancement for details of emotional events will exist only when the emotional arousal is evoked by the to-be-remembered item rather than being evoked by a source that is causally unrelated to the to-be-remembered item. It has therefore been concluded that:

> *"…a state of increased emotional arousal is significant as an intervening variable in explaining memory enhancements only when the emotional reaction is an inherent property of the to-be-remembered event." (Christianson, 1992, p. 293)*

Beside the beneficial effect on storage and retrieval of emotional information, there are empirical findings that suggest that there may also be some additional critical aspects of increased memory consolidation for emotional arousal items. It has been argued that beside the different encoding process for emotional and neutral events, there may also be recall patterns that are different for the two types of events which reflect different patterns of storage. Heuer and Reisberg (1990), for example, argued that unlike neutral memories, emotional memories are centered around the causes of the emotions and as such may provoke thoughts, feelings, and other reactions that would cause subjects to personalise the meaning for the emotional event - a process which will result in better and longer memory for the emotive event compared to the non-emotional one.

Similarly, MacKay and Ahmetzanov (2005) have argued that flashbulb memory effects may reflect enhanced elaboration and repetitive encoding of emotional experiences during the recall interval, rather than the superior initial encoding that the term ‘‘flashbulb’’ suggests. An experimental paradigm (a Stroop colour-naming task) designed to induce an analogue of flashbulb memories was used in two experiments (MacKay et al., 2004; MacKay & Ahmetzanov, 2005) to assess memory for emotional events (taboo words) and their contextual details (font colour and location of the taboo and neutral words) while controlling for attention, stimulus factor, elaborative encoding and rehearsal. Participants were instructed to first name the font colour of the word as quickly as possible and to then recognize the contextual details (colour or the location) of the words in a surprise recognition memory test (to prevent rehearsal or elaborative encoding). In both experiments participants remembered the contextual details better and with higher confidence ratings when the words were associated with emotional-taboo words than when they were associated with neutral words. The authors suggested that the results support the binding hypothesis in which emotional reactions trigger binding mechanisems that link the specific source of an emotion (the meaning of emotional word or event) to salient contextual details such as location and colour. Memory for contextual details was enhanced only for those details that were directly linked with the emotional word but not for details that were indirectly linked with the emotional words, the fuzzy-photograph hypothesis, which suggests that emotions induce imagelike memories (storage of all perceptual features that are active simultaneously during the induction of an emotional event regardless of their relation to the emotion), was rejected as a possible account for the flashbulb memory effects.

Taken together with the studies reviewed above, it can be concluded that the processing of emotional arousal information implements an elaboration mechanism that may interact with preattentive, fast, automatic mechanisms. The evidence that subjects remember central detail better from emotional events than from neutral events, even when the detail is shown only for very brief durations, may suggest that preattentive processes and attentional capture alert people to attend to emotional information which then leads to more elaborative, controlled processes that eventually enable people to preferentially process central details over peripheral details. Furthermore, there is evidence that even when attention, elaboration and rehearsal processes during emotional processing are controlled, binding mechanisms between units representing an emotional event and its closely related perceptual details are active during emotional reactions to the emotionally charged event (or word) and allow for a memory facilitation effect for these contextual features

2.1.3 Effect of valence on memory

In comparison to the large number of studies investigating memory abilities for arousing items, relatively few studies have examined memory for non-arousing positively or negatively valenced information. Nevertheless, the studies that have examined memory for the two types of emotive stimuli have suggested that the valence dimension is sufficient to boost memory performance (Kensinger & Corkin, 2003). A few recent studies which have used words (Kensinger & Corkin, 2003; Doerksen & Shimamura, 2001; D'Argembeau & Linden, 2004) as well as photographs (Dolcos & Cabeza, 2002; Kensinger et al., 2002; Ochsner, 2000; Margaret et al., 1992) found that positive and negative items were better remembered than neutral ones. Unlike the findings from the arousal literature, which mostly demonstrated memory facilitation for the gist of emotional events at the expense of peripheral details, studies investigating emotionally valenced words tend to reveal memory enhancements not only of the emotional item itself and its closely related details but also of its contextual and more peripheral information. For example, Kensinger & Corkin (2003) asked subjects to judge whether a visually presented word was (a) vividly remembered from a collection of neutral and negative words (b) familiar and believed it had been presented before, or (c) a new one that was not presented previously. In a second experiment, subjects were also asked to indicate the colour in which the word was initially presented. The results revealed that 'remember' responses were more frequently assigned to negative words than neutral words and that subjects remembered the correct colours in which negative words were initially presented significantly more than the colours of neutral words. Likewise, Doerksen and Shimamura (2001) used colour as a contextual detail presented in two different ways: colour was used as the ink colour of emotionally valenced and neutral word stimuli and even more peripherally as the colour of the background. The results demonstrated the same pattern of memory facilitation shown in the former study, with memory enhancement for the content and the contextual colour (when used both as background and ink) of the emotionally valenced stimuli but not for the content or context of the neutral stimuli.

What cognitive explanation may support the memory enhancement effect for valenced emotional stimuli and their associated details? Suggestions have been made toward processes distinct from those mediating the enhanced memory for arousing items which, as discussed above, are known to be affected more by automatic, attentional modulation (Kensinger, 2004). Craik, 2002 among others (e.g. Macrae et al., 2004; Kensinger & Corkin, 2004; Talmi & Moscovitch, 2004) has proposed that memory for positive and negative non-arousal stimuli may benefit most from conscious encoding strategies, like elaboration that can be either autobiographic or semantic. For example, the author suggested that people may process negative or positive information in regard to themselves such that words like ‘grieving’ and ‘gladness’ may be more likely to be associated with previous autobiographic memories than neutral words such as ‘equalize’ or ‘abstain’. Similarly, it can be argued that valenced items contain a semantic cohesiveness typically not present with neutral items. Talmi and Moscovitch (2004) have specifically tested this postulation and found that the memory advantage for valenced over neutral stimuli is eliminated when both types of stimulus share similar inter-item associations (this elimination of memory enhancement however was not present for arousal stimuli, Buchanan, Etzel, Adolphs & Tranel, 2006; Doerksen & Shimamura, 2001). Contrary to the above findings, D'Argembea and Linden (2004) provided evidence that suggests that the influence of affective meaning on context memory may involve an, automatic modulating effect of attention on the contextual and perceptual details of the emotional item. Their findings showed that subjects remembered the colour in which affective words were presented significantly more than the colour of neutral words only when subjects were not directly instructed to remember the colour details (when given incidental instructions rather than intentional instructions). Memory of the emotional stimuli themselves, however, was consistently higher than the memory of neutral stimuli, regardless of the type of instructions given. The authors then further argued that this memory enhancement effect, evident for both the emotional stimulus itself and its contextual information, was due to the distinctiveness of these stimuli relative to neutral words since the memory advantage was eliminated when the stimuli were presented to subjects in pure lists of emotional valenced and neutral stimuli.

Considering that the benefit of valenced emotional stimuli can be explained due to their being more semantically cohesive or distinctive than neutral stimuli, and given also the known phenomenon of colour and emotion association (which will be discussed in more detail in the following chapter), it may reasonably be assumed that such association will benefit memory of emotional stimuli more than neutral stimuli, particularly when the emotional information is presented with highly associated colours of emotions. Further support for this hypothesis comes from a recent study (Kensinger, Garoff-Eaton & Schacter, 2006) which, contrary to the previous study's failure to show effects of emotion on memory for visual detail, succeeded in providing evidence that emotional content can increase the likelihood that visual details are remembered. The study therefore indicates that emotional information can influence not only the subjective feeling of vividness associated with a memory (Dewhurst & Parry, 2000; Kensinger & Corkin, 2003; Ochsner, 2000; Reisberg et al., 1988) but also the likelihood that specific visual details (like colour) are remembered quite well from a previously encountered emotional item.

Since the majority of the studies reviewed above report a memory advantage for non-arousing negatively and positively valenced information compared to neutral information, the question of whether this memory advantage is different for the two types of valenced stimuli, negative versus positive, is still unanswered. Generally, isolating the effect of happy or positive non-arousing information on memory is evident only to a limited extent in the literature (Kensinger, 2004) and the few experimental investigations that have addressed this issue reveal inconsistent patterns. For example, Matlin and Stang (1978) found better memory (recall) for pleasant verbal materials than for unpleasant materials, an effect called the Pollyanna Principle. The effect was explained by the human tendency to store positive information more accessibly in memory since information that is positive may have greater levels of contextual associations than negative information. Warr (1971) similarly argued that positive words are, in general, used more often than negative words, which may imply that there is a lower information-processing threshold for positive characteristics versus negative characteristics. More recently, D'Argembeau, Linden, Comblain and Etienne (2003) conducted an experiment in which participants were presented with happy and angry faces in an intentional or incidental learning condition and were later asked to recognise the same faces displaying a neutral expression. The results showed that the neutral expressions were better recognised when presented with a happy rather than an angry expression, but only when the subjects were given intentional instructions. The authors suggested that this recognition facilitation for happy facial expressions reflects the social meaning of emotional expressions given by the observer.

Many other studies indicate that cognitive processes tend to favor negative rather than positive information. Taylor (1991) reviewed the literature and noted that negative stimuli produce "more cognitive activity", "more cognitive work" and "more complex cognitive representations" than positive stimuli do (pp. 70-71). Robinson-Riegler and Winton (1996) also presented results in favour of memory facilitation for negative information. Their participants were presented with two encoding phases, one visually and the other auditory, and they were then assigned to two recognition conditions. The first recognition condition required them to exclude all the items presented during the first encoding phase and to identify old items from new only if they had been presented in the auditory encoding phase. In the second condition, all items previously presented were included as old and participants were asked to identify them from a set of new items. Results showed that participants assigned to the first (exclution) condition were significantly better at correctly rejecting negative items than positive items. Other experiments have revealed either marginal or non-significant differences between the two types of stimuli (Bradley & Baddeley, 1990; Bradley, Greenwald, Petry & Lang, 1992).

2.1.4 Biological and neurological mechanism of emotional memory

Taken together, the studies reviewed above suggest that emotion has powerful influences on memory which involve multiple cognitive stages of information processing. The question that will be addressed in this section is - what neural and biological mechanisms support these effects? Just as recent findings suggest the involvement of different types of information processing for arousing versus valenced emotional stimuli, the corresponding neural mechanisms have also been recently suggested to be quite distinct (Kensinger & Corkin, 2004; Lewis, 2007; Sharp et al., 2004, Small et al., 2001).

When processing emotional arousal stimuli which can be selectively attended and may also benefit from preattentive processes, a sub-cortical structure within the temporal lobe called the *amygdala* usually shows high activation. Psychophysiological studies (McGaugh, & Roozendaal, 2002; McGaugh, 2004) suggest that stress and emotional arousal lead to the release of two stress hormones: norepinephrine (a fast acting neuromodulator) and glucocorticoids (a slow acting neuromodulator). These hormones influence the activity in the amygdala which then feeds back into memory consolidation and storage sites as well as the amygdala itself to enhance memory over long time delays (Buchman, Karafin & Adolphs, 2003; LaBar & Cabeza, 2006; Kensinger, 2004). The amygdala does not seem to store emotional memories (or associations to previously experienced emotional events) but rather modulates the hippocampus which activates these memory representations (Roozendaal, 2003; Richter-Levin, 2004). Hippocampal function is also sensitive to glucocorticoids but in a non-liner fashion. Low levels of this chemical, such as that released during a mildly stressful event, can facilitate hippocampal function (Roozendall, 2003; Sapolsky, 2003; Richter-Levin, 2004). The slow-acting nature of glucocorticoids may explain the findings that memory improvement for arousal emotional items is greater after longer delays than after relatively short ones (Eysenck, 1976; Heuer & Reisberg, 1990; LaBar & Phelps, 1998). Furthermore, this mechanism can reconcile the inconsistency in literature that on one hand shows memory enhancement for arousal stimuli but on the other hand presents evidence that stress can impair memory. Since the amygdala is sensitive to emotional stimuli, it may encourage (via modulation of memory areas like the hippocampus) selective processing of particular emotive information. The result is an enhanced emotional memory for the item itself but at the expense of consolidation of the neutral peripheral information associated with that item (LaBar & Cabeza, 2006; Phelps, 2006).

Numerous neuroimaging and patient studies examining the neural responses associated with processing valenced versus arousing stimuli have shown distinct brain regions mediate the analysis of each type of stimulus. Amygdala activation varies with arousal but not with the valence of presented stimuli, whereas activity in the prefrontal cortex varies with valence but not with arousal (Corkin, 2004; Kensinger & Schacter, 2006; LaBar & Cabeza, 2006; Lewis, et al., 2007; Phelps, 2006; Savage et al., 2001). These studies specifically suggest that the neural processes that underlie the conscious encoding (and elaboration) of valenced non-arousing stimuli are mostly mediated by prefrontal-hippocampus interactions (Kensinger, & Corkin, 2004; Kensinger & Schacter, 2006; LaBar & Cabeza, 2006; Lewis, et al., 2007; Phelps, 2006; Savage et al., 2001). Evidence for the role of the prefrontal cortex in mediating elaborative processes partly derives from data from patients with specific prefrontal damage who could not engage in controlled, self-introspective or encoding strategies (Gershberg & Shimamura, 1995). Other support comes from findings showing correlations between depth of processing, likelihood of memory enhancement and prefrontal activity (Sharp, Scott & Wise, 2004; Savage et al., 2001) and from the modulation of prefrontal activation during encoding disruption, such as when the subject's attention is divided (Anderson et al., 2000).

Although most studies to date have confirmed that amygdala activity has been found to relate to the intensity, or arousal, of the stimuli irrespective of valence, Kim et al. (2003) found evidence that the dorsal amygdala may respond on the basis of arousal, whereas the ventral sub-regions may respond in a valence dependent manner. Lewis et al. (2007) recently found that orbitofrontal modulation mostly correlated with increases in valence, but a small region of this area also correlated with changes in arousal. The latter study, like a number of others, also proposed a neurological distinction between aversive versus positive responses as reflected in the activation of lateral prefrontal cortex regions and medial prefrontal cortex regions respectively (Kensinger and Schacter, 2006; O'Doherty et al., 2001; Small et al., 2001).

2.2 Study Rationale II

In summing up the findings so far, one can conclude that the interaction between emotion and memory is very complex. The focus of this thesis will be on the differences in memory between emotional and neutral facial expressions and words with special regard to the effect of colour congruency on these memory differences.

Thus, this thesis seeks to expand on the previously shown findings of memory facilitation for emotive stimuli compared with neutral stimuli and to investigate whether the addition of colour associations with each type of stimuli will also reveal a similar pattern of memory enhancement. The key question is, will the difference in recognition memory between appropriately and inappropriately coloured emotive stimuli be greater than the difference between appropriately and inappropriately coloured neutral stimuli? Since this investigation mainly focuses on the effect that colour and emotion associations may have on memory, the use of six basic emotions is particularly imperative for the representation of such emotional associations. As it will be shown in the following chapter, when assessing the associative relationship between colour and emotion, research has often utilised at least some of the six basic emotions for emotional representations. Thus, within the emotional dimension (and with the addition of appropriate and inappropriate colours) the present study will focus more on the difference in recognition memory among the six basic emotions than on differences between positive or negative emotions, thus relying more on the contribution of valence to memory than on the contribution of arousal to memory.

Finally, the above discussion also suggested that visual details (e.g. colours) are often stored during the participants' exposure to emotional information. Thus it is expected that when these visual (colour) cues are also presented in retrieval they will aid memory performance of the emotional stimuli itself. Such memory advantage may be even stronger for visual details that are closely associated with the to-be-remembered item than for visual details that are not associated with the to-be-remembered stimulus. As will be demonstrated later, colour is undoubtedly a good candidate to examine these assumptions.

CHAPTER 3

Overview III: The Relationship between Colour and Emotion

My Red is so confident
He flashes trophies of war and ribbons of euphoria
Orange is young, full of daring
But very unsteady for the first go round
My Yellow in this case is not so mellow
In fact I'm trying to say that it's frightened like me
And all these emotions of mine
Keep holding me from giving my life to a rainbow like you.
Jimi Hendrix, *AXIS - Bold as Love* [1968]

3.1. Colour and Emotion Associations

As was suggested in the first chapter, the basic purpose of human colour vision may involve the discrimination of objects among similarly structured stimuli. At a more elaborate level, however, this sensory capacity may also be used to attribute salience and meaning to colourful stimuli that are constantly present in our everyday lives. A prime example is that individuals not only show specific colour preferences but also attribute emotional characteristics to colours from a very early age (Boyatzis & Varghese, 1996; Zentner, 2001). This phenomenon was verified both within and across cultures (e.g. Hemphill, 1996; Valdez & Mehrabian, 1994; Wexner, 1954). A large number of empirical studies offer scientific evidence for the influence of colour on emotional responses, many of which have specifically focused on the link between colour and emotional associations. To date, this evidence for colour-emotion effects spans several disciplines including art, design, marketing, linguistics, health and psychology. Together these disciplines encompass a multitude of applications. Artists, for example, often use certain colours to evoke particular emotions or to create a certain type of atmosphere in an artwork. The colour red, for instance, is often used in art to convey energy, danger, anger, passion, desire or love. Within the domains of marketing and consumer behaviour, studies suggest that colour can be used to increase or decrease appetite (Zellner & Kautz, 1990), enhance mood, calm down customers and reduce perception of waiting time, among others (Singh, 2006). Psychological investigations that have employed colour present a wide array of effects on human behaviour. Colour, in its many applications, has been shown to affect not only people's preferences or their conceptual associations, but also physiological measures of emotional responses, work performance, mood and even voting behaviour. Thus, it seems that colour information impacts upon many aspects of human behaviour, and emotional state. This chapter presents a review of the extant literature on colour and emotion associations, together with a few other effects of people's emotional responses to colour. It therefore begins with reviewing colour effects that have been studied thoroughly in previous years but have received rather limited support recently and continues with what is currently and most commonly agreed on.

3.1.1 Physiological responses to colour

The literature on the effect of colour on human behaviour initially pondered whether physiological responses can determine an individual's reaction to colour and how these responses interact with emotional responses. The argument developed from the predominant findings on colour and its effect on plant growth. Colour has the ability to evoke physiological changes in plant growth (Birren, 1961). For example, most plants will react in opposite directions to red and blue light. They turn toward and experience increased growth under warm coloured light (red, orange, yellow) and become inactive or experience slowed growth under blue light (Birren, 1961). Research that followed studied the physiological effects of colour on humans and measured physiological responses to colour by means of galvanic skin response (GSR), electroencephalograms (EEG), heart rate, respiration rate, oximetry (level of oxygen in the blood), eyeblink frequency and blood pressure (Kaiser, 1984). These studies have been largely motivated by the hypothesis that long-wavelength colours (warm colours: red, orange, yellow, etc.) are more arousing than short-wavelength colours (cool colours: green, blue, etc.) (Lewinski, 1938; Goldstein, 1942; Dixon, 1960; Wilson, 1966; Valdez & Mehrabian, 1994). Empirical studies generally have shown that the colours red and yellow are indeed more arousing than blue and green (e.g. Jacobs & Suess, 1975; Schauss, 1985; Wilson, 1966). Similarly, Lüscher (1971) demonstrated that the colour red resulted in a faster heart beat, increased pulse, increased blood pressure and faster breathing frequency in subjects. More recently, Abbas, Kumar and McLachlan (2005) exposed subjects to eight different colours at various light intensities and revealed changes in heart rate, skin conductance and self-assessment reports of arousal and valence due to change in colour and lighting conditions. However, since most of the above findings were not successfully replicated (Ingram & Lieberman, 1985; Kunishima & Yanase, 1985), Davidoff (1991) assumed that most studies had resulted in premature conclusions that were based on poor experimentation by failing to implement proper stimulus control (e.g. the brightness of different coloured lights). When Kaiser (1984) reviewed studies on physiological responses to colour, he acknowledged that there may be a certain effect of colour on physiology but critically concluded that the evidence of various physiological tests were inconclusive and the results were not yet stringent enough to reveal a general tendency. Detenber, Simons, Roedema and Reiss (2000) subsequently, demonstrated that colour does not cause any effect on the physiological component of emotional experience. The investigation involved the emotional effects of colour in brief television clips using physiological (skin conductance, heart rate and facial electromyography) and self-report measures of the participants' emotional reactions. Participants reported that colour pictures were more pleasing and exciting than monochrome versions of the same images, yet there was no difference in their physiological responses.

3.1.2 Effect of colour on mood, performance and other behaviours

Studies on the measurement of behavioural patterns of emotional response to colour carried out both under laboratory and field conditions also reveal a few well-documented effects of colour on behaviour. Colour has been employed in the participant's environment in many different ways (e.g. colour of light, colour as a contextual or environmental cue) and yielded a variety of behavioural effects on perception (Damhorst & Reed, 1986; Hill & Barton, 2005), identification of odors and tastes (Zellner, Bartoli & Eckard, 1991), voting behaviour (Garrett & Brooks, 1987), aggression in sport (Frank & Gilovich, 1988) and enhanced work or other performance attainment (Ainsworth, Simpson, & Cassell, 1993; Hill & Barton, 2005; Stone, 2001). To illustrate, in a study by Schauss (1985), subtle shades of pink were purported to reduce aggression and violence. Its application indeed revealed some success in police detention cells. Damhorst and Reed (1986) showed that male raters perceived female models wearing dark jackets as more powerful and competent than models wearing light jackets. Garret and Brooks (1987) found that the colour of ballot papers (pink or green) influenced voters' choice. Female voters more favourably chose candidates whose details were displayed on pink paper, whereas male voters more favourably chose candidates whose details were displayed on green paper. Respondents' behaviour was also shown to be affected by the colour of the questionnaire. Matteson (1974) had found, in a mailing survey, that a pink questionnaire compared to a white questionnaire increased the response rate significantly. The colours of the physical environment are thought to have important effects on human behaviour. Read, Sugawara and Brandt (1999) found that wall colours were related to levels of cooperative behaviour among preschool children. A white ceiling compared to a red ceiling led children to lower levels of cooperation (i.e.

playing together with a toy). Furthermore, coloured lighting was suggested to have the capacity to exert a powerful influence on an individual's mood. The idea behind this hypothesis posits that long-wave light (red) can produce a direct effect on the endocrine system via the pituitary gland and through its activation it increases aggressive behaviour. Under the short-wave (blue/purple) light, however, such behaviour seems to decrease (Lewinski, 1938; Nourse & Welch, 1971; Schauss, 1985; Wilson (1966). Rosenathal, Sack, Cerpenter, Parry, Mendelson and Wehr (1985) accordingly found that bright light has an antidepressant effect and was therefore found to be a useful intervention tool for patients suffering from seasonal affective disorder. More recently, a study (Knez, 2001) investigated the influence of the colour of light (‘warm’, ‘cool’ and artificial ‘daylight’ white lighting) on subjects' self-reported mood, cognitive performance and room light estimation. Although no direct effect on positive and negative mood was indicated, all subjects performed better in the ‘warm’ than in the ‘cool’ and artificial ‘daylight’ white lighting on a short-term memory task. On a long-term memory task males performed best in the ‘warm’ and ‘cool’ white lighting and women performed better than men in artificial ‘daylight’. Colour was also found to have a significant role in odor identification tasks (Zellner et al., 1991; Zellner & Kautz, 1990). Zellner et al. (1991) for example found that participants identified flavors more accurately when they were appropriately coloured (e.g. orange-orange) than when they were coloured inappropriately (e.g. orange-cherry). Furthermore, Zellner & Kautz (1990) showed that colour can also affect the intensity of flavors, regardless of the appropriateness of the colour, their participants judged flavor solutions more intense than equally concentrated flavor solutions without colour. Interestingly, Elliot, Maier, Moller, Friedman and Meinhardt (2007) demonstrated cross-culturally that the perception of red prior to an achievement task unconsciously impairs cognitive performance (on anagram, analogy, and numeric tests) relative to the perception of green or an achromatic colour. The effect was shown when colour was inconsequentially manipulated such as including the colour of the participant's number on an IQ test cover or using red as the background colour of the test cover itself. Considering its irrelevance to the tasks used in the last study, the fact that colour significantly affected performance in each of the given tasks may suggest a profound effect of colour on people's behaviour. Nevertheless, the pattern of results revealed from the majority of studies investigating these colour effects on behaviour to date is fairly inconsistent. Many studies have simply failed to replicate these effects, showing null effects of colour on performance and mood (e.g. Ainsworth, Simpson, & Cassell, 1993; Goodfellow & Smith, 1973; Green et al., 1982; Hatta et al., 2002; Kwallek & Lewis, 1990; Kwallek, Lewis, Lin-Hsiao & Woodson, 1996; Kwallek, Lewis & Robbins, 1988; Kwallek et al., 1997; Profusek & Rainey, 1987; Rosenstein, 1985; Shick, 1975; Stone & English, 1998) and others demonstrating opposite patterns of results compared to previous studies (e.g. James & Domingos, 1953; Nakashian, 1964; Sinclair, Soldat & Mark, 1998; Soldat et al., 1997; Stone, 2001). A good example is a study (Ainsworth at el., 1993) which examined the affect of three colours (using three painted office walls coloured red, white-neutral and blue-green) on mood (e.g. anxiety, depression and arousal) and work performance (e.g. typing and basic office tasks). No significant differences were found among the three coloured environmental conditions on either of the dependent variables.

Given that the research is inconsistent in this respect, it may be argued that any effect that colour may have on human behaviour or mood is first and foremost a result of the tendency to associate specific meaning and convey specific information with colour. In other words, any behavioural influence of colour, be it on an individual's cognitive performance, his/her mood or his/her psychological functioning, can be explained by the individual's colour associations with emotions. Although it will be argued that some of these colour-emotion associations are either culturally dependent (learned) or deeply embedded in individual predispositions (innate), they can nevertheless vary significantly between individuals. Thus, individual differences in colour and emotion associations may at least partly explain the inconsistency of colour effects that were reviewed above. One particular example claimed to have a notable effect on colour and emotion associations is an individual's colour preferences (Terwogt & Hoeksma, 1995). The following section is therefore dedicated to the body of literature that has investigated, more directly, emotional associations with colour and its relation to an individual's colour preferences.

3.1.3. Colour Preference

Colour preferences have been widely studied throughout the years (e.g. Birren, 1973; Eysenck, 1941; Frank, 1976; Guilford, 1934, 1940; Norman & Scott, 1952; Terwogt & Hoeksma, 1995, Guilford & Smith, 1959). Most studies have yielded a considerable variation in findings, depending on age, gender and culture. Within Western society, for example, the favourite adult colour is blue, followed by red and green and the least preferred colours are yellow and black (Chongourian, 1967, 1972). Normann and Scott (1952) found that young children prefer the colours red and yellow. Terwogt and Hoeksma (1995) recently found patterns of colour preference similar to previous colour preference studies. Within a group of 7-year-olds, blue was also rated the highest colour preference *("Which of these colours do you feel is the most beautiful one?"*) followed by yellow and red. At older ages, yellow was less favoured, but the popularity of green tended to increase (Birren, 1978; Norman & Scott, 1952; Choungourian, 1969). Achromatic colours such as white and black were consistently disliked, regardless of age (Osgood, 1975; Williams, Boswell & Best, 1975; Terwogt & Hoeksma, 1995). Boyatzis (1994) and Hemphill (1996) provide further support for the different patterns of colour preferences among different populations. In two different studies the authors investigated both colour preferences and colour and emotion associations on adult and child populations. The results revealed significant differences in age and gender. Within the older population, men preferred blue the most followed by black, brown, green and red. Women also rated blue as the most favourite, however this was followed by orange, yellow, purple, green and red. The most preferred colours for children were also different for boys and girls. Boys rated blue followed by red as their favourite colours and girls rated pink followed by purple.

Despite the fact that the colour preferences revealed in the above studies are only partially similar, at best, Terwogt and Hoeksma (1995) have argued that the links between colours and emotions can be accounted for by preferences for both colours and emotions. In other words, the authors posited that colours and emotions may be related to each another due to the preference given to each of them within their own domain. The hypothesis was tested by asking participants to rate their preferences both on colours and six basic emotions (*"Which of these emotions do you like best or feel is less bad."*). However, high correlations between the two types of preferences were only found for 7-year-old children. Burkitt, Barrett and Davis (2003) found similar results, with children aged from 4 to 11. In their study, participants first completed two different colour performance tasks: colour rating task (*"How do you feel about this colour…point to the face to show how you feel about the colour."*) and ranking task ("*Point to the colour which you like the most.*"). Correlations between these two rating tasks were found significant at all ages, but reflected a very narrow emotional dimension - positive, negative or neutral only. Thus, children tended to give a more positive rating to colour that was ranked highly on the colour rating task. In a different session, each child was also asked to colour in three pre-drawn outline drawings of a man, a dog and a tree that were varied by their level of valence (positive, negative and neutral). Children's colour preferences were found by the colour selected for completion of the three drawing tasks. Highly ranked colours were used significantly more for the positive drawing tasks and lowest ranked colours were used more significantly for the negative drawing tasks. Although the evidence that the children's colour preferences can explain their emotional associations with colours is far from conclusive, the results do support the notion that, from a young age, children use colour symbolically and can alter their colour choices in response to affective topics.

The correlation between colour preferences and colour-emotion associations was also used to explain a documented link between colour preferences and psychopathology. The two seemingly unrelated areas have been linked in research involving the Rorschach Test (Exner, 1974, 1978; Exner & Wiener, 1982*)* and the Beck Depression Inventory. For instance, Nolan, Dai and Stanley (1995) found that undergraduates scoring above ten on the Beck Depression Inventory expressed a preference for black and brown. Holmes, Fouty, Wurtz and Burdick (1985), however, found that the colour preferences of psychiatric patients completely reflected those of the normal population. Luscher's (Luscher & Scott, 1969; Scott, 1970) test of personality also relied on the link between colour preference and colour-emotion associations, but was simply based on preference for colour patches and as such its validity has been questioned due to its lack of any predictive value.

In summary, attempts to explain the relationship between colour and emotion via an individual's colour preferences have not gained consistent support. Such equivocal results demand a careful evaluation of how extensive the phenomenon of colour and emotion associations really is.

3.1.4 Emotional associations with colour

That an individual can readily associate colours with emotions (or adjectives of emotions) is supported both empirically and linguistically. The English language abounds with expressions relating colours with emotions. It is possible, for instance, to be in a state of feeling blue or being green with envy. There are a few examples that can be given from other languages too. In the Hebrew language, for example, a ‘black day’ refers to a very bad or negative day, whereas the common blessing ‘may you have an orange day’ is used to wish one the opposite - a very happy day. And in Dutch, one turns yellow with envy.

Significant support for the human ability to associate colours with emotions also comes from a large number of studies that have used visual colour stimuli (D'Andrade & Egan, 1974; Johnson, Johnson & Baksh, 1986; Osgood, 1960; Osgood, May & Miron, 1975; Adams & Osgood, 1973; Byrnes, 1983; Schaie, 1961, 1962; Terwogt & Hoeksma 1995). Wexner's (1954) study is one of the earliest studies which sought to appraise the degree to which colours (hues) are associated with mood tones. Based on previous work on verbal associations of colour and mood, Wexner's study, illustrated a relationship between colours (e.g. red, orange, yellow, green, blue, brown and black) and a list of eleven moods (presented as words which had been selected by agreement by four judges). For each mood tone, certain colours were found to be associated with a specific mood tone significantly more often than the remaining colours. For example, blue was found more often to 'go with' secure-comfortable than with the remaining mood tone words. Moreover, no significant differences were obtained in colour-mood relationship between men and women.

Other research has used more rigorous methods to explore colour and emotion associations with children as well as with adults. Valdez and Mehrabian (1994) used experimental controls in investigating emotional reactions to hue, saturation, and brightness. Using the PAD model that illustrates the dichotomous dimensions of Pleasure-displeasure, Arousal-non-arousal and Dominance-submissiveness for the description of emotional states, the association of brightness and saturation to emotional reaction was found to be stronger and more predictive than the relationship between hue and emotions. For instance, more saturated colours elicited greater feelings of arousal; brighter colours were rated as more pleasant, less arousing and induced less dominance than darker colours. In addition, the short-wavelength hues (e.g. blue, green) were rated as the most pleasant whereas long-wavelength hues were rated the least pleasant. Weaker results were obtained with relating hue to arousal and dominance emotions. Comparing the results between men and women, it was suggested that women were slightly more sensitive in their emotional reaction to brightness and saturation levels of colours, as evidenced by a larger number of significant effects.

3.1.5 Colour-emotion associations at different developmental stages

The study by Boyatzis and Varghese (1994) represents one of the latest investigations into children's emotional associations with colours. Sixty children aged between five and six-and-a-half years old were asked to select their preferred colour from eight different options (pink, red, yellow, black, gray, blue, purple and brown). They were further asked to state their emotional feeling about the remaining eight colours and to explain why they felt that way. A positive colour-emotion relation was found as a higher percentage of positive emotional responses were obtained for bright colours than for dark colours. Additionally, for girls, negative feelings were induced by dark colours, but boys were more likely to react positively to dark colours than girls. Using an identical procedure, Hemphill (1996) tested these results on adults and compared them with those of Boyatzis and Varghese (1994). It was indicated that the association of colour and emotion becomes more complex with increasing age but nevertheless with similar trends. More recently, Zentner (2001) conducted a study using three emotional facial expression (sadness, happiness and anger) to detect emotional associations with colours using an unusually large sample size (n=127) and an unusually young age group. The ability to detect a relationship between the two perceptually unrelated categories, colours and emotions, was evident even for 3- to- 4-year-old children. For this young population, yellow was the best match for happiness, whereas blue was most consistently associated with sadness. The use of unique emotional stimuli also revealed similar colour associations to studies that have used textual or pictorial stimuli. Brighter colours such as yellow, red, green and blue were assigned to songs identified as *happy* songs while gray mostly corresponded to songs identified as *sad* songs (Barbiere, Vidal & Zellner, 2007).

Although the above findings may indicate in general that colours are perceived to have emotional meaning, a closer examination suggests that the nature of this relationship is far from consistent. To illustrate, the colour blue has been shown to be related to ‘sad’ (e.g. Zentner, 2001) but also to ‘pleased’, ‘peace’, and ‘soothed’ (Collier, 1996), to ‘secure’ and ‘comfortable’ (Wexner, 1954), to ‘relaxed’ and ‘released’ (Luscher, 1971), ‘good’ (Adams & Osgood, 1973) and ‘happiness’ (Terwogt et al., 1995). Similar variation has been found for other colours (Whitfield & Whitfield, 1990). The variability of results may reflect the fact that people differ in the meaning they give to colours. These associations may be a function of cultural conventions or simply a function of individual differences. This raises the issue of nature versus nurture in attempting to provide some explanations for the psychological phenomenon of acquiring colour and emotion associations.

3.1.6 Cross-culture evidence for colour-emotion associations

The question whether emotional meanings of colours are culturally dependent (learned) or similar across cultures (innate) has been investigated by an assortment of studies (D'Andrade and Egan, 1974; Pecjak, 1970; Murray & Deabler, 1957; Osgood, 1960; Osgood, May & Miron, 1975; Oyama, Tanaka & Haga, 1963; Hupka, Zaleski, Otto, Reidl & Tarabrina, 1997), which resulted in findings that both support (D'Andrade et al., Pecjak, Murray et al., and Osgood et al) and undermine cross-cultural consistencies (Courtney, 1986).

D'Andrade and Egan (1974) sampled across the entire Munsell colour chip set and compared two entirely different cultures (Americans and the Tzeltal from Chiapas in Mexico). For both cultures they found, for example, that ‘good’ is strongly associated with saturated colours while ‘bad’ relates more to unsaturated ones. Similarly, Wright and Rainwater (1962) studied German subjects and found that lighter or more saturated colours consistently corresponded with happy connotations. Arguments in favour of the innate (nature) causation idea posit that all human beings may be exposed to some learned associations of common environmental features. For example, many naturally occurring objects and events have the same colours in different cultures (e.g. the yellowness of the sun, the blueness of the sea and the redness of one's blood). Davidoff (1991) pointed toward a possible anatomical locus for universal associations of mood and colour, which is suggested to arise from links between neural areas responsible for colour categorisation (that are thought to be universal) and subcortical structures. Furthermore, the neural links from colour categorisation areas and mood areas have been shown to be separated (after brain damage) from neural links that are correlated with learned colour names (Damasio, Mckee & Damasio, 1979). Nevertheless, as was the case with studies investigating colour and emotion associations within cultures, any similarities that the above cross cultural investigations demonstrated are not necessarily consistent across studies. Most notable is the association with the colour red. It may seem that this colour might be the most automatic to be linked emotionally with 'fear' or 'anger', and thus also the most consistent in showing such associations, Courtney (1986) in fact revealed that it was not conclusively universal. Consequently, Hupka et al., (1996) were well aware that culture plays an important role in giving emotional meanings to colours. They thus postulated that emotions with a strong cultural component such as 'envy' or 'jealousy' may acquire colour associations that are culturally specific. Emotions that are common to all human beings, however, such as 'anger' and 'fear' (two of the six basic emotions suggested by Ekman) were hypothesized to be universally associated with colours. Their results supported the hypothesis in showing more cross-cultural agreement in colour-emotion associations for 'anger' and 'fear' than for 'envy' and 'jealousy'. For example, five different nations, Germany, Mexico, Poland, Russia and the US, listed the colours black and red as the best to remind them of the emotion 'anger'. The colour associations for 'envy', however, differed significantly among the five nations. Mexico, Poland, and the United States associated it with black, whereas Germany and Russia thought that yellow was more closely related.

Regardless of whether colour associations are consistent or not across cultures or from one individual to another, studies conclusively show that people do give emotional meaning to colours. This raises the question of whether there are specific neural structures or particular neural pathways that can be identified with and activated by such associations. The failure to find consistent colour and emotion associations, both within and across cultures, may refute any arguments in favour of an innate explanation for these associations. This in turn may reduce the likelihood for a specific neural mechanism common to all human beings. However, it has been suggested the neural mechanism involved in the neurological phenomenon of synaesthesia may mediate colour emotion associations in non-synaesthets.

3.1.7 Synaesthesia (associations with colours in the brain)

Synaesthesia derives from the Greek words *syn* (union) and *aesthesis* (sensation), which can be literally interpreted as a mixing of the senses. It is an involuntary neurological condition in which one type of stimulation evokes the sensation of another (Baron-Cohen & Harrison, 1997; Cytowic, 1989, 2002). This sensation or perceptual experience is elicited in the absence of normal sensory stimulation. The sensation of taste, for example, can be experienced as shape (Cytowic, 1993) or in response to specific sounds (Beeli et al., 2005; Ward & Simner, 2003). The most common form of synaesthesia and the most studied one is grapheme-colour synaesthesia, in which graphemes (letters or digits) elicit colours (Ward & Mattingley, 2006). A typical synaesthetic sensation would be to perceive, for example, the letter ‘a’ as pink, ‘b’ as blue, and ‘c’ as green, no matter in what colour they are printed.

Syneasthesia research has experienced a resurgence of interest in recent years, such that many investigators from different fields of research (e.g. neuroscience, philosophy, linguistics) pursue the study of synaesthesia using a variety of techniques (e.g. psychophysics, neuroimaging). Recently, studies have attempted to address the similarities between synaesthetic experiences and normal perceptual experiences. It has been acknowledged that synaesthesia can shed light on the neural and cognitive substrates of perceptual awareness (Gray, 2003, Gray et al., 2006). Since synaesthesia typically represents a case of cross-modal processing, or inter-attribute binding with in a modality it may be of relevance to understanding the interaction of different senses in the brain (Calvert, et al., 2004). Treisman (1999) has raised, for example, the question of how form and colour are integrated in perception in the absence of external colour information. Answers to such questions are thought to help clarify the basic neural mechanism and level of representations behind cross-modal processing and inter-attribute binding. For this reason, research of synaesthesia has recently involved the investigation of whether synaesthetic experiences really resemble those experienced by normal individuals using both psychophysical and functional neuroimaging techniques. Ward et al., (2005) recently found an overlap between brain regions involved in synaesthetic cross-modal processing and cross-modal processing areas.

Further evidence of possible similarities between synaesthetic experiences and normal perceptual experiences is documented by a line of studies which have used a psychophysical approach to compare performance of synaesthetes to that of non-synaesthetes on a variety of tasks. Many have, in fact, resulted in the conclusion that synaesthetic colours are incorporated within the stream of normal visual processing. Witthoft and Winawer (2005), for example, were able to demonstrate that synaesthetic colours are susceptible to normal mechanisms of lightness constancy. Their results showed that a grey background affected the perceived lightness of the synaesthetic colour induced by an achromatic grapheme. Hubbard et al., (2006) found that the contrast between a grapheme and its background affected the extent to which synaesthetic colours biased performance and thus postulated that synaesthetic colours may be elicited at contrast dependent stages of visual processing.

Theories attempting to provide an underlying mechanism for the unique phenomenon of synaesthesia have proposed that synaesthetic colour can be determined by factors that include both perceptual and conceptual properties and may reflect a cross-wiring of areas in the brain between limbic regions (responsible for emotions) and cortical regions, such as the fusiform, which is known to be involved in visual recognition and colour processing (Cytowic, 1989; Nunn et al., 2002; Ramachandran & Hubbard, 2001; Weiss, et al., 2001). Ramachandran and Hubbard (2001) specifically suggested a distinction between ‘higher’ and ‘lower’ synaesthesia which is assumed to reflect the individual differences between conceptual and perceptual processing of an inducer, respectively. More specifically, ‘lower’ synaesthetic induced colours are thought to be a form of grapheme-colour synaesthesia that is mostly determined by the physical appearance of the inducing stimulus and less by its meaning or identity (and thus is more perceptual in nature). An account for the perception of ‘lower’ synaesthetic induced colours posits a cross-activation between colour selective regions (V8/ hV4) and regions involved with visual recognition of number graphemes and visual words which are both located in the fusiform gyrus. Other researchers have focused more on ‘higher’ synaesthesia which was found to be influenced conceptually from the emotional responses that a certain grapheme may evoke, as well as from the meaning or the identity of the inducing stimulus (Dixon et al., 2005; Gray et al., 2006; Callejas et al., 2007; Lupianez & Callejas, 2006; Ward, 2004). Gray et al., compared synaesthetes who have a synaesthetic colour that does not match the meaning of the word (e.g., where the word 'red' is experienced as blue) to those who experience the same colour as the word's meaning (e.g., 'red' as red) and revealed significantly greater hippocampal activation in the former which the authors interpreted as reflecting conscious conflict resolution.

Weiss, Zilles, Gereon & Finka (2005) provide evidence that grapheme-colour synaesthesia may originate from enhanced cross-modal binding of form and colour. They compared neural activity during surface colour processing and grapheme-colour synesthesia. Enhanced activity in the left intraparietal cortex was evident during the experience of grapheme-colour synaesthesia, whereas the perception of surface colour per se preferentially activated the colour centers in the fusiform gyrus bilaterally. Interestingly, as was found in non-synaesthetes (discussed in section 2.1 Colour-dignosticity in the brain) who were presented with abnormally coloured objects (e.g., a violet banana) an incongruent synaesthetically induced grapheme-colour (when surface colour was different from the synaesthetic colour) also activated the left dorsolateral prefrontal cortex (DLPFC). Since the DLPFC has been implicated in cognitive control (MacDonald et al., 2000) the authors (Weiss et al, 2005) concluded that synaesthetes implemented the cognitive control processes to resolve the perceptual conflict resulting from a mismatch between the synaesthetically induced colour and the visually presented surface colour. This similarity in the neural correlates (activation of the DLPFC) of the induced incongruent colours in both synaesthetes non-synaesthetes suggests that the incongruity of colour associations experienced by non-synaesthetic subjects relies on a neural process somewhat similar to that experienced by synaesthetes.

More evidence to support the similarities between colour association in synaesthetes and non-synaesthetes comes from studies that were specifically interested in whether emotion can mediate the phenomenon of synaesthesia (Ward, 2004). There is considerable debate in the literature concerning which aspect of an inducing stimulus (or level of representation) is critical for triggering a synaesthetic colour. Arguments have been made in favour of shape information (Edquist et al., 2006), abstract identity

(Dixon et al., 2006) and other properties such as pronunciation (Baron-Cohen et al., 1993). Ward (2004) postulated differently - that it is the affective component of, or the emotional response evoked by, the induced stimulus that directly elicits a synaesthetic sensation of colour. The study reports a synaesthete, GW, who experiences colours in response to certain people, words, letters and numbers. GW's colour associations differ from those generated by control subjects in terms of both consistency and automaticity as measurements of genuineness (Baron-Cohen et al., 1987). Ward used the Stroop paradigm to demonstrate that stimuli with an emotional connotation (familiar people) were more likely to induce a synaesthetic response than those that do not (e.g. colour names, food) despite the fact that these stimuli usually have colour associations. Furthermore, word stimuli that had emotional connotation also elicited synaesthetic colours and the valence of these emotional responses greatly affected the colour induced. For instance, for GW bright synaesthetic colours (e.g. pink, orange, yellow, and green) were elicited for words associated with positive emotions. Words associated with negative emotions evoked dark synaesthetic colours such as brown, grey and black, whereas blue and white were elicited by neutral or non-valenced words. These colour-and-emotion associations clearly resemble those found in non-synaesthetic, adults and youngsters (e.g. Boyatzis & Varghese, 1996; Hemphill, 1996; Valdez & Mehrabian, 1994; Zentner, 2001). This evidence of emotionally mediated synaesthesia fits with other studies that pointed toward an involvement of the limbic system and thus to an underlying emotional mechanism (Cytowic, 1989; Ward, 2004; Callejas, Acosta & Lupianez, 2007) common to both synaesthetes and the normal population:

> *...certain synaesthetic individuals have an exaggerated cross-wiring (or some other neural mechanism) between centres involved in emotional processing and colour perception, which enables the emotion-inducing stimulus to explicitly acquire this novel dimension…some forms of synaesthesia can be considered to be exaggeration of normal, innate cross-modal mechanisms that are present in us all. The key difference is that the mechanism results in an automatically elicited conscious percept in the case of the synaesthete.* Ward (2006) p.771.

Diagnostic colours of emotions

While conducting our own investigation on the effect of colour and emotion associations on memory, we were also witness to synaesthetic experiences triggered by emotional responses evoked in three participants who revealed their condition of synaesthesia to the researcher. All three synaesthetes reported somewhat unique synaesthetic sensations as a result of their exposure to the experiment's emotional stimuli. The specific sensation, described below by SS, demonstrates the elicitation of taste and sound sensations for a specific emotion, beside other induced grapheme-colour sensations. Since such sensations disappeared over time it may mean that the specific synaesthetic sensations of taste and sound as reported below were merely a result of the exposure to the emotional stimulus of 'surprise'.

Further neuropsychological evidence for an embedded human ability to associate colours with emotions is demonstrated by a case study of brain damage (Ferro & Santos, 1984). The patient reported in the study is a 58-year-old male who had an intact ability to associate colours with emotions despite a severe visual recognition impairment. Furthermore, performance on visual perceptual and categorisation tests revealed an inability to categorise or name colours but a preserved ability to recall the colours of objects. This finding not only provides neuropsychological support for emotional associations with colour, but also suggests that such associations may be closely related to the associations between colours and objects (as suggested in Chapter 1).

3.1.8 An associative network theory for colour and emotion

From infancy onward, people encounter both obvious and subtle pairings between colours and particular meaningful messages, concepts and emotionally laden experiences. With repetition, these pairings are posited to produce strong colour associations, such that the mere perception of a colour in a particular situation activates its paired associate and influences affect, cognition and behaviour accordingly (Baldwin & Meunier's 1999). *An associative network theory* (e.g. Anderson & Bower, 1973; Bower, 1981; Collins & Loftus, 1975; Kintsch, 1988) is suggested to account for this type of learning. Collins and Loftus (1975) proposed a model of semantic knowledge that represented semantic information as an elaborate network of conceptual nodes and connections between them. When a concept is accessed (e.g. because it is presented to the visual system) the node for that concept is activated. However, nodes connected to the accessed node are also activated. Nodes connected to these nodes are then activated. As the activation spreads out from the accessed node it grows weaker. This was termed by Collins and Loftus as *the spread of activation*, which allows us to access semantic information about concepts. Based on the Collins and Loftus model of associative networks, Bower (1981) more specifically suggested the *network theory of memory and emotion*, where an emotion rather than a general semantic concept serves as a memory unit such that its activation serves to prime other related emotional knowledge. According to this theory, each distinct emotion such as joy, fear or sadness has a specific node or unit in memory that collects together many other aspects of the emotions. Verbal labels of each emotion as well as expressive behaviour (like facial expressions) are therefore connected to the emotion by associative pointers. Since colours are constantly integrated in every one of our life’s events (and as a result are associated with emotions evoked by daily events) colour nodes may be linked to emotional nodes accordingly. Thus, the emotional network theory assumes a strong direct relationship between the activation of an emotion associated with a stimulus and an identification of the semantic content of the stimulus (e.g. colour). In other words, the theory reflects a function of the links between the semantic (colour) and affective content of the stimulus (a specific event) in a person's semantic network.

Many studies further suggested that the activation of the colour association, as well as its influence on affect, cognition and behaviour, may occur without the individual's conscious awareness or intention (Callejas et al., 2007; Dixon, 1960, 1981; Lupianez & Callejas, 2006; Ward, 2004). If colour association is presumed to operate non-consciously this may explain its automatic influence on psychological functioning (Bargh, 1990) and cognitive performance (e.g. implicit memory tasks, Stroop tasks). Experiment 4 of this dissertation implemented the Stroop paradigm to specifically test the above hypothesis on the normal population.

3.2 Study rationale III

The ability to associate colours with emotions is unquestionably part of being human. What is less certain, however, is how consistent these associations are, not only across different cultures, but more importantly from one individual to another.

The majority of the literature reviewed above suggests that unlike colour associations with natural objects, the degree to which people associate colours with emotions is highly varied not only across cultures but also from one individual to another (e.g. Eysenck 1941; Wexner, 1954; Choungourian 1968; Valdez & Mehrabian 1994; Boyatzis & Varghese 1996; Hemphill 1996; Hupka et al. 1997). For exmple, the colour blue has been shown to be related to 'sad' (e.g. Zentner, 2001) but also to 'pleased', 'peace', and 'soothed' (Collier, 1996), to 'secure' and 'comfortable' (Wexner, 1954), to 'relaxed' and 'released' (Luscher, 1971), 'good' (Adams & Osgood, 1973) and 'happiness' (Terwogt et al., 1995). Similar variation has been found for other colours (Whitfield & Whitfield, 1990). This evidence of idiosyncratic colour and emotion associations necessitates an investigation which accounts for the individual differences in associating colours with emotions. Therefore, the studeies presented in this thesis do not represent a universal investigation of colour and emotion and therefore could not be generalized from one culture to another. Rather, it aimed to study on the individual level, whether the beneficial effect of colour on recognition memory of objects extends to the recognition memory of emotional information.

Consequently, we have decided to account for any potential individual differences that may occur within our student population. Thus, emotional word and facial stimuli were coloured according to each individual's associations of colour with emotions. For example, an angry facial expression or word was coloured in the individual's most highly associated colour of 'angry' or in the least associated colour of 'angry, depending on which condition he or she was assigned to. As many of the studies above used descriptions or facial expressions as the emotional stimuli (Boyatzis, Varghese, 1996; Collier, 1996; Hupka, et al., 1996; Terwogot et al., 1995; Wexner, 1954; Zentner, 2001) the present study, accordingly, implemented both types of stimuli in the colour-emotion association task as well as in the following memory tasks.

With regard to the colour manipulation that was used in this investigation, colours were mostly varied in hue while keeping the measurements of brightness and saturation constant. Although many studies have shown that emotional reactions to brightness and saturation are stronger and more consistent than emotional reactions to hue, previous research (Garro, 1986, Mervis, Catlin & Rosch, 1975; Glynis 2002 Davidoff & Ostergaard, 1984; Lucy & Shweder, 1979; Ridley, 1987) have also demonstrated that it is easier to name, communicate, remember and to form associations with certain colours (focal colours) compared with others (non-focal colours). This was found across speakers of languages with different colour naming systems (Heider, 1972). The supposition of universality of basic colour terms and their focal colours was first made by Berlin and Kay (1969). They prepared a rectangular array of Munsell colour chips and asked informants to choose a "focal colour" i.e., the best example of each colour. The informants were tested in their native language, including 20 different languages. The chosen focal colour chips (the best examples of English "black", "white", "red", "yellow", "green", and "blue") for each basic colour term were narrowly clustered regardless of the language the informant spoke. Thus these studies suggest that focal colours constitute a universal cognitive basis for both colour language and colour memory. Although there are number of studies that failed to replicate this advantage of focal colours (Lucy, 1997; Roberson, Davies & Davidoff, 2000; Roberson, Davidoff, Davies & Shapiro, 2005), there is in fact recent evidence for colour naming universals (Kay & Regier, 2003; Kuehni, 2005; Regier, Kay & Cook, 2005; MacLaury, 1997; Webster & Kay). Furthermore, psychophysically, particular hues of blue, red, yellow and green, are also considered as 'pure colours' or 'unique' in the sense that they seem to observers not to be tinted with any other colours (Hurvich & Jameson, 1957; Hering, 1964; Valberg, 2001). Using identical colour stimuli Miyahara (2003) have recently indicated high correspondence between focal colours and unique hues and concluded that these two concepts of colours are very similar.

Focal colours appear to be salient for children as young as four months of age (Bornstein, 1975) and have specific colour-name labels (Mervis, Catlin & Rosch, 1975). Non-focal colours on the other hand take significantly longer to name, and may attract a variety of basic and non-basic terms (Brown & Lenneberg, 1954; Lantz & Steffire, 1964). For example, a colour near the category boundary between green and yellow might be trigger the verbal terms 'green', 'yellow', 'lime', 'turquoise' or by some other name. Thus, focal colours tend to be remembered more successfully than non-focal colours since the former could be remembered using a verbal recoding strategy (Davidoff & Ostergaard, 1984; Garro, 1986; Lucy & Shweder, 1979; Ridley, 1987). Similarly, since colour-emotion associations may also activate verbal representations of colour names, it may be argued that for memory purposes specifically, (unique or focal) hues may provide more beneficial information than the brightness or saturation of colour patches. Accordingly, in this dissertation I employed hues that were chosen to be close to the 'unique hues' or 'focal colours' in the sense that they were similar in their degree of lightness- not particularly bright or particularly dark.

The next section will summarise the main hypotheses that this dissertation adheres to. This will be followed by a report on four experiments which, together, are designed to investigate the effect of colour on recognition memory of emotional information.

CHAPTER 4

Summary of the study rationale and main hypotheses

Individuals encounter a kaleidoscope of color in navigating daily life. Surprisingly, almost nothing is known at present regarding how the different colors that people perceive impact their affect, cognition, and behavior. We suspect that the influence of color on psychological functioning is as pervasive as it is subtle and provocative, and we urge other researchers to join us in adding color, literally and figuratively, to the scientific literature. Elliot et al. (2007) p.166.

4.1 Summary of the study rationale

Despite considerable empirical support for the association between colours and emotions (Figure 4.1 b.), the effects of mood/emotion on memory (c.) and the contribution of colour to recognition memory (a.), a study that attempts to tie all the three main effects together is still missing (d.). This study will therefore investigate whether diagnostic colours of emotions will aid recognition memory for emotional information presented as facial expressions and words that reflect the six basic emotions: happiness, sadness, anger, fear, disgust and surprise (e.). If colour contributes at high-level cognitive processing and takes part in the memory representations of emotional information, and if the colour diagnosticity effect extends to emotional information, emotional stimuli presented in high diagnostic colours of emotions should be recognized better than emotional stimuli presented in low diagnostic colours or neutral information presented in either high or low diagnostic colours of emotions. However, if colour only contributes at a sensory, low-level processing, then no differences should be evident between emotional stimuli coloured appropriately or emotional stimuli coloured inappropriately.

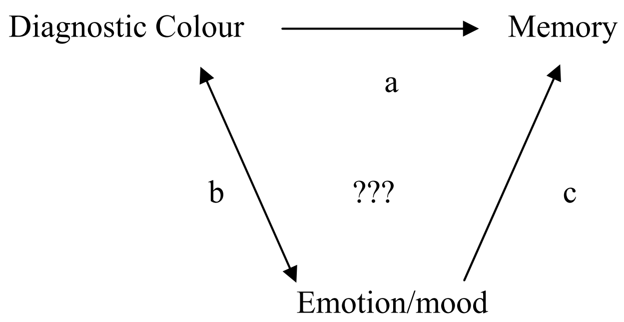
Figure 4.1: An Illustration of the Study Rationale

a. Colour → Memory (objects, pictures, words, faces)

b. Colour → Emotion (e.g. six basic emotions)

c. Mood/Emotion (vs. neutral) → Memory

d.



e. Diagnostic Colour → Recognition of emotional information

a+b+c

The question of whether diagnostic colours can enhance the recognition memory of emotions is inevitability contingent on whether colour can be identified as diagnostic of an emotion. Accordingly, Study 1 relied on the methodology used by Tanaka and Persenall (1999) to assess the colour diagnosticity of objects. Their feature listing task was applied specifically to the six basic emotions, in order to determine whether colour is a symptomatic feature of each of the six basic emotions (e.g. *If anger was an object or something tangible that you can hold in your hands, how would you describe it or what would it look like? Give eight different* ***perceptual features***). Whereas many colour emotion association studies have used a version of the Colour Typicality Task on emotions (asking *Which of the selected colours is most typical of a specific emotion?*, is equivalent to asking, *Which of the selected colours best represents a specific emotion?*) to our knowledge no study to date has attempted to adjust the colour feature listing task (typically used for objects: e.g. *Indicate which of the selected colours is the most typical of a target object.*) to emotions. Thus, although many investigations attempted to address the link between colour and emotion in an associative manner only (as reviewed in Chapter 3) Study 1 of this dissertation aims to deal with the same issue on a deeper level by asking whether the revealed associations between the two types of stimuli (colour and emotion) are also diagnostic in nature.

Considering the results from Study 1 which revealed colours as symptomatic of emotions and given the fact that the majority of the literature on colour and emotion associations does not support a high degree of consistency in associating the two types of information, particularly not as it is evident for colours and objects (that are high on colour diagnosticity), Studies 2 and 3 continued to scrutinise the colour diagnosticity effect in short-term and long-term recognition memory of emotional information, respectively, while accounting for the variability in associating colours with emotions. Specifically, in each of the following experiments colour emotion associations will be used individually. Thus, all emotional stimuli will be coloured for each subject individually, reflecting his or her own colour-emotion associations. Furthermore, the consistency in which each individual associate colours with emotions and its effect on recognition memory will be also measured. This investigation is therefore unique and powerful in two ways: it uses emotions as stimuli for the investigation of colour diagnosticity effect on memory and it accounts for the individual differences in associating colours with emotions. However, the question of whether the individual consistency in associating colour with emotions impairs or improves recognition memory of diagnosticly coloured information has not been investigated at all for objects or emotional stimuli, thus there is no support of a hypothesis in a specific direction. Memory enhancement in both Study 1 and 2 was assessed by the use of the Signal Detection Theory (SDT) measures and Reaction Time. The SDT measures of 'hits', 'false alarms', 'misses' and 'correct rejections', specifically, enable the effect of sensitivity and response bias to be teased out from memory facilitation.

In Study 3, an additional aim was added to the investigation of colour diagnosticity on recognition memory of emotional information, that is, to explore whether non-diagnostic colours of emotions impair recognition memory relative to diagnostic and any other *random* colours. Consequently, the study used a retention interval of 1 week only and assigned subjects to an additional third colour condition in which the emotional stimuli were coloured in a random order. The question of whether non-diagnostic colours of objects specifically impair recognition memory has not been investigated enough for objects and certainly no evidence exists for emotional stimuli, thus there is no support of a hypothesis in a specific direction. If non-diagnostic colours of emotions impair recognition memory of emotional information, then memory performance for stimuli coloured with the individual's low diagnostic colours of emotions should be significantly lower than for stimuli coloured randomly. However, if non-diagnostic colours of emotions do not impair recognition memory of emotional information, then memory performance for stimuli coloured with low diagnostic colours of emotions should not differ from stimuli coloured randomly.

Finally, results from Studies 1, 2 and 3 together provide support for the theory of colour diagnosticity and its beneficial effect on recognition when using emotions as stimuli. Study 4 then used the naming Stroop paradigm as used by Klein (1967) and Naor et al., (2003) for object stimuli to further investigate whether colour plays a significant role, not only within the individual's conceptual representations of objects, but also of their conceptual representations of basic emotions. Subjects' performance on all the different measurements used in the four studies was consistently assessed for emotional information as well as for neutral information. Thus, any differences in performance between the two information types, emotion versus neutral, were the within-subjects-variables, whereas differences in performance as a result of the colour manipulation, low diagnostic, high diagnostic or random colours, were the between-subjects-variables.

4.2. Main hypotheses

Relying on the large body of literature that was reviewed in the previous chapters, our main hypotheses are in line with prior studies' conclusions.

4.2.1 Study 1 - colour is a symptomatic feature of emotions (Hypothesis 1)

Based on the large body of literature reviewed in Chapter 3 which demonstrates the relation between colour and emotions (e.g. Boyatzis & Varghese, 1996; Hemphill, 1996; Valdez & Mehrabian, 1994; Zentner, 2001) it is expected that the findings will support the notion that colour, in general, is indeed a symptomatic feature of emotions. More specifically, by keeping the subjects naive to the studys' expectations and restricting them to using adjectives only, it is assumed that for most emotions colour features will be used at least once by the majority of subjects. Furthermore, colour-emotion associations that were found fairly stable across cultures (e.g. red and anger) may reveal a similar pattern of consistency with subjects using colour information in accordance with cross-cultural findings (e.g. Hupka et al., 1996) and in higher frequency for emotions with consistent colour associations than for emotions with inconsistent colour associations.

4.2.2. Studies 2 and 3 - higher recognition memory for facial expressions and emotional words coloured in the individual's highly associated colours of emotions than for the individual's least associated colours of emotions (Hypothesis 2)

Relying on the supporting evidence (e.g. Olivia & Schyns, 2000; Price & Humphreys, 1989; Tanaka & Persenall, 1999; Wichmann, Sharpe & Gegefurtner, 2002) for memory enhancement of appropriately coloured objects (as discussed in Chapter 1) or objects high in colour diagnosticity (e.g. orange carrot, yellow sun) over inappropriately coloured objects or objects low in colour-diagnosticity (e.g. violet strawberry, blue leaves) and considering the well-documented human tendency to associate colours with emotions (reviewed in Chapter 3), it is expected that memory performance will be better for emotional stimuli (words and facial expressions) high in colour diagnosticity than for emotional stimuli low in colour diagnosticity. Specifically, shorter response times, higher proportions of hits and lower proportions of false alarms are anticipated for emotional stimuli coloured with the individual's high diagnostic colours of emotions (also referred to as appropriate colours) than for emotional stimuli coloured with the individual's least diagnostic colours (also referred as inappropriate colours) of emotions.

4.2.3 Studies 2 and 3 - the difference in memory between the two colour types (low and high diagnostic colours) should be greater for emotional stimuli than for neutral stimuli (Hypothesis 3)

Based on the extensive body of research that indicates enhanced memory for emotional material over neutral material, it is expected that, overall, coloured emotional stimuli will be remembered better than coloured neutral stimuli. When the additional proposed relationship between colours and emotions is taken into consideration, it will be also expected that the contribution of high diagnostic colours to recognition memory of *emotional* stimuli will be more significant than the contribution of high diagnostic colours to recognition memory of *neutral* stimuli. This means that the difference in memory between appropriately coloured emotional stimuli and inappropriately coloured *emotional* stimuli will be significantly higher than the difference in memory between appropriately and inappropriately coloured *neutral* stimuli.

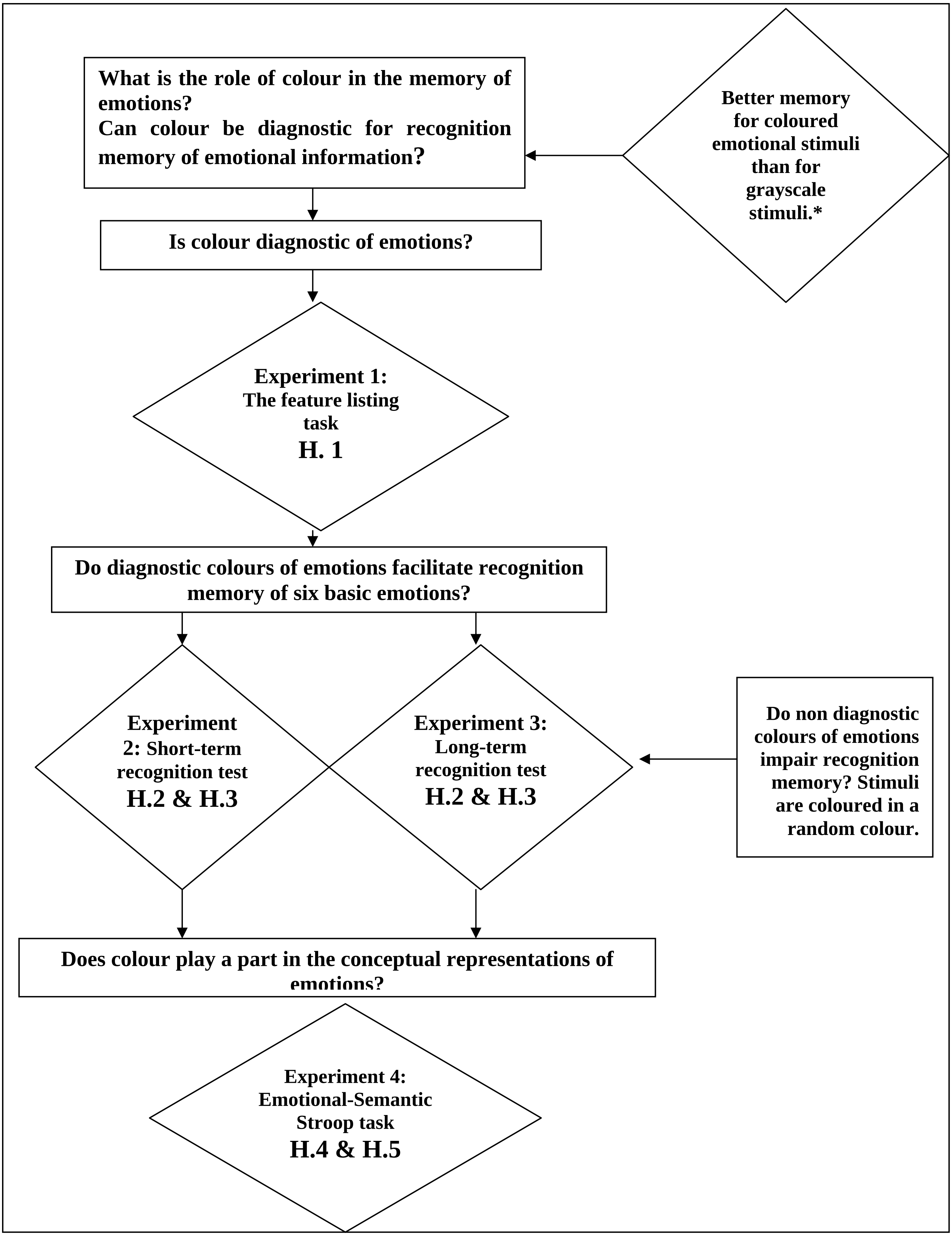
4.2.4 Study 4 - shorter colour-naming times (Stroop task) for emotional words coloured with the individual's highly associated colours of emotions than for the individual's least associated colours of emotions (Hypothesis 4)

A few studies previously used the Stroop paradigm to explore the question whether diagnostic (or natural) colours of certain objects play a substantial part in the conceptual representation of objects (Menard-Buteau & Cavanagh, 1984; Klein, 1964;

Naor-Raz, Tarr & Kersten, 2003). Their results mostly demonstrated faster mean response times for objects coloured in typical colours than for objects coloured in atypical colours. Since the present investigation, in fact, leans on the possibility that colours also play a notable role in the conceptual representation of emotions, the Stroop paradigm was used in Study 4 to empirically support or refute that possibility. Accordingly, mean response time for emotional stimuli coloured in the individual's high diagnostic colours of emotion are expected be faster than for emotional stimuli coloured in the individual's least diagnostic colours of emotion.

4.2.5 Study 4 - The difference in naming ink colours (Stroop task) of emotional words coloured in the two types of colour (low and high diagnostic colours), separately, should be greater for emotional stimuli than for neutral stimuli (Hypothesis 5)

Since colour information is mostly associated with emotional stimuli rather than neutral stimuli (e.g. Valdez & Mehrabian 1994; Terwogt & Hoeksma, 1995; Zentner, 2001) the difference in naming ink colours of emotional words coloured in low and high diagnostic colours should be greater for emotional stimuli than for neutral stimuli.


What is the role of colour in the memory of emotions?
Can colour be diagnostic for recognition memory of emotional information?
Better memory for coloured emotional stimuli than for grayscale stimuli.*
Is colour diagnostic of emotions?
Experiment 1: The feature listing task
H. 1
Do diagnostic colours of emotions facilitate recognition memory of six basic emotions?
Experiment 2: Short-term recognition test
H.2 & H.3
Experiment 3: Long-term recognition test
H.2 & H.3
Do non diagnostic colours of emotions impair recognition memory? Stimuli are coloured in a random colour.
Does colour play a part in the conceptual representations of emotions?
Experiment 4: Emotional-Semantic Stroop task
H.4 & H.5

CHAPTER 5

EXPERIMENT 1:

The feature listing task as a test of colour diagnosticity of emotion

5.1 INTRODUCTION

Colour diagnosticity refers to the degree to which a colour is associated with, or symptomatic of, a particular stimulus (Tanaka & Persenall, 1999). The theory of colour diagnosticity has been studied previously by several researchers who used either objects or everyday scene information to address the question whether colour can be diagnostic for recognition memory of these stimuli and, as such, will facilitate memory performance (Bedirman & Ju, 1988; Gegenfurtner & Rieger, 2000; Olivia & Schyns, 2000; Nagai & Yokosawa, 2003; Olivia & Schyns, 2005; Olivia & Torralba, 2001; Tanaka & Persenall, 1999; Uttle et al., 2006; Vernon & Lloyd-Jones, 2003; Vailayan et al., 1998; Wichmann et al., 2002; Wurm et al., 1993). The findings reported from many of these studies are inconsistent in supporting the colour diagnosticity effect on recognition memory. Some have reported that memory indeed benefits from the colour diagnosticity of objects and scenes (Gegenfurtner & Rieger, 2000; Olivia & Schyns, 2000; Nagai & Yokosawa, 2003; Olivia & Schyns, 2005; Olivia & Torralba, 2001; Tanaka & Persenall, 1999; Vernon & Lloyd-Jones, 2003; Wichmann et al., 2002) while others have demonstrated a null effect (Bedirman & Ju, 1988; Ostergaard & Davidoff, 1985; Uttle et al., 2006). One explanation that has been suggested to account for such inconsistency concerns the different methods used to assess colour diagnosticity (Nagai & Yokosawa, 2003; Tanaka & Persenall, 1999). Researchers determined to explore the issue of colour diagnosticity and its contribution to memory have urged scientists to use rigorous, well controlled measurements of colour diagnosticity (Olivia & Scyns, 2000; Price & Humphreys, 1989; Tanaka & Persenall, 1999; Wurm et al, 1993). Wurm et al., (1993), for example, recommended that a stimulus can be considered high in colour diagnosticity only if a specific colour is consistently mentioned as a perceptual feature and is also rated as a typical colour of the stimulus:

> *… from an information-theory perspective, two factors determine whether colour is diagnostic of an object: The colour must be symptomatic of the object (e.g., "green" is a "symptom" of spinach), and not many other objects in the allowable domain should have the same colour. (p. 901)*

Nevertheless, prior measurements of colour diagnosticity of objects were often assessed by one measure only, most often via the typicality test for colour diagnosticity, which normally requires participants to indicate the colour that they thought was the most typical of a target object (e.g. Biederman & Ju, 1988; Vernon & Lloyd-Jones, 2003; Uttle et al., 2006). In contrast, Tanaka and Persenall (1999) as well as Nagai and Yokosawa (2003) employed the feature listing task beside the typicality task. This task aims to identify colour as a typical perceptual feature of a certain object. Both studies showed an enhancement effect of memory as a result of colour diagnosticity. Stimuli were considered high in colour diagnosticity only if the ratio of subjects' agreement of a typical colour was above 70% and the same colour was additionally mentioned more than 35% as a the first typical feature (Tanaka and Persenall (1999), though, set a higher baseline of 80%).

Within our everyday environments there are objects that tend to occur naturally with a specific colour (e.g. red apple, yellow banana). The suggestion that colour is diagnostic of these objects is clearly justified. However, we are also quite familiar with the phenomenon of colour association with emotion - a phenomenon that has been well investigated scientifically (Barbiere, Vidal, Zellner, 2007; Boyatzis & Varghese, 1996; D'Andrade and Egan, 1974; Hemphill, 1996; Hupka, et al., 1997; Pecjak, 1970; Murray and Deabler, 1957; Osgood, 1960; Osgood, May & Miron, 1975; Oyama, Tanaka & Haga, 1963; Terwogt & Hoeksma 1995; Valdez & Mehrabian, 1994; Wexner, 1954; Zentner, 2001). Many of these studies demonstrated that children as well as adults around the world tend to give emotional meaning to colours. Nevertheless, the question of whether colour can be diagnostic not only of objects but also of emotions has not been investigated. It can be argued, however, that many colour-emotion association studies have used some version of the colour typicality task on emotions. Asking participants for example: *Which of the selected colours is most typical of a specific emotion?* is not that much different from asking: *Which of the selected colours best represent a specific emotions?* There is no evidence, however, of any study that also attempted to apply the colour feature listing task to emotions. The purpose of this experiment, therefore, is to use the feature listing task to investigate whether colour associations with emotions are diagnostic. If colour is found as a symptomatic feature of emotions among the majority of participants, it may have further implications for its significant role in the memory of emotional stimuli, similar to the memory enhancement effect that have been found previously with diagnostic colours of objects and natural scenes. Since colours do not occur naturally as surface colour of emotions, as they do for objects, this experiment set a lower baseline of high diagnosticity (20%) than the experiments of Tanaka and Presnell and Nagai and Yokosawa (2003). Contrary to studies that demonstrated colour diagnosticity of objects and were interested in the participants' agreement for the typicality of a *specific* colour of objects, this investigation is more interested in whether participants generally use colour information as a typical feature of emotions while having no awareness whatsoever of the substantial role of colour in the experiment.

Consequently, based on the considerable previous support for the existence of colour-emotion associations, it is predicted that colour information will be mentioned as a typical perceptual feature of emotions with more than 50% agreement in general and as the first mentioned with more than 20% agreement, in particular.

5.2 METHOD

Participants: The participants were 120 undergraduate students at The University of Sydney (79% women and 21% men, aged 18-53) with a reported range of 13-28 years of formal education who received either course credit or payment for their participation. One participant did not pass the Ishihara test for colour-blindness (1917) and was thus excluded from the data analysis. All other participants had normal colour vision (according to the Ishihara test for colour-blindness, 1917) and were tested individually.

***The feature-listing questionnaire*:** the questionnaire was designed according to Tanaka and Persenall's (1999) feature listing task (also used by Nagai & Yokosawa, 2003) which originally assessed the level of colour diagnosticity of objects. The basic requirement was to list eight perceptual features associated with seven different emotions with the restriction that each feature should include one word only and preferably adjectives. For example, for the basic emotion 'anger' the feature-listing question was: *If 'anger' was an object or something tangible, palpable that you can hold in your hands how would you describe it or what would it look like? Give eight different perceptual features.* The questionnaire thus included seven similar questions for each of the six basic emotions as well as for a neutral emotion (anger, happiness, sadness, fear, surprise, disgust and neutral). The order of these seven questions was randomised for each participant. An example of a randomised questionnaire is given in the Appendix.

Procedure and Apparatus: participants entered the lab individually and were told that the experiment was designed to discover the common associative features people may have with emotions. The questionnaire was displayed on a PC (personal computer) as a word document which allowed participants to type in their answers for each of the given questions. Each question had eight empty slots which participants were asked to fill out with their answers. Before entering their answers, each participant had five to ten minutes to read the basic instructions and the following seven feature-listing questions. Participants were also given time to ask questions or clarify any ambiguity regarding their answers. When needed, the experimenter gave an example of a possible answer which helped to clarify the restriction of using only a one word adjective as a perceptual feature. For instance, it was demonstrated that if one of the associative features that came to mind was the object 'knife', instead of typing in the *noun* 'knife', he/she could type the *adjective* 'sharp'. The participants were instructed to complete at least five out of the eight given slots of answers for each of the seven questions (emotions) and were given 30 to 40 minutes to do so. No participant was aware of the experiment’s full expectations or its hypothesis so that all types of answers that were in line with the given restrictions were acceptable as correct answers (e.g. shape and tactile information were also possible answers). On completion, participants were tested for colour blindness (according to the Ishihara test for colour-blindness, 1917) and were given a full debrief.

5.3 RESULTS

Table 5.1 depicts the mean percentage of the total colour information that was listed as perceptual features for each of the seven emotions. The colour features that were mentioned by all participants were categorised into 15 different types of colour information. Table 2 demonstrates the mean percentage of the specific colour features given for each of the seven emotional categories. The results shown in Table 5.1 confirm the assumption that colour information is a symptomatic feature of emotions. As the table depicts, colour features were mentioned in 73% to 89% of the completed feature slots as possible perceptual features in each of the seven emotional feature-listing questions. Furthermore, Figure 5.2 plots the order in which participants have mentioned colours as the perceptual feature of the seven emotional categories. The results from the colour feature order graph shown in Figure 5.2 reveal that the majority of the colour features that were mentioned for each emotional category were given either in the first or the second slots of perceptual features with a mean of 52.65% across all the seven emotions. In contrast, only 10.27% of the total colour features were mentioned in the 6^{th} to 8^{th} slots of a given feature-listing question. Regression analysis revealed a significant correlation of -0.916 between the percentage of colour details given for each emotional category and the position (location of slots), (p = 0.000, R^2 = 0.839). Together, these two patterns of results support the hypothesis that colour features are prioritised over other perceptual features which characterise emotions and are thus mentioned generally in more than 50% of cases and as a first mention in more than 20% of cases.

The highest percentage of colour features mentioned by the participants was for the emotion 'happiness' (89.92%) followed by 'sadness' (87.71%) and 'surprise' (85.71%). Colour information was also mentioned quite often (80.68%) as a possible feature of the neutral (non-emotional) category which may imply that emotional information is not different from non-emotional information in colour diagnosticity. Nevertheless, Table 5.3 clearly reveals that the specific type of colour information mentioned as perceptual features for the neutral category mostly involves achromatic information as white (34.92% of the colour features), colourless/transparent (22.22% of the colour features) and grey/silver (15.87% of the colour features). On the other hand, colour information mentioned as a perceptual feature of the six basic emotions tends to include more chromatic colour information than the features of the neutral category. The colour perceptual features of the emotions 'anger', 'happiness', 'sadness' and 'disgust', for example, included the colours: red in 66.66% of the cases, yellow in 21.2% of the cases, blue in 25.5% of the cases and 'green' in 23.33% of the cases, respectively. Thus, although Table 5.1 shows that, in general, colour information is equally symptomatic of emotions and non-emotions, Table 5.3 demonstrates that chromatic colour information specifically is symptomatic of emotions. Finally, the data also emphasis the high level of variability in associating specific colours with specific emotions as demonstrated by the fact that no particular colour, except for the colour red, was mentioned in more than 50% of the cases as a possible perceptual feature of any particular emotional category (see Table 5.3). The colour features 'bright' and 'dark', however, were mentioned more frequently than any other colour feature for the basic emotions 'fear', 'surprise' 'happiness' and 'sadness' with a mean of 32.63% agreement.

Table 5.1: Mean % of the total colour features given for each emotional category in the feature-listing questionnaire.

	Anger	Fear	Surprise	Happiness	Sadness	Disgust	Neutral
Mean % of Colour Features	78.15	73.11	85.71	89.71	87.39	78.99	80.68

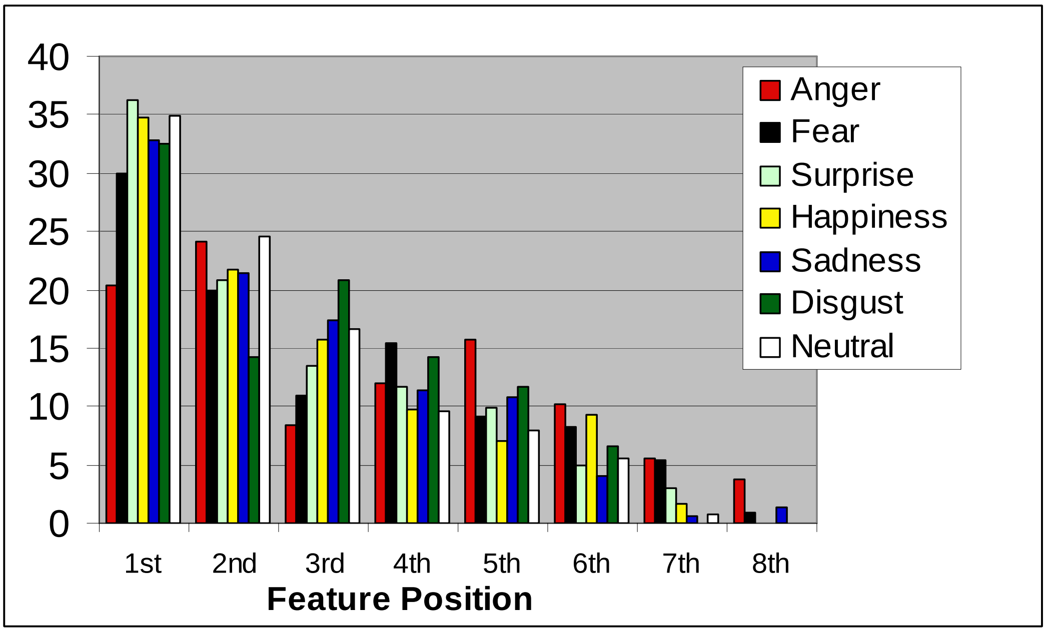


Figure 5.2: Mean % of colour information mentioned for each slot and for each emotion in the feature-listing questionnaire.

Table 5.3: Mean % of the specific colour features given for each emotional category in the feature-listing questionnaire.

	Anger	Fear	Surprise	Happiness	Sadness	Disgust	Neutral
Yellow	1.87	0	14.11	**21.2**	0	4.17	0
Red	**66.66**	3.64	6.13	5.43	0.67	5.83	1.59
Blue	0.9	15.45	1.22	5.43	**25.5**	0.83	6.35
Green	0	3.34	3.07	3.26	2.68	**23.33**	1.59
Brown	0	0.91	0.61	0	0	19.17	4.76
Orange	1.85	0	6.14	3.8	0	4.15	0
Pink	0	0	5.52	5.43	0	0	1.59
Purple	0	2.72	1.22	0.54	1.34	2.5	0
Black	6.48	**20**	0	0	16.2	15	2.38
White	0.93	3.64	0.63	2.72	0	0	**34.92**
Grey/Silver	0	15.45	0	0	**20.13**	12.5	15.87
Bright	5.57	2.27	**39.88**	**35.87**	1.34	1.66	7.94
Dark	15.74	**24.56**	0	0	**30.2**	10	0.79
Colourful e.g. 'rainbow colours'	0	0.91	**21.47**	15.78	0.65	0.86	0
Colourless/ Transparent	0	6.36	0	0.54	1.32	0	**22.22**

5.4 DISCUSSION

The findings clearly confirm the hypothesis that colour is a symptomatic feature of emotions. Without any awareness of the experiment's objectives and expectations, participants consistently chose to use colour information as a perceptual feature of six basic emotions: happiness, anger, sadness, disgust, fear and surprise (81.92% on average). This was also true for the non-emotional, neutral category. However, the specific type of colour information mentioned for the non-emotional category was consistently different from the type of colour information used for the six basic emotions. The findings show that participants have used chromatic colour information such as red, yellow and blue as symptomatic features of the six emotional categories and achromatic colour information such as grey, white and transparent as symptomatic features of the neutral category.

The findings further demonstrate that the colour features of each emotion were consistently mentioned as either the first or the second feature from a list of eight possible perceptual features (see Figure 5.2). The fact that colour information was used so often (in 81.92% of the total given features), and appeared mostly as the first or as the second feature, strongly emphasises the close associative relationship colours share with emotions. The findings are therefore in line with the numerous studies which showed that people readily associate colours with emotions or commonly have emotional meanings for colours (e.g. Barbiere, Vidal, Zellner, 2007; Boyatzis & Varghese, 1996; Hupka, et al., 1997; Zentner, 2001). The specific colour features mentioned for the seven different emotions, as shown in Table 5.3, reveal two additional patterns of results that are also consistent with prior colour and emotion studies. The first concerns the level of variability in which participants associate colours with emotions (Oyama, Tanaka & Haga, 1963; Hupka, et al., 1997) and the second relates to the findings that emotions tend to be closely related to the measurements of brightness of a colour rather than to its hue (Barbiere, Vidal, Zellner, 2007; Boyatzis & Varghese, 1996; Valdez & Mehrabian, 1994). The first pattern of results is evident by the fact that participants provided 15 different types of colour features (as shown in Table 5.3) and that among the 15 colour categories, no specific hue (except for red) was mentioned in the majority of the total given colour features (above 50% of total agreement). This is clearly in line with the documented tendency to associate colours with emotions in a fairly inconsistent, varied pattern (as discussed in Chapter 3). Furthermore, a close look at the specific colour features mentioned for each emotion reveals that the colour features 'bright' and 'dark' are either the most or second most mentioned colour features for the majority of emotions. For example, for the emotions 'fear', 'surprise', 'happiness' and 'sadness' these colour features were mentioned more often than any other colour features with a mean of 32.62% of the total colour features mentioned for these emotions. Another interesting result that fits with other studies' findings is the unique and high consistency level of mentioning the colour red as a perceptual feature of the emotion 'anger'. As shown in Table 5.3, for the emotion 'anger' alone, no other colour feature has received a similar percentage of agreement and, among the seven emotions, no other emotion has received the colour feature red with such great agreement. Again, this stresses the unique or even the innate association of the colour red with the emotion 'anger' (Hupka et al., 1997; Wexner, 1954).

In conclusion, the present investigation has succeeded in revealing similar patterns of results to those found previously, although from a slightly different angle. Without the necessity to specifically use colour information, participants consistently defined and described emotions by using colour features more often than any other perceptual features (e.g. shape or tactile information). Thus, it seems that people not only have meaningful and emotional associations with colours but may also tend to define or even experience their emotions through the use or the experience of colours. In other words, the present experiment has found support for the notion that colour is not only diagnostic of objects and everyday scenes (Gegenfurtner & Rieger, 2000; Olivia & Schyns, 2000; Nagai & Yokosawa, 2003; Olivia & Schyns, 2005; Olivia & Torralba, 2001; Tanaka & Persenall, 1999; Vernon & Lloyd-Jones, 2003; Wichmann et al., 2002) but is also diagnostic of emotions.

CHAPTER 6

EXPERIMENTS 2 AND 3:

Colour diagnosticity in recognition memory of emotions

6.1 INTRODUCTION

In Experiment 1 it was demonstrated that colour is a symptomatic or diagnostic feature of emotions. One possible implication of these findings is that individuals may not only give emotional meanings to colours, and thus can easily make associations between the two types of information (e.g. Barbiere, Vidal & Zellner, 2007; Boyatzis & Varghese, 1996; Hupka, et al., 1997; Zentner, 2001), but they may also use colour information to aid cognitive processes that involve their emotions. Indeed, many scientific studies have been devoted to the investigation of whether colour plays a beneficial role in the memory of many types of stimulus. Objects, faces, natural scenes and line drawings are just a few examples of these stimuli (e.g. Olivia & Schyns, 2000; Latimer et al., 2002; Wichmann, Sharpe & Gegefurtner, 2002). In many cases, studies which compared recognition memory for coloured over grayscale stimuli resulted in a common conclusion - that colour is a powerful tool for recognition memory enhancement (Ostergaard & Davidoff, 1985; Price & Humphreys, 1989; Intraub & Nicklos, 1985; Homa & Viera, 1988; Park & Mason, 1982; Suzuki & Takahashi 1997; Olivia & Schyns, 2000; Latimer et al., 2002; Wichmann, Sharpe & Gegenfurtner, 2002). A few other investigations, however, failed to show any effect of colour on memory performance (Biederman & Ju, 1988; Davidoff & Ostergaard, 1988; Ostergaard & Davidoff, 1985). Some studies suggested only a low-level contribution of colour to recognition memory (Mollon & Jordan, 1998; Polyak, 1975; Walls, 1972; Gegenfurtner & Rieger, 2000) but many others have shown that colour can also contribute at a higher level of visual processing (Wichmann, Sharpe & Gegefurtner, 2002; Olivia & Schyns, 2000; Tanaka & Persnell, 1999; Mapelli & Behrmann, 1997; Humphreys, Goodale, Jakobson & Servos, 1994; Price & Humphreys, 1989). For example, at the lower level, Mollon & Jordan (1998) found that colour plays a highly specialised role in some image segmentation tasks (e.g. detecting ripe fruit among mature foliage) and Gegenfurtner & Rieger (2000) revealed a recognition memory advantage of colour cues for very brief presentations (16ms) even when they were tested in black and white. At a higher level, Humphreys et al., (1994) showed that people with impaired object recognition abilities benefit from colour information and that the performance of normal observers is higher for coloured stimuli only when objects are presented in their natural colour. Thus, the literature does provide evidence that colour is part of our recognition memory as it boosts our ability to remember things faster and better. A critical question, then, is whether this superiority effect of colour on memory appears with all kinds of stimuli, particularly emotions. To date, no study has been conducted to validate or refute this suggestion. In empirical research conducted by the author in 2003 (henceforth referred to as the ‘2003 Study’) as part of fulfilment of the Graduate Diploma in Science (Psychology), this question was addressed and resulted in further evidence for the superiority effect of colour on memory. A beneficial effect of colour on recognition memory was found when using emotional information (emotive words and facial expressions) representing the six basic emotions: happy, sad, angry, disgust, fear and surprise. According to the findings of the 2003 Study, participants performed significantly better when asked to recognise faces and words initially presented with colours as opposed to emotional information originally presented in a greyscale (with no colour). This prominent role of colour was manifested even after a one week retention interval and when colours were available only during induction. Participants were slower but more accurate when recognising facial expressions than emotional words. A higher percentage of accurate responses was obtained for pleasant (happy words and happy facial expressions) versus unpleasant emotions (which include all the sad, angry, fear and disgust stimuli). Colour was found particularly advantageous for recognition memory of unpleasant emotions and facial expressions but no evidence was elicited to support the theory of colour-diagnosticity. Diagnostic colours of emotions were based on the colour and emotion associations of a pilot study of 26 participants and were generalised to a sample of 120 participants in the memory experiment. The participants were assigned randomly to three colour conditions which presented the emotional stimuli coloured (a) in the most frequently associated colour of emotion (*appropriate* condition), (b) in the least associated colour (*inappropriate* condition) or (c) in grayscale (*grayscale* condition). Studies that previously tested the colour diagnosticity theory on recognition memory of objects and everyday scenes (Wichmann, Sharpe & Gegefurtner, 2002; Olivia & Schyns, 2000; Tanaka & Persnell, 1999; Mapelli & Behrmann, 1997; Humphreys, Goodale, Jakobson & Servos, 1994; Price & Humphreys, 1989) claimed that colour information would affect recognition of stimuli high in colour diagnosticity (e.g. orange carrot, yellow sun) but not those low in colour diagnosticity (e.g. pink carrot, brown sky). Neuropsychological research provides further evidence that the neural correlates of typical and untypical coloured stimuli are distinct (Luzzatti & Davidoff, 1994; Zeki & Marini, 1998). Typical colours of objects (e.g. red strawberries) activate the fusiform gyrus, hippocampus and ventrolateral portion of the frontal cortex - brain areas that are also involved during the performance of object colour-knowledge tasks (e.g. responding 'red' to a picture of red strawberries). In comparison, objects coloured atypically activated the dorsolateral region of the frontal cortex.

The 2003 Study showed that colour assists to recognition memory of emotional stimuli, as is evident from the significantly higher performance in the two colour conditions compared to the grayscale condition. However, differences in recognition memory between the two colour groups (high diagnostic/appropriate colours of emotions versus low diagnostic/inappropriate colours of emotions) were not significant. Thus, participants did not perform better when the emotional stimuli presented were coloured appropriately than when they were coloured inappropriately. This null effect of colour diagnosticity could be a result of generalising colour emotion association when these associations are in fact quite individual. The colour and emotion associations demonstrated in the 2003 Study revealed a high degree of variability with regard to mapping of the appropriate (best associated) versus inappropriate (least associated) colours of the stimuli - a pattern of result that also fits with prior findings (Wexner, 1954; Valdez & Mehrabian, 1994; Boyatzis & Varghese, 1996; Hemphill, 1996; Burkitt, Barrett & Davis, 2003; Hupka, et al., 1997). These previous studies showed that colour diagnosticity is influenced by the degree of consistency between the stimulus to be remembered and its associative/diagnostic colour. These findings have raised the need to use an *individual* (rather than a *general*) colour-emotion association to enable control of the extensive individual differences of colour and emotion associations found in the literature. Consequently, the two experiments reported in this chapter utilise individual colour-emotion associations in the investigation of whether or not colour can be diagnostic to recognition memory of emotions. In doing so, this investigation expands on the previous studies that scrutinised the effect of colour diagnosticity on recognition memory of various types of stimulus (e.g. Tanaka & Persenall, 1999; Wichmann, et al., 2002; Wurn et al., 1993) by using emotional stimuli, individual colour-emotion associations and a comparison within-subject condition of neutral, non-emotional stimuli.

Diagnostic colours of emotions

Given that colour diagnosticity is the degree to which colour is symptomatic of a particular stimulus, and that Experiment 1 of this dissertation provides some support that colour can be diagnostic of emotions the following experiments specifically focus on the role diagnostic colours of emotion have in recognition memory of emotional words and facial expressions. The experiments are thus designed to investigate whether high diagnostic colours of emotions will facilitate recognition memory of emotions more significantly than low diagnostic colours of emotions. As postulated before, it is expected that there will be better recognition performance for presentations coloured with high diagnostic colours of emotion (appropriate colours of emotions) than for presentations coloured with low diagnostic colours of emotions (inappropriate colours of emotion).

Finally, since only emotional information was used in the 2003 Study, an additional aim of the present study is to investigate the comparable contributing effect that colours may have on recognition memory of emotional information over neutral information. Consequently, a 'neutral emotion category' in addition to the six basic emotions was added to the within-subjects variable (neutral facial expressions and neutral words). Amygdala activation during encoding of emotional information may provide a mechanism by which emotional information is remembered significantly better than neutral stimuli (Hamann et al., 1999; Heuer & Reisgerg, 1990; Dewhurst & Parry, 2000, Fox, Lester, Russo, Bowels, Pichler & Dutton, 2000). Doerksen and Shimamura, (2000) have further argued that memory for contextual information (e.g. colour of clothing, background details, etc) is also enhanced by emotional stimuli (pleasant and unpleasant words) as source memory for the associated colour was enhanced for these particular stimuli. More recently, Kensinger and Corkin (2003) found support for a quantitative (better memory performance) as well as qualitative (details of presentations) memory benefit for emotional words compared to neutral words.

Accordingly, the present investigation further hypothesised that, overall, better recognition performance will be shown for the emotional presentations than for the neutral ones. With the specific contribution effect of colour diagnosticity on memory it is also expected that an interaction effect will be revealed as significant. That is, *the difference* in memory between high diagnostic colours of emotions and low diagnostic colours of emotions is expected to be significantly higher than the difference in memory between high diagnostic colours of neutral stimuli and low diagnostic colours of neutral stimuli. Thus, the contribution to recognition memory as a result of colour diagnosticity should be more significant for emotional stimuli than for neutral stimuli.

6.2 EXPERIMENT 2: Colour diagnosticity for short-term recognition memory of emotional information

6.2.1 INTRODUCTION

The main objective of this experiment was to investigate the role diagnostic colours of emotions have on recognition memory - whether high diagnostic colours of emotions (Appropriate condition) indeed induce better memory performance than low diagnostic colours of emotions (Inappropriate condition). Accordingly, Experiment 1 had a four-factor (2 x 2 x 2 x 7) design: 2 Colour Conditions (Appropriate/Inappropriate) x Consistency (Consistent/Non-Consistent) x 2 Stimulus Type (Words/Faces) x 7 Emotion Categories (Six Basic Emotions/Neutral). The first hypothesis was that participants would be more sensitive and accurate when recognising information coloured with high diagnostic colours of emotions (appropriately coloured stimuli) than information coloured with low diagnostic colours of emotions (inappropriately coloured stimuli). A second objective was to evaluate the degree to which colours specifically affect recognition memory of emotion. Since previous research has demonstrated that emotional information is remembered significantly better than neutral stimuli, the second hypothesis was of an interaction such that differences in memory performance between high and low diagnostic colour conditions would be higher for the emotional presentations than for the neutral ones.

6.2.2 METHOD

Participants: The participants were 112 undergraduate students at The University of Sydney (82% women and 18% men aged 18-35) with a reported range of 13-21 years of formal education who received course credit for their participation and were randomly allocated to six experimental groups. All had normal colour vision (according to the Ishihara test for colour-blindness, 1917) and were tested in groups of 4-6 participants.

Stimuli: All emotional stimuli (words and facial expressions) were taken from the 2003 Study and their selection procedure is described below. Since neutral (non-emotional) stimuli were added to the collection of emotional stimuli there were 84 stimuli comprising 42 words and 42 faces - six words and six faces for each of the seven emotional categories.

Six basic emotions - the emotions involved were the six basic emotions as defined by Ekman and Friesen (1975): anger, happiness, sadness, fear, surprise and disgust which are considered to have distinctive facial expressions. An additional non-emotional, neutral category was included as a comparable within-participants condition to the six basic emotions.

Emotional words - as part of the 2003 Study, a pool of 36 emotional words was collected for each basic emotion by using a Microsoft Office Word 2003 'thesaurus' computer tool. The words obtained were matched with respect to word frequency norms (Kucera & Francis Corpus, 1967). All were low-frequency words (1-2 times per million) and consisted of six to nine letters. A pilot study of 15 subjects agreed upon their match to six different emotional groups of basic emotions (with an average agreement range of 88% - 97%, see Appendix). Six additional neutral words were selected in a similar manner to that of the emotional words and received an average agreement of 92% as judged by nine judges (see Appendix).

Faces - A set of 36 emotional faces was collected from a web source - MacArthur Face Stimuli - to represent the six emotions. Six different faces were matched to each emotion category according to the Ekman and Friesen (1975, pp. 34-128) classification of facial expressions.

Colours - Seven different colours were chosen according to Wexner’s (1954) verbal association of colours and mood-tone. These were blue, red, yellow, orange, brown, green and purple. An additional grey colour was also included to correspond with the inclusion of the neutral condition. All colours were manipulated such that their saturation and luminance were as similar as possible.

Colour-Emotion Association Questionnaire - to assess the participants’ individual colour and emotion associations, a webpage questionnaire was created (www.adizohar.com/navit) to allow participants to demonstrate their colour-emotion associations at their own pace. Experiment 3 required the participants to return to the lab after one week, allowing participants to complete the questionnaire at home and thus reduce possible drop out rates. The questionnaire instructed participants to click on the one colour that *best* represents a specific basic emotion, then the one colour that *worst* represents the same emotion. The emotions involved were the six basic emotions and a neutral, non-emotional category. For each emotional category, the words (e.g. 'angry', 'happiness' etc) and a representative facial expression appeared together on a separate page. The word 'neutral' and a neutral facial expression represents the seventh neutral category. Colours were the seven colours used in the 2003 Study (blue, red, yellow, orange, brown, green and purple) with the addition of grey to parallel the addition of the neutral category. All colours had the same measures of brightness and saturation as those presented in the actual experiment. *High diagnostic colours of emotions* (*Appropriate condition*) represented the seven colours (which need not be always different colours) a participant had chosen to *best* represent the seven different emotional categories. Similarly, *low diagnostic colours of emotions* signify the colours (which also need not be different colours) each participant had chosen to *worst* represent the seven different emotions (*Inappropriate condition*).

Experimental stimuli - Words and face size, stimulus background size, level of contrast (ranging from 0.004-0.42) and measures of colour (brightness, saturation and luminance) were constructed and presented by SuperCard 10.4 software. All faces stimuli (280mm x 280mm) were coloured and presented on a background (400mm x 320mm) coloured with the individual low or high diagnostic colour of emotion, depending on the colour-emotion association questionnaire results. All word stimuli (240mm x 60mm) were coloured with the low or high diagnostic colour of emotion according to the results from the colour-emotion association questionnaire. Word backgrounds were coloured grey except for cases in which the colour *grey* was part of the participant's colour-emotion associations (e.g. *grey* was chosen to best represent the emotion *sad* or to worst represent the emotion *happy*). In these cases, word backgrounds were coloured white to keep the contrast level at each presentation in the standardised range. Half of the total 84 stimuli were used as test stimuli and the remainders were the distractors. Both sets of stimuli had an equal amount of words and faces stimuli (24 words and 24 faces in each set). Retention intervals of 15 minutes and one week were used in Experiment 2 and in Experiment 3, respectively. In both experiments, participants were randomly assigned to each of the colour groups: high diagnostic colours (appropriate colours), low diagnostic colours (inappropriate colours) and random colours (in Experiment 3 only).

Apparatus: The experiment was run using SuperCard software on a Macintosh monitor. Stimuli were viewed on screen at a distance of 60 cm, face stimuli subtended

26.6 x 33.7 degrees of visual angle and word stimuli subtended 21.8 x 5.7 degrees of visual angel.

Procedure: Before arriving at the experiment, participants completed the colour-emotion web questionnaire twice (without knowing about the second completion in advance). Via email, participants' were first instructed to submit their results seven days before their experiment participation and then one to two days before their arrival they were contacted again to submit their second results. Consequently, all the participants first submissions were received five to seven days before their actual participation and all the second submissions were received the day before or on the same day of their participation. The level of participants' consistency in associating colour with emotion was determined by the similarities between the first and the second completions. Participants who had at least 5 out of 7 different colour-emotion associations similar were defined as *consistent* in their ability to associate colours with emotions (their level of consistency was 71 % or more, based on a rough median split). Participants who had 4 or less different colour-emotion associations similar were defined as *non-consistent* in their ability to associate colours with emotions (their level of consistency was 57 % or less, based on a rough median split). In the consistent group those who were more consistent with colours that *best* represent emotion were assigned to the *high diagnostic colours* (of emotion) condition which is also called the *Appropriate* (colour of emotion) condition. Conversely, those who were more consistent with colours that *worst* represented the seven different emotion categories were assigned to the *low diagnostic colour* (of emotion) condition, also called the *Inappropriate* (colour of emotion) condition (see Table 6.1). Since participants were much more consistent with the appropriate colours of emotions than with the inappropriate colours, those who were consistent with both types of association were assigned to the inappropriate condition (about 40% of the participants in this condition). Non-consistent participants were assigned to the two experimental conditions (Appropriate versus Inappropriate) randomly (see Table 6.1).

Table 6.1: Sample size per cell for the between subject design (Experiment 2).

	Consistent	**Non-Consistent**	**Total**
Appropriate	n = 36	n = 20	N = 56
Inappropriate	n = 36	n = 20	N = 56
Total	n = 72	n = 40	N = 112

The stimulus presentation program allowed the researcher to adjust the colour presentations, from one participant to another, by entering the last participant's colour-emotion association details prior to their participation. On arrival, each participant was asked to sit next to the computer screen which comprised his/her individual colour choices. In the induction phase, participants were instructed to view the stimuli as they appeared on the screen. Stimuli included three words and three faces from each set of emotive stimuli as well as three words and three faces from the neutral stimuli (42 stimuli overall) presented in a random order. If a participant was assigned to the Appropriate colour condition, he/she was presented with words coloured with the colours the participant chose to best represent the seven emotional categories and with faces background coloured with the same colours (see Figures 6.3 and 6.4). However if a participant was assigned to the Inappropriate colour condition, his/her words and facial expression presentations were coloured with the colours that were chosen to worst represent the seven emotional categories (see Figures 6.5 and 6.6).

Following the induction phase participants were asked to complete a filler task, a paper copy of a MENSA intelligence test, for 15 minutes and then to immediately continue to the next experimental phase - retrieval. In the retrieval phase there were a total of 84 stimuli (which included the 42 induction stimuli and an additional 42 distractors). For each participant all stimuli were coloured with the same colours that were presented in the induction phase. For example, those who were presented with the set of appropriate colours of emotions were also tested with the same appropriate colours and those who were presented with the set of inappropriate colour of emotions were tested with the same inappropriate colours. Participants were instructed to recognise the original emotional stimuli as accurately and quickly as possible by pressing different counterbalanced screen buttons for 'I recognise' and 'I don't recognise'. Stimulus presentation time during both the induction and retrieval phases was four seconds per stimulus with a 'white blank' interval of 2 seconds between each stimulus (see Figures 6.7 and 6.8). Each subject was presented with a different random sequence of stimuli in both of the experimental phases. Before leaving the lab participants were debriefed and able to ask questions.

Figures 6.3 and 6.4: Example of the two stimulus types as they appear in the induction-appropriate colour and test-appropriate colour conditions (Experiment 2 and 3).

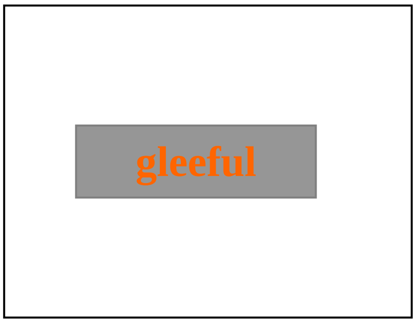


Figure 6.3: Word presentations for participants who chose orange as an appropriate colour for 'happy'.

Figure 6.4: Face presentations for participants who chose red as an appropriate colour for 'angry'.

Figures 6.5 and 6.6: Example of the two stimuli types as they appear in the induction-inappropriate colour and test-inappropriate colour conditions.

Figure 6.5: Word presentations for participants who chose purple as an inappropriate colour for 'happy'.

Figure 6.6: Face presentations for participants who chose blue a an inappropriate colour for 'angry'.

Figure 6.7: Example of an induction trial (Experiment 2 and 3)

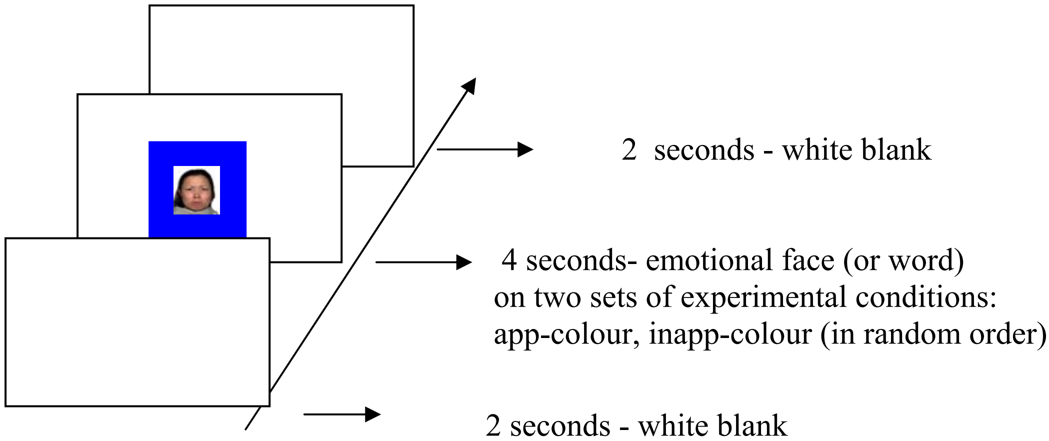
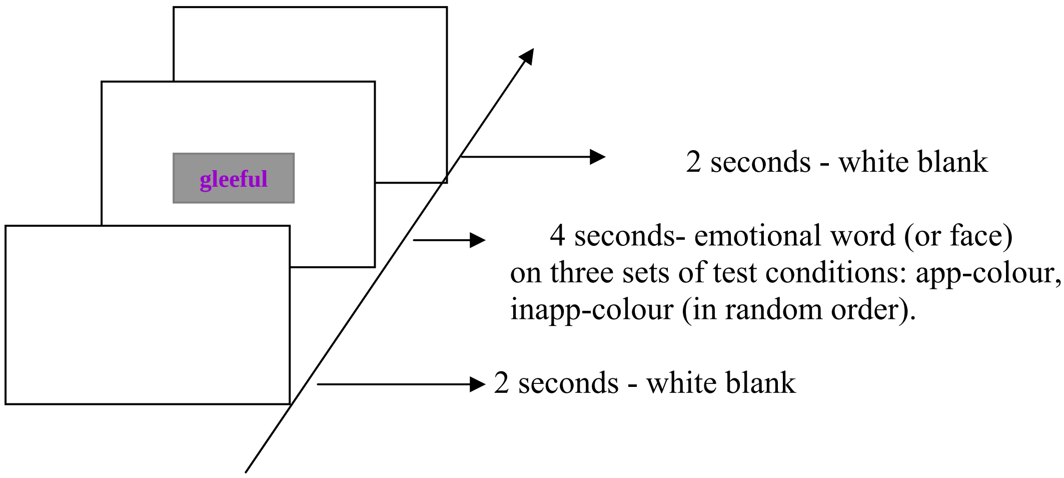


Figure 6.8: Example of a test trial (Experiment 2 and 3)



6.2.3 RESULTS

Experiment 2 hypotheses were tested by analysis of variance with a significance level of 0.05. Figure 6.9 depicts the mean percentage correct recognition for the between subject variables 2 (Appropriate and Inappropriate) x 2 (Consistent and Non-Consistent). Figure 6.12 sets out the mean percentage correct recognition for the within subject variables 2 (Emotional and Neutral) x 2 (Words and Faces). Results showed significant differences between the Appropriate and Inappropriate experimental conditions. Regardless of consistency level, participants' correct responses were significantly higher when stimuli were coloured with the appropriate colours of emotions than when they were presented with inappropriate colours of emotions $F(1,110) = 7.353$, $p = 0.008$. The interaction effect of the colour conditions and consistency level was not significant $F\ (3, 108) = 1.804$, $p = 0.151$.

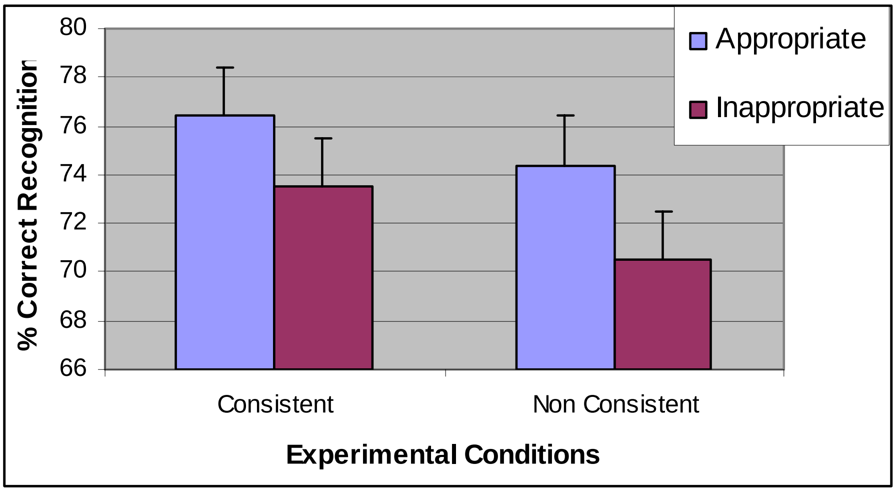


Figure 6.9: Mean percentage correct recognition for Appropriate versus Inappropriate presentations as a function of consistency level (Experiment 2).

In addition to calculating the % of correct responses, we applied SDT to measure d-prime for each of the two factors (consistent vs. non consistent). Figures 6.10 and 6.11 show that not only did participants have significantly higher correct responses in the Appropriate colour condition than in the Inappropriate colour condition but also that participants were more sensitive in discriminating between 'old' and 'new' stimuli (faces or words) when the stimuli were presented with appropriate rather than inappropriate colours of emotion $F(1,110) = 6.181$, $p = 0.014$. No significant bias effect among the between variable conditions was found $F(1,110) = 1.942$, $p = 0.166$)

as β values were nearly consistent among all groups (see Figure 6.11). That is, participants consistently used a conservative recognition approach to decide whether to reject or accept a stimulus, thereby reducing false alarms.

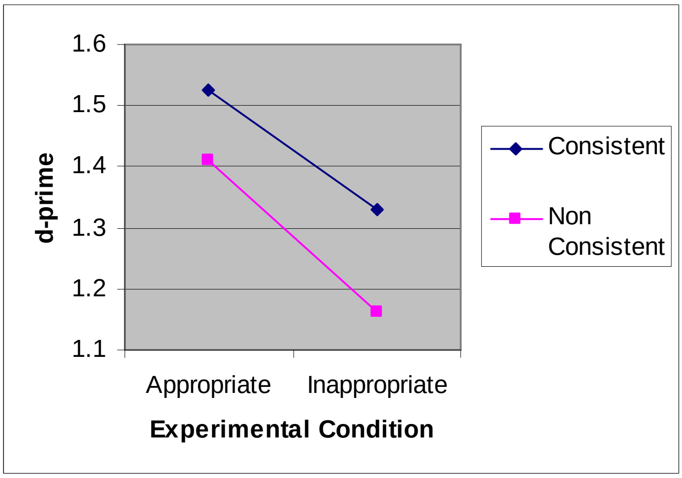


Figure 6.10: d' values as a function of colour condition and level of consistency (Experiment 2).

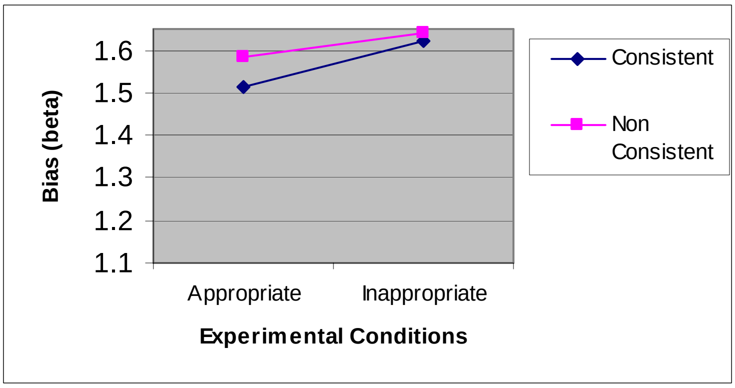


Figure 6.11: Bias (β) in recognition memory performance as a function of experimental condition (Experiment 2).

An ANOVA also confirmed the expectation for an interaction effect (F (3, 220) = 4.204, p = 0.006) between the Stimulus Type (Emotion vs. Neutral) and the Colour conditions (Appropriate vs. Inappropriate). Figure 6.12 plots the mean percentage of correct responses in each of the experimental conditions. As the figure shows, the differences in recognition memory between the two colour conditions (Appropriate vs. Inappropriate) were significant only for emotional stimuli, $F(1, 110) = 8.168$, p = 0.005, but not for neutral stimuli, $F(1, 110) = 0.149$, p = 0.7. The measures of d' (Figure 6.13) and β also revealed a similar finding. Participants were significantly more sensitive to emotional stimuli coloured with the individual's high diagnostic colours of emotions $F(1,110) = 6.366$, $p = 0.013$ than when they were presented with low diagnostic colours of emotions (in these presentations β measures were only marginally significant $F(1, 110) = 3.787$, $p = 0.54$). This sensitivity in discriminating 'old' stimuli from 'new' stimuli, as well as the memory facilitation, did not appear when participants viewed the set of neutral stimuli $F(1, 110) = 0.045$, $p = 0.832$ (β measures were also non-significant $F(1, 110) = 0.74$, $p = 0.392$).

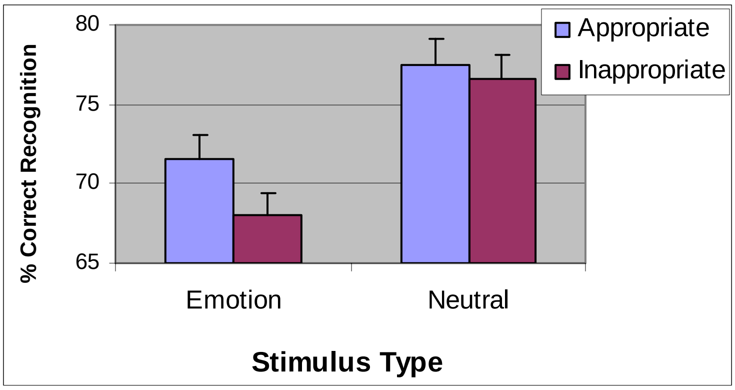


Figure 6.12: Mean percentage correct recognition as a function of stimulus type and colour Condition (Experiment 2).

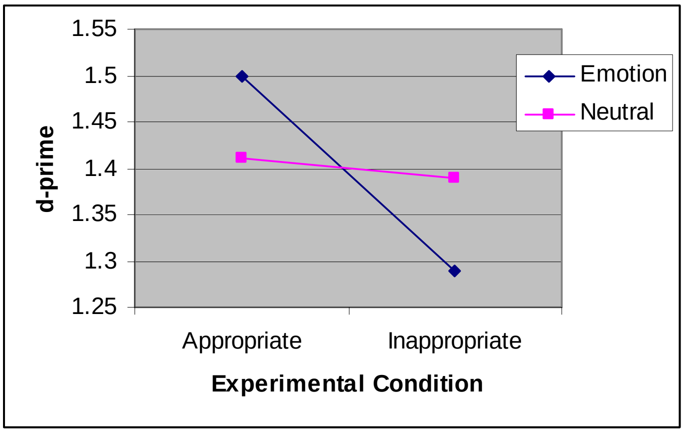


Figure 6.13: d' values as a function of colour condition and stimulus type (Experiment 2).

Finally, Figure 6.14 depicts the mean percentage of correct recognition for the four different stimulus types used in the experiment as the within-participants variables, 2 (Emotion vs. Neutral) x 2 (Words vs. Faces). The findings shown in Figure 6.14 disclose a peculiar and unexpected pattern of results. Specific interaction effects between stimulus type (words/faces) and stimulus category (emotion/neutral) revealed that unlike other experimental conditions, participants performed extremely well when recognising neutral words from a set of distractors $F(1, 222) = 168.25$, $p = 0.000$ (see Figure 6.14). However, participants performed significantly better when they were presented with emotional facial expressions than when presented with neutral facial expressions $F(1, 222) = 5.24$, $p = 0.023$. Reaction time data tested by analysis of variance indicated no significant findings (see Figure 6.15). Participants responded with similar decision times across all the experimental conditions.

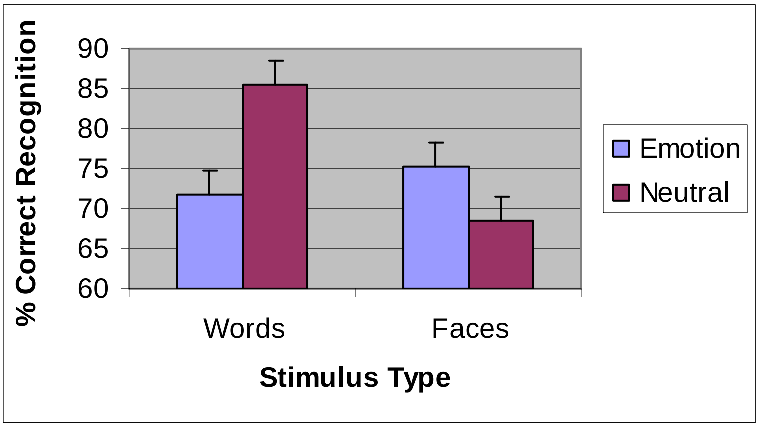


Figure 6.14: Mean percentage correct recognition for emotional versus neutral information as function of stimulus type (Experiment 2).

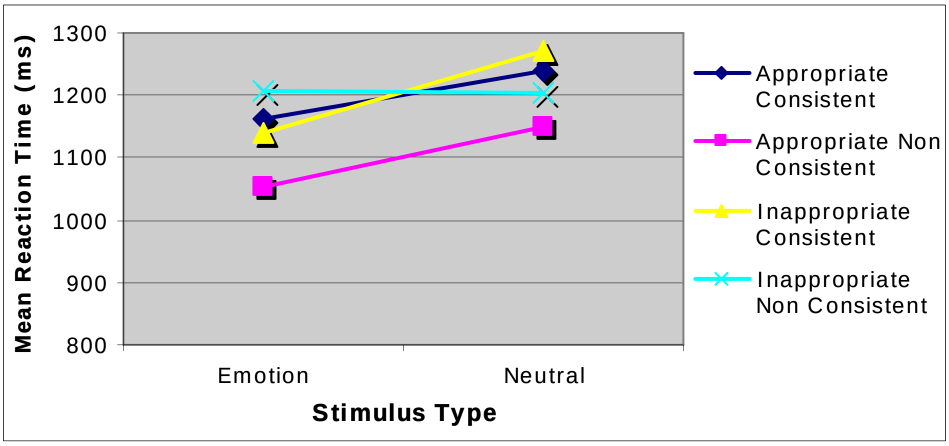


Figure 6.15: Mean reaction time as a function of stimulus type and colour conditions (Experiment 2).

6.2.4 DISCUSSION

The presence of diagnostic colours of emotions (or the individual's highly associated colour with emotion) aid performance in a short-term recognition memory task. The findings of Experiment 2 give strong affirmative answers to both of the experimental hypotheses and thus expand on previous findings in showing that emotional stimuli, like other stimulus types (objects, everyday scenes), can also benefit from the use of diagnostic colours in recognition memory tasks. Overall, the participants' performance was significantly improved when they were presented with emotional stimuli coloured appropriately (with the high diagnostic colours of emotions) compared to emotional stimuli coloured inappropriately (with the low diagnostic colours of emotions). The colour diagnosticity enhancement effect was uniquely present for emotional words and emotional facial expressions but not for the non-emotional/neutral stimuli. These results are consistent with existing studies that show a superiority of recognition memory for objects and natural scenes high in colour diagnosticity (Ostergaard & Davidoff, 1985; Price & Humphreys, 1989; Intraub & Nicklos, 1985; Homa, & Viera, 1988, Park & Mason, 1982; Suzuki & Takahashi, 1997; Olivia & Schyns, 2000; Latimer, Palethorpe, Mezey, Ellwood, Raju & Hicks, 2002; Wichmann, Sharpe & Gegenfurtner, 2002).

As mentioned before, the fact that neutral words were remembered significantly better (14%) than emotional words is in contradiction with many other studies that show, in fact, a memory facilitation for emotional information over neutral information. However, the fact that this uncharacteristic result was not evident for the facial expression stimuli raised the possibility that the neutral word stimuli used in the current experiment do not reliably represent the non-emotional or neutral category, at least not in a similar way to the collection of emotional words representing the six basic emotions. Furthermore, neutral words were judged as non-emotional even though they were not as closed in meaning as were the emotional words for each of the basic emotions. For example, although the words *bombastic*, *immutable*, *atheistic*, *diligent*, *credible and cosmetic* are indeed non-emotional, they do not mean 'neutral'. In contrast the emotional words of *fearing, horrified, worrying, frightful, panicked, terrorize* all convey the meaning of 'fear'. Consequently, a new collection of neutral words was employed in Experiment 3 by using the exact method of collection that was done with emotional words - using a Microsoft Office Word 2003 'thesaurus' computer tool to find words that have the same or similar meaning to the word 'neutral'.

6.3 EXPERIMENT 3: Colour diagnosticity for long-term recognition memory of emotional information

6.3.1 INTRODUCTION

Experiment 2 validated the theory of colour diagnosticity in showing memory facilitation for emotional stimuli coloured in the (individual) diagnostic colours of emotions compared with emotional stimuli coloured in the non-diagnostic colours of emotions. This memory enhancement was demonstrated using 15 minute retention intervals. Thus, there was still a need to investigate the role of diagnostic colours of emotions in long-term memorisation. Experiment 3, therefore, used a retention interval of one week and employed similar methods to that in Experiment 2 two additions. The first concern the use of six new neutral words and the second involved the addition of a third colour condition in which the emotional stimuli were coloured in a random colour. A random colour was any colour that differed from the participant's best choice (appropriate) and worst choice (inappropriate) of colour for a specific emotion. This third colour condition provided a baseline measure against which individual’s high diagnostic colours of emotions (appropriate colours of emotions) improve performance on both. For example, if non-diagnostic colours of emotions impair recognition memory of emotional information then memory performance for stimuli coloured with the individual's low diagnostic colours of emotions should be significantly lower than for stimuli coloured randomly.

Since the colour diagnosticity effect in Experiment 2 was evident even for participants with non-consistent colour-emotion associations, the present investigation did not account for the participants' level of consistency. Accordingly, Experiment 3 had a three-factor (3 x 2 x 7) design: 3 Colour Conditions (Appropriate/Inappropriate/Random) x 2 Stimulus Type (Words/Faces) x 7 Emotion Categories (Six Basic Emotions/Neutral). It was expected that participants would be more sensitive and accurate when recognising information coloured with high diagnostic colours of emotions (Appropriately coloured stimuli) than information coloured with low diagnostic colours of emotions (Inappropriately coloured stimuli). However, this colour diagnosticity effect was expected to appear specifically for emotional words and facial expressions but not for the neutral stimuli. The question of whether non-diagnostic colours of objects (or natural scenes) particularly impair recognition memory has not been investigated previously. Consequently, there is no support for a hypothesis in a specific direction.

METHOD

Participants: Experiment 3 included 90 participants (79% women and 21% men aged 18-42) with a reported range of 13-26 years of formal education. All were screened using the Ishihara Test to confirm that they had normal colour vision. All participants were allocated randomly to each of the experimental groups.

Stimuli: All colours, faces and word stimuli, except for the six neutral words, were the same as in Experiment 2. The new set of neutral words was collected by using the same method as in the 2003 Study and Experiment 2 by using a Microsoft Office Word 2003 'thesaurus' computer tool which produced alternative words that matched the word-meaning 'neutral'. The new set of words was: *impartial, balancing, equalize, abstain, unbiased* and *equitable* which was compatible with the set of emotional words in frequency and length (all were low-frequency words and consisted of six to nine letters). A group of 12 judges agreed upon their match with the term 'neutral' and demonstrated a total of 94% agreement (see Appendix).

Apparatus and Procedure: The experiment's apparatus and procedure were the same as in Experiment 2 with the exception that following the induction phase, participants were asked to return seven days later for a retrieval phase. Furthermore, in this experiment participants were assigned to three colour conditions rather than two (in Experiment 2), where both emotional and neutral stimuli were coloured either in the individual's high diagnostic colours of emotions (Appropriate colour condition), in the individual's low (or non) diagnostic colour of emotion (Inappropriate colour condition) or in a random colour - a colour that was necessarily different from both low and high diagnostic colours of emotions (random colour condition).

6.3.3 RESULTS

Overall, the ANOVA revealed that significant differences among the three colour groups, F (1, 87) = 12.006, p = 0.001. Priori contrast showed that the percentage of mean correct responses was significantly higher for stimuli coloured appropriately than for stimuli coloured inappropriately, t (87) = 2.017, p = 0.047 or for stimuli coloured in a random colour t (87) = 3.465, p = 0.001 (Figure 6.16). Differences in correct responses between stimuli coloured inappropriately and stimuli coloured randomly were not significant, t (87) = 1.448, p=0.151.

Figure 6.16: Mean percentage correct recognition as a function of colour conditions (Experiment 3).

Differences in correct responses between stimuli coloured inappropriately and stimuli coloured randomly were not significant, t (87) = 1.448, p=0.151.The measure of *d'* also revealed a similar significant pattern in line with the experimental expectations. An overall ANOVA revealed significant differences in *d'* among the three colour groups, F (2, 87) = 5.749, p = 0.005. Figure 6.17 shows significant *d'* differences between the Appropriate and Inappropriate colour conditions t (87) = 2.264, p = 0.026 as well as between the Appropriate and the random colour conditions t (87) = 3.318, p = 0.001. However, no significant differences were found in *d'* between the Inappropriate and the random colour conditions t (87) = 1.054, p = 0.295. Furthermore, no differences in bias in the participants' discrimination between 'old' and 'new' stimuli were found among the three colour conditions, F (2, 87) = 0.052, p = 0.949. Specifically, differences in β values between the appropriate versus inappropriate colour conditions and between the appropriate versus the random conditions were not significant, t (87) = 0.229, p = 0.819 and t (87) = 0.312, p =

0.756, respectively. Thus, the short-term memory patterns of enhanced performance, for diagnostic colours of emotions over non-diagnostic colours of emotions revealed in Experiment 2, were replicated in Experiment 3 for long-term memory performance.

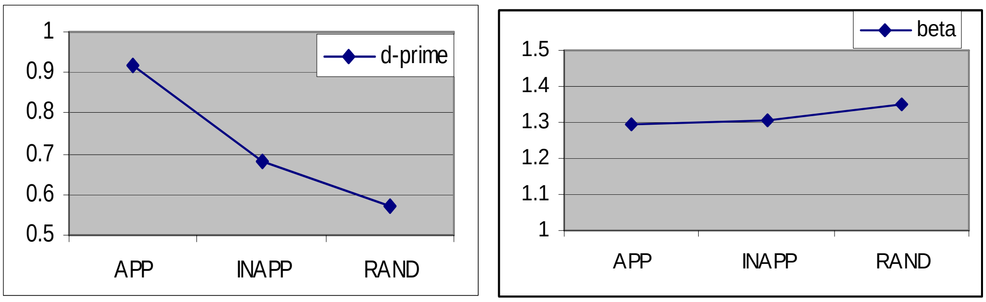


Figure 6.17: d’ and β values as a function of colour condition (Experiment 3).

Overall, emotional faces and words were remembered significantly better than neutral faces and words F (1,178) = 19.501, p = 0.000 (Figure 6.18). Unlike in Experiment 2, differences between the emotional words and neutral words specifically, were not significant F (1,178) = 1.271, p = 0.261. Significant differences in percentage correct responses were again found between the emotional facial expressions and the neutral facial expressions F (1,178) = 25.781, p = 0.000.

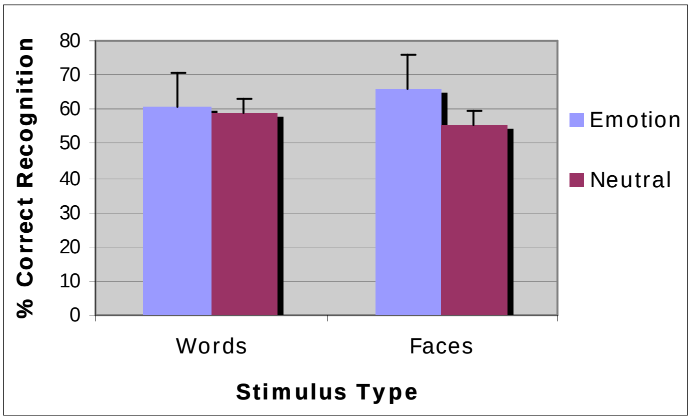


Figure 6.18: Mean percentage correct recognition for emotional vs. neutral information as a function of stimulus type (Experiment 3).

Furthermore, the hypotheses for an interaction effect between the Colour conditions (Appropriate vs. Inappropriate vs. Random) and the Stimuli Type (Emotion vs. Neutral) were also confirmed (Figures 6.19 and 6.20). Contrasts analysis applied separately for each type of stimulus revealed significant differences in mean correct percentage between the three colour conditions for the emotional stimuli, $F(2, 87)$ =

6.057, $p = 0.002$, but not for the neutral stimuli, $F(2, 87) = 1.149$, $p = 0.255$. Although the findings depicts in Figure 21 may reflect a floor effect for the neutral stimuli, this is not consistent with the results shown in Experiment 2 (Figure 6.12). Further, interaction results for emotional versus neutral stimuli were also found with *d'*. Differences among the three colour conditions were significant for emotional stimuli, $F\ (2, 87) = 4.063$, $p = 0.021$ (with β values constant and not significant across the three groups, $F\ (2, 87) = 0.562$, $p = 0.32$) but not for neutral stimuli, $F\ (2, 87) = 0.523$, $p = 0.594$. Although for emotional stimuli, differences in *d'* between the appropriate and inappropriate colour conditions were only marginally significant $F\ (2, 87) = 3.162$, $p = 0.065$ the differences between the appropriate and random colour conditions showed a stronger significance - $F\ (2, 87) = 8.564$, $p = 0.005$. Finally, as it was found in Experiment 2, results form the Reaction Time Measure did not reveal any significant differences across the experimental conditions (see Figure 6.21).

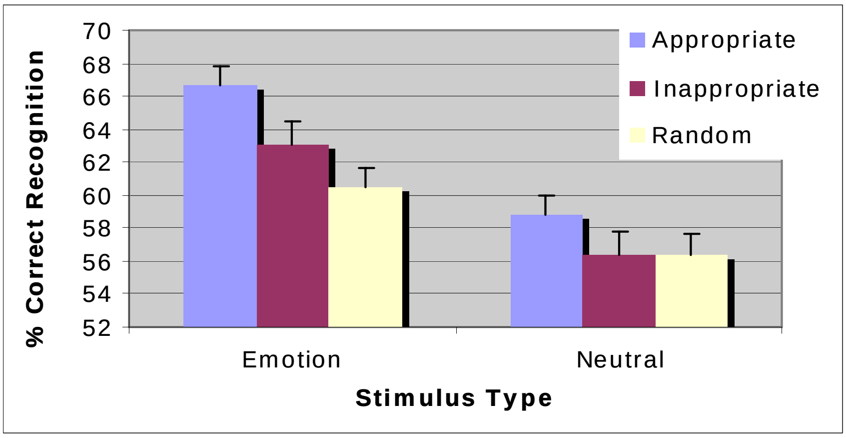


Figure 6.19: Mean percentage correct recognition as a function of stimulus type and colour condition (Experiment 3).

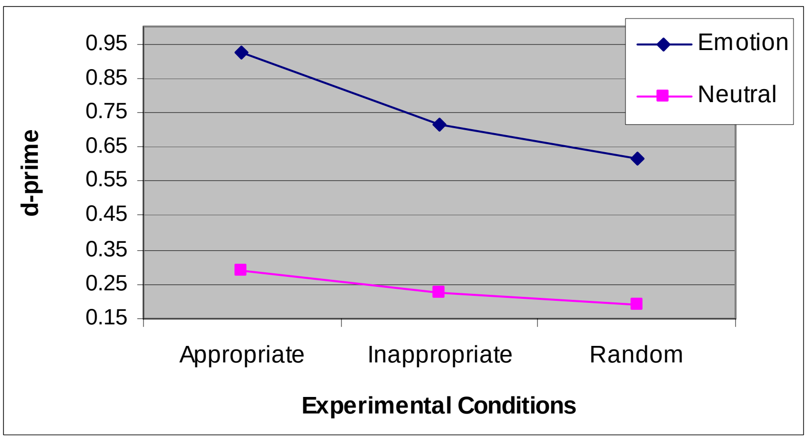


Figure 6.20: d' values as a function of colour condition and stimulus type (Experiment 3).

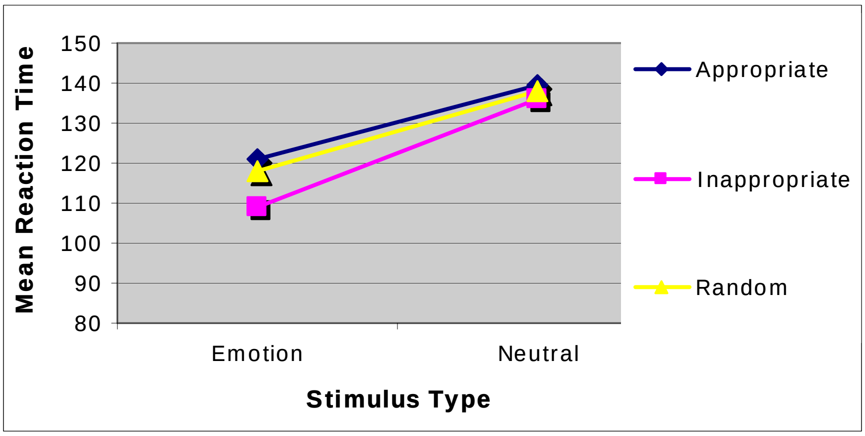


Figure 6.21: Mean Reaction Time as a function of stimulus type and colour conditions (Experiment 3).

6.3.4 DISCUSSION

Experiment 3 overall showed an enhanced memory performance for emotional stimuli over neutral stimuli - a pattern than supports previous findings (Sven-Ake, 1991; Kensinger & Corkin, 2003a; Kensinger & Corkin, 2003b; Hamann et al., 1999; Doerksen & Shimamura, 2001; Hiroyuki, Hiroto, Matthew & Ralph, 2002). Experiment 3 also replicated Experiment 2's finding by demonstrating a facilitation of recognition memory of emotional stimuli coloured with diagnostic colours (Appropriate colour condition) compared to emotional stimuli coloured with non-diagnostic colours (Inappropriate and random colour conditions). The interaction effect between the colour conditions, appropriate versus inappropriate, and the stimulus type, emotional versus neutral, was only moderately significant. In contrast, the interaction effect between the appropriate and random colour conditions which did show strong significant differences. This difference may relate to the fact that participants were asked to associate both appropriate and inappropriate colours with the seven categories of emotions but were not asked to do so for random colours. Thus, the fact that participants actively associated appropriate and inappropriate colours with emotions prior to the experiment may have resulted in some degree of learning or memory facilitation for these colours that was not possible for the collection of random colours. Nevertheless, the fact that the differences between the inappropriate and the random colour conditions were not significant may suggest that the beneficial effect of colour-emotion associations on memory, as evident by this study, lies beyond a mere learning process.

The fact that no significant differences were found among the three colour conditions for neutral stimuli may further suggest that colour-emotion associations are stronger and more meaningful for the individual than the associations between colour and non-emotional or neutral stimuli. Finally, while both Experiments 2 and 3 were designed to look at whether highly associated colours of emotions (appropriate colours) can enhance recognition memory of emotions more significantly than the least associated colours of emotions (inappropriate colours), Experiment 3 also aimed at investigating whether inappropriate colours of emotions impair recognition memory of emotions compared to any other colours. The findings showed that this third colour condition did not result in significantly different memory performance than the memory performance shown in the inappropriate colour condition. This was also evident as an interaction effect between the three colour conditions and the stimulus type. For emotional stimuli only, differences in memory performance between the appropriate and the random colour conditions were significant whereas differences between the inappropriate and random colour conditions were not significant.

Two conclusions can be made based on these findings. First, any colour other than the individual appropriate colour of a certain emotion is effectively a non-diagnostic colour and thus is likely to impair the memory of that emotional stimulus as much as any individually chosen inappropriate colour. Second, as mentioned above, the findings that highly associative colours of emotions enhance memory cannot be explained merely by a learning process in which participants were engaged during the colour-emotion association questionnaire. Instead, the data indicates that the individual's highly associated colours of emotion are, in fact, part of their memory representations and are therefore activated during the retrieval process - a suggestion that will be investigated specifically and more thoroughly in Experiment 4. However, preceding the description of Experiment 4 some post hoc findings from both Experiment 2 and Experiment 3 are presented in the following section.

6.4 EXPERIMENTS 2 and 3: Post Hoc Findings

6.4.1 INTRODUCTION

Since both Experiment 2 and Experiment 3 required that participants associate appropriate and inappropriate colours with seven emotional categories, in two different experiments (with a gap of one year between each) it was possible to assess the consistency level with which our student population from both experiments linked colour and emotional information, even though it was not originally one of the study's objectives. Although colour-emotion association consistency had been investigated quite thoroughly cross-culturally (D'Andrade & Egan, 1974; Pecjak, 1970; Murray & Deabler, 1957; Osgood, 1960; Osgood, et al., 1975; Oyama et al., 1963; Hupka et al., 1997) only one study looked at these associations within the Australian population (Hemphill, 1996) and none had checked their consistency level over time. Furthermore, studies that looked at the colour-emotion relationship have mostly focused on the association of colours that best represent emotions (appropriate colours of emotions) and none have investigated the associations of colours that worst represent emotional information (inappropriate colours of emotions). Consequently, the two experiments described above provided an opportunity to explore two well-studied, colour-emotion association attributes. First, the two experiments allowed the degree of consistency (Boyatzis & Varghese, 1996; Hemphill, 1996; Valdez & Mehrabian, 1994; Wexner, 1954; Zentner, 2001) with which participants associate inappropriate and appropriate colours with emotions to be explored. Consistency was measured firstly by the total percentage agreement from both experiments for appropriate versus inappropriate colour-emotion associations (Table 6.22). Second, the two experiments also provided the ability to assess the consistency in associating colours the seven different emotions. That is, whether some specific emotions tend to be linked more easily and thus more consistently with colours than with any other emotions (Figures 6.23 and 6.24).

In summary, the data given in this section may highlight some important questions for further investigations using a statistical analysis. The first is whether the consistency level in associating appropriate colours with emotions is significantly different than the consistency level in associating inappropriate colours of emotions (Table 6.22).

The second is whether there are significant differences in the participants' agreement in associating specific (appropriate and inappropriate) colours with certain emotions (Figures 6.23 and 6.24). Specifically, the figures provide insights into whether some emotions tend to be associated more consistently with specific (appropriate and inappropriate) colours than other emotions and as a result tend to receive an overall higher agreement of colour-emotion associations than any other emotion and whether the same highly associated emotions with appropriate colours are also highly associated with inappropriate colours. Finally, since the main objective of this thesis was to study recognition memory in relation to the participants' ability to associate colours with emotions, an interesting question is whether the participants' consistency level in associating colours with emotions had an effect on memory performance among the various types of the colour-emotion associations, for example, whether high percentage agreement in associating specific colours with specific emotions resulted in a higher percentage of correct recognition responses for the same emotions (Figures 6.25 and 6.26).

6.4.2 RESULTS AND DISCUSSION

Figures 6.23 and 6.24 depict the total percentage agreement from Experiment 2 and Experiment 3 of associating appropriate and inappropriate colours with seven emotions, respectively. Overall, the findings demonstrate that four specific *appropriate* colour-emotion associations have been agreed by the majority of participants from both experiments (percentage agreement 50% or higher) whereas only two *inappropriate* colour-emotion associations resulted in the same level of agreement.

For both appropriate and inappropriate colour-emotion associations, the emotions 'happiness' and 'sadness' received a consistent level higher than 50% for the colour associations: yellow-happy (appropriate), grey-happy (inappropriate), sad-grey (appropriate) and sad-yellow (inappropriate). The appropriate colour-emotion associations (Figure 6.23) additionally show high percentage agreement (above 50%) for the emotions 'anger' and 'disgust' associated with 'red' and 'brown', respectively. The first appropriate highly associated colour-emotion combination (anger-red) received an agreement level higher than any other colour-emotion combinations (appropriate or inappropriate) from the participants in both experiments (an average of 93%).

A higher consistency level was shown for appropriate colours than for inappropriate colours. It was therefore worth looking at whether such consistency patterns had some effect on recognition memory performance on emotions with consistent colour combinations versus emotions with specific non-consistent colour associations. Figures 6.25 and 6.26 plot the percentage correct recognition for emotions that had colour associations with a total percentage agreement of 20% and above in the two experiments for appropriate and inappropriate colours respectively. As Figure 6.25 depicts, 11 different appropriate color-emotion associations received a percentage agreement at that level and Figure 6.26 shows a total of 10 different inappropriate colours of emotions with the same agreement level. Although both experiments were not designed specifically to compare the recognition memory of emotions with consistent and stable colour associations to those with non-consistent colour associations (the group number is not equal) the findings do suggest that for appropriate colours specifically, as the total agreement level for the colour-emotion associations increases, so does the memory performance for these colour-emotion combinations. That is, emotions that received a high degree of agreement for a specific colour-emotion combination tended to be remembered better than emotions that received low level agreement in their colour associations. This pattern of result is more evident for the appropriate colour-emotion associations than for the inappropriate colour-emotion associations. For example, the emotions ‘angry’ ‘happiness’, ‘disgust’ and ‘sadness’ received a degree of consistency higher than 50% for the association of the appropriate colours red, yellow, brown, and grey respectively. These were the only consistent colour-emotion associations that received a percentage of correct responses higher than the average percentage of correct responses for the same emotions across all colours. The inappropriate colour-emotion combinations, happy-grey and sad-yellow, were the only ones that received a degree of consistency higher than 50% among all other inappropriate colour-emotion associations. Only the first combination had a percentage of correct responses higher than the average percentage of correct responses for the same emotions presented across all colours. Table 6.22 depicts the percentages of correct recognition and the consistency level for each of these highly associated colour-emotion combinations.

The pattern shown for inappropriate colour-emotion combinations reveals that most of the emotions that had colour associations with a total percentage agreement of 20% or higher were remembered equally well (Figure 6.26). For the consistent appropriate colour emotion associations, on the other hand, the majority of colour-emotion associations that received a percentage of correct responses equal to, or higher than, the percentage of correct responses for the same emotions presented with any colour, on average, had an agreement level of at least 50%. Thus, it seems that the consistency level in associating colours with emotions may have a greater effect on the memory of emotions presented with appropriate colour-emotion associations than on the memory of emotions presented with inappropriate colour-emotion associations.

Table 6.22: Relationship between high agreement level and recognition memory of Appropriate and Inappropriate colour-emotion associations (Post hoc findings, Experiments 2 and 3).

	Colour-Emotion Associations	% Agreement for the specific colour-emotion association	% Correct Recognition for the specific colour-emotion association	Average of % CR for the same emotion presented with any colour
Appropriate Colour Associations	Angry-Red	93.2	75.2**	72.5
	Happy-Yellow	79.2	76.7**	70.7
	Disgust-Brown	64.7	71.3**	66.6
	Sad-Grey	52.1	70.1**	67.9
Inappropriate Colour Associations	Happy-Grey	78.6	72.**	64.8
	Sad-Yellow	68.4	64.9	68.9

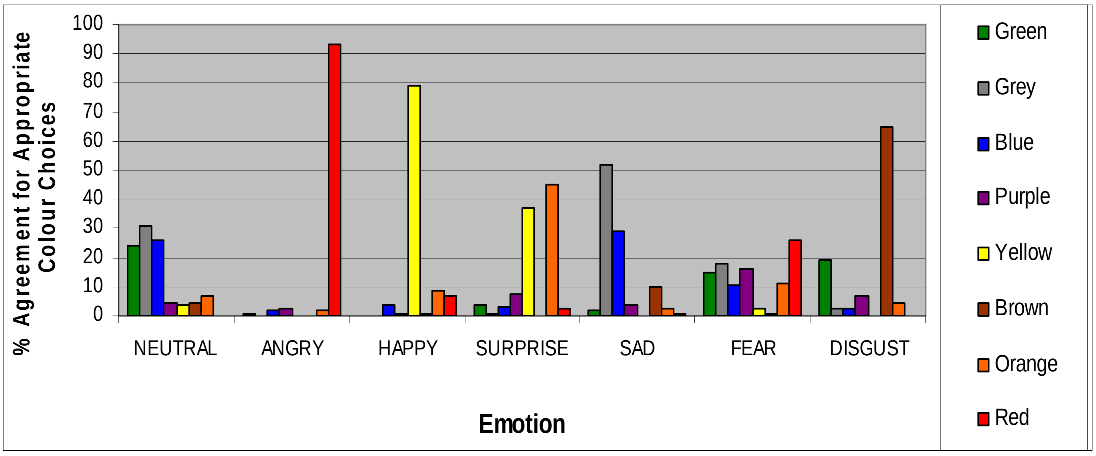


Figure 6.23: Percentage agreement of Appropriate colour choices for each of the seven emotional categories in Experiments 2 and 3 (N = 66).

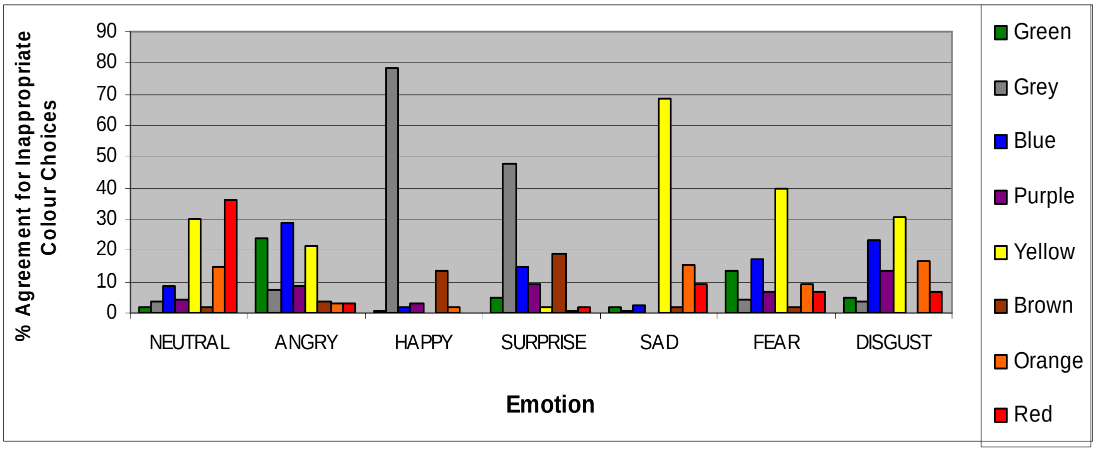


Figure 6.24: Percentage Agreement of inappropriate colour choices for each of the seven emotional categories in Experiments 2 and 3 (N = 66).

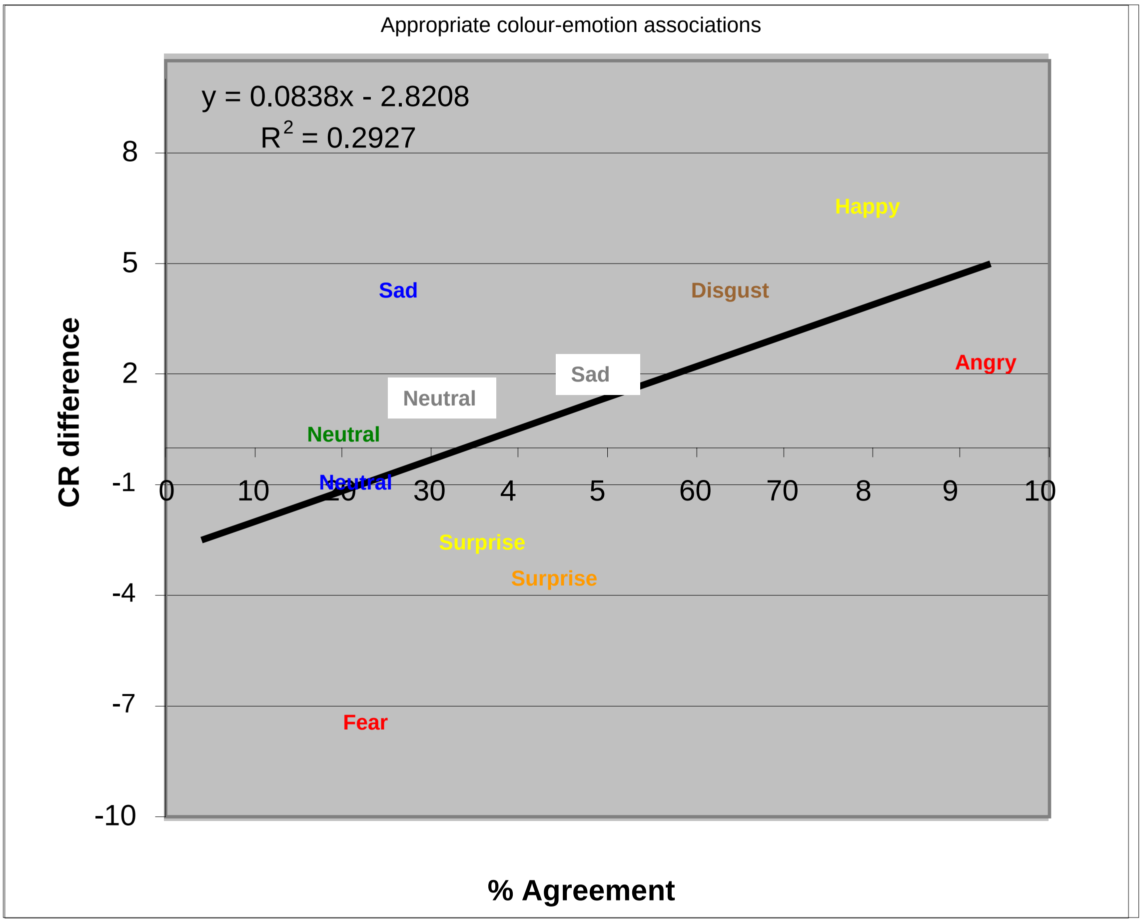


Figure 6.25: % Correct recognition differences for Appropriate colour-emotion associations (which had 20% agreement or more in Experiments 2 and 3) as a function of % Agreement.

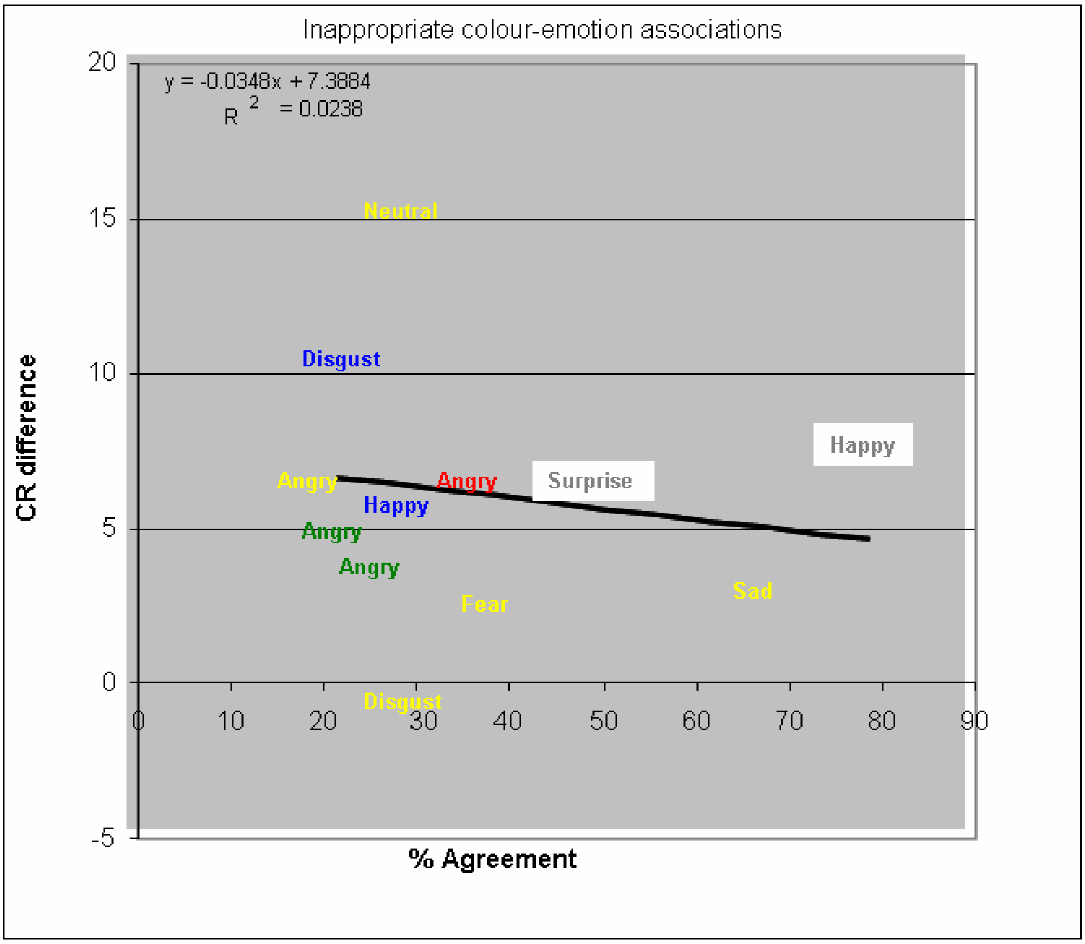


Figure 6.26: % Correct recognition differences for Inappropriate colour-emotion associations (which had 20% agreement or more in Experiments 2 and 3) as a function of % Agreement.

6.4.3 CONCLUSIONS

The post hoc findings shown above reveal a few consistent patterns in which participants associate colours with emotions. First, it seems that participants tend to be more consistent in associating appropriate colours with emotions than in associating inappropriate colours with emotions. Nevertheless, some emotions (happiness and sadness) seem to be easier to associate colours with than other emotions regardless of whether it is an appropriate associative colour or an inappropriate associative colour (e.g., 'happiness', 'sadness'). Furthermore, the data emphasises that specific appropriate colour associations of 'anger' with red, and 'happiness' with yellow are the most consistent associations across the two experiments. These highly consistent colour-emotion associations were also shown to be quite dominant in Experiment 1 of this dissertation as well as in previous studies (Hupka, et al., 1997; Luscher, 1971; Wexner, 1954). More uniquely, the findings reveal two novel inappropriate colour-emotion associations, happy-grey and sad-yellow, that had strong agreement rates in both of the experiments. This may be related to the idea that happy and sad are opposite emotions on the valence dimension, and are often indicating a strong negative correlation (Green, Goldman, & Salovey, 1993; Feldman Barrett & Russell, 1998).

Finally, the data demonstrate a link between consistent colour-emotion associations and the degree to which these emotions are remembered. Specifically, emotions that had highly appropriate consistent colour associations among participants from both experiments may tend to be remembered better when they were presented with these highly associative colours than emotions with associated colours that had a lower degree of consistency. Inappropriate colour-emotion associations however, revealed that for emotions that had colour- associations with a consistency level of 20% or above were remembered roughly the same regardless of which colour they were presented with. Thus, as far as memory performance of emotional information is concerned, post-hoc analysis suggests that consistent appropriate colour-emotion combinations may have a greater effect on memory (of these emotions) than consistent inappropriate colour-emotion associations. Consequently, more research is needed to investigate the particular question of whether emotions presented with their consistent *appropriate* colour-emotion associations are indeed remembered significantly better than emotions presented with their consistent *inappropriate* colour-emotion associations.

CHAPTER 7

EXPERIMENT 4:

Stroop Test for Colour Diagnositicity of Emotions

7.1 INTRODUCTION

The results from Experiments 1, 2 and 3 together, validate the theory of colour diagnosticity in showing memory facilitation for emotional stimuli coloured in the (individual) diagnostic colour of emotion compared with emotional stimuli coloured in the (individual) non-diagnostic colour of emotion. Previous colour and memory investigations have suggested that this superiority effect of colour diagnosticity on recognition memory of objects and natural scenes is (at least partly) a result of high level of visual processing of colour information. At this level of processing, colour activates memory representations that are linked to the knowledge of the stimulus's congruent colour (Davidoff, 1991; Joseph & Proffitt, 1996; Joseph, 1997; Nicholson & Humphrey, 2004; Tanaka et al, 2001; Wichmann, 2003). Thus, studies that have shown a beneficial effect of colour diagnosticity on memory usually imply that the diagnostic colours themselves are part of the memory representations of the to-be-remembered items (Gegenfurtner & Rieger, 2000; Olivia & Schyns, 2000; Nagai & Yokosawa, 2003; Olivia & Schyns, 2005; Olivia & Torralba, 2001; Tanaka & Persenall, 1999; Vernon & Lloyd-Jones, 2003; Wichmann et al., 2002).

Do the findings presented so far in this dissertation directly indicate that the individuals' diagnostic colours of *emotions* are also part of the conceptual (or memory) representations of basic emotions? Studies to date, aimed at investigating the question of whether diagnostic (or natural) colours of certain objects play a substantial part in the conceptual representation of objects, often preferred the Stroop paradigm to recognition tests (Menard-Buteau & Cavanagh, 1984; Klein, 1964; Naor-Raz, Tarr & Kersten, 2003). For example Naor et al claimed that object identification and recognition tasks employ both visual and nonvisual sources of information and thus hinder the ability to establish the specific level or levels of processing (visual, conceptual, or lexical) at which the surface properties of an object affect its recognition. Thus, to test whether the visual representation of an object intrinsically includes surface properties such as colour, Naor-Raz et al used a Stroop task and asked observers to make judgments that do not directly invoke object identity- to name the colour of the object (rather than to name or identify the object itself). Since both, Klein's and Naor-Raz, et al's studies found a faster mean response times for objects coloured in typical colours than for objects coloured in atypical colours, they agreed that colour is indeed, an intrinsic property of object representation.

Our previous results (from Experiment 1 to 3) showed a colour diagnosticity superiority effect for the memory of emotional stimuli. However, the automaticity of this colour-emotion diagnostic relationship, demonstrated by an interference effect for emotional words coloured with non-diagnostic (inappropriate) colours, has not yet been studied. The experiment described herein aims to investigate this effect empirically by using the Stroop paradigm to test colour diagnosticity of emotions. If any knowledge of colour is stored in the representations of the individuals' emotions, this experiment should reveal a faster naming times of the (individual) appropriate colours of emotional words than the naming times of the (individual) inappropriate colours of emotional words. However, if colour is not part of the conceptual representations of emotions, than naming time of appropriate colours of emotions should not differ than the naming time of inappropriate colours of emotions. Furthermore, if colour representations are unique to emotions but not to non emotional information, than such differences in naming times of appropriate versus inappropriate colours, should not be evident when participants are presented with the collection of neutral words.

The current study involves the manipulation of colours on emotional and non-emotional (neutral) stimuli A Stroop task designed to look at the differences in reaction time of naming appropriate versus inappropriate emotional colours when the carrier words are either emotional or neutral, may be affected not only by the Semantic Stroop effect discussed above, but also by the Emotional Stroop effect. The emotional Stroop effect is the slowdown in naming the colour of the emotional words compared with the naming speed of the neutral words, as a failure of fully selective focusing on colour induced by the carrier words (for reviews, see MacLeod, 1991; Williams et al.,1996; Melara & Algom, 2003). Although the majority of emotional Stroop studies have reported larger interference in non-clinical groups to negative concern-related stimuli (Williams et al., 1996), a few researchers have demonstrated that emotional interference for nonspecific negative stimuli (McKenna & Sharma, 2004; McKenna & Sharma, 1995; Pratto & John, 1991; Richard et al, 1992). Little or no interference has been found however for positive emotional stimuli (McKenna &

Sharma, 1995; Pratto & John, 1991; Richard et al, 1992). To exclude any biased contradicting effects on the naming times of positive and negative words, the basic emotions used in the current Stroop task exclude the emotions 'happy', 'surprise' and 'disgust' and include only 'sadness', 'anger' and 'fear'. Thus, although this experiment is mainly focused on the differences in naming emotional versus neutral words as a function of the colour manipulation, the well-documented Emotional Stroop effect may be also evident in showing faster reaction times for naming neutral words than naming emotional words. Experiment 4 included a three-factor (2 x 3 x 4) design: 2 Colour Conditions (Appropriate/Inappropriate) x 3 Word Stimulus Type (Emotional/ Neutral/ Non Word) x 4 Order (Appropriate Emotion/Inappropriate Emotion/ Appropriate Neutral/Inappropriate Neutral).

METHOD

Participants The participants were 70 undergraduate students at The University of Sydney (78% women and 22% men, aged 18-43) with a reported range of 13-23 years of formal education who received course credit for their participation and were randomly allocated to two experimental Stroop tasks. All had normal colour vision (according to the Ishihara test for colour-blindness, 1917) and were tested individually.

Apparatus and Material Word stimuli- all emotional and neutral word stimuli were taken from the collection of words obtained for the previous experiments (Experiment 2 & 3), with the addition of six nonwords which were created from the existing six neutral words (impartial; balancing; equalize; abstain; unbiased; equitable) by changing the order of their letters (lapmirtia; glabiancn; uezlaqie; tabinsa; dsbuinae; etqeblaiu). The emotional words represented the basic emotions 'sad', 'anger' and 'fear' and included two words per category (desolate and grieving; enraged and furious; panicked and fearing, respectively). The total percentage agreement of emotional words was 95 % as judged by 21 participants overall (in Experiments 2 & 3). The total percentage agreement of the neutral words was 94% as judged by 12 participants (see **Appendix)**.

Colours- to ensure that each colour was used in the colour-emotion association questionnaire only once (see the procedure section for more details) colours included eight colours used in Experiments 2 & 3 (blue, red, yellow, orange, brown, green, purple, grey) with the addition of two colours: white and pink. The exclusion of 'black' form this collection of colours was to prevent the possibility of associating only achromatic colours with the neutral category (a pattern that was shown in piloting).

Word and face stimuli were constructed and presented using SuperCard 10.4 software and were identical in all measurements to those used in the previous experiments (Experiments 2 and 3). Additionally, all word stimuli were coloured with the low or high diagnostic colours of emotions, in a similar fashion to that used in Experiments 2 and 3 according to the results from the colour-emotion association questionnaire.

Design and Procedure: Before testing participants on the Emotional Stroop task designed specifically for this experiment's objectives, there was a need to test whether the specific Stroop paradigm (block design) used in the current experiment was also capable of producing the standard colour Stroop effect, originally introduced by Stroop (1935). According to Stroop (1935), when participants are asked to name the ink colour of words (usually colour names), they experience a delay by the presence of an irrelevant colour word that conflicts with the target colour (Classic Stroop Effect). For example, if the word *red* is presented in green ink, then the word interferes with the identification of the ink. Studies (Klein 1964; Naor-Raz et al, 2003) that established the Stroop-like effect with objects words that had typical colours (Semantic Stroop) have usually relied on a blocked design (similar to that used in the standard Stroop task) in which participants read through lists of entirely colour-typical or colour-atypical colour -word pairs and the dependent measure is the time taken to name all colours in the complete list. We adopted this particular block design for our Emotional Stroop task, as a group of ten participants who were tested on the standard Stroop task showed results consistent with the standardized Stroop effect (see the Result section for the detailed findings).

The remaining 60 participants were then tested on the Emotional Stroop task which had a similar block design to that used in the Standard Stroop, with the exception of presenting emotional and neutral words (or non words) as the carrier words, instead of colour words. To assess their colour-emotion associations, all 60 participants were asked initially to complete the online questionnaire used in Experiments 2 and 3 by instructing them to associate only one colour with each emotion and three different colours with the neutral condition. The questionnaire included two types of colour associations, association of the *best* and *worst* colour with each emotion category. To ensure that the same colour was not presented twice or more in the Stroop naming task that followed, participants were not allowed to choose one colour more than once in each of the two association tasks (as they were in the previous experiments). Thus, the collection of the individual *best* colours of emotions (appropriate colours of emotions) as well as the collection of the individual *worst* colours of emotions (inappropriate colours of emotions) in the present experiment resulted in different individual colour associations.

Following the completion of the colour-emotion association questionnaire, participants were randomly assigned to one out of two different block-designed Stroop tasks, each comprising four different blocks. One Stroop task included the blocks: emotional (negative) words coloured appropriately, emotional (negative) words coloured inappropriately, neutral words coloured appropriately and neutral words coloured inappropriately (Table 7.1). The second included the blocks: neutral words coloured appropriately, neutral words coloured inappropriately, non-words coloured in the appropriate neutral colours and non-words coloured in the inappropriate neutral colours (Table 7.2). The second blocked Stroop task was designed to exclude any potential bias in reaction time as a result of the participants' tendency to specifically use achromatic colours (e.g. white, grey, brown) as the appropriate colours of neutral category, and chromatic colours (e.g. red, pink, orange) as the inappropriate colours of the neutral category. Within each block, four different trials displayed the six emotional, neutral or non-words stimuli, in a random order. In each trial participants were presented with three columns (and 12 rows) of words displaying the six different coloured word stimuli repeated 12 times (Figure 7.3). Thus, there were 36 word stimuli in each trial and a total of 144 word stimuli in each block. All 36 words within each trial were randomized in such a way that no ink colour appeared twice or more in succession within one raw. Similarly, all trials within each block as well as the order of the emotional versus the neutral blocks were presented randomly. An additional practice trial was used prior to the actual testing, to allow participants to familiarize themselves with the task. Participants were instructed to verbally name the ink colour of each word from left to right (three words per row) as quickly and accurately as possible, and to press a button when they have finished naming all the 36 colour words on each trial. Between each trial participants were given five minutes break to prevent any potential emotional interference effect (slow emotional effect that can last among trials and may result with the slowdown of naming neutral words) as suggested by McKenna, and Sharma, (2004). The researcher was provided with the list of correct colour names for each trial which enable to notify participants when a mistake was made. In this case, the instruction was to repeat the colour name until it was named correctly.

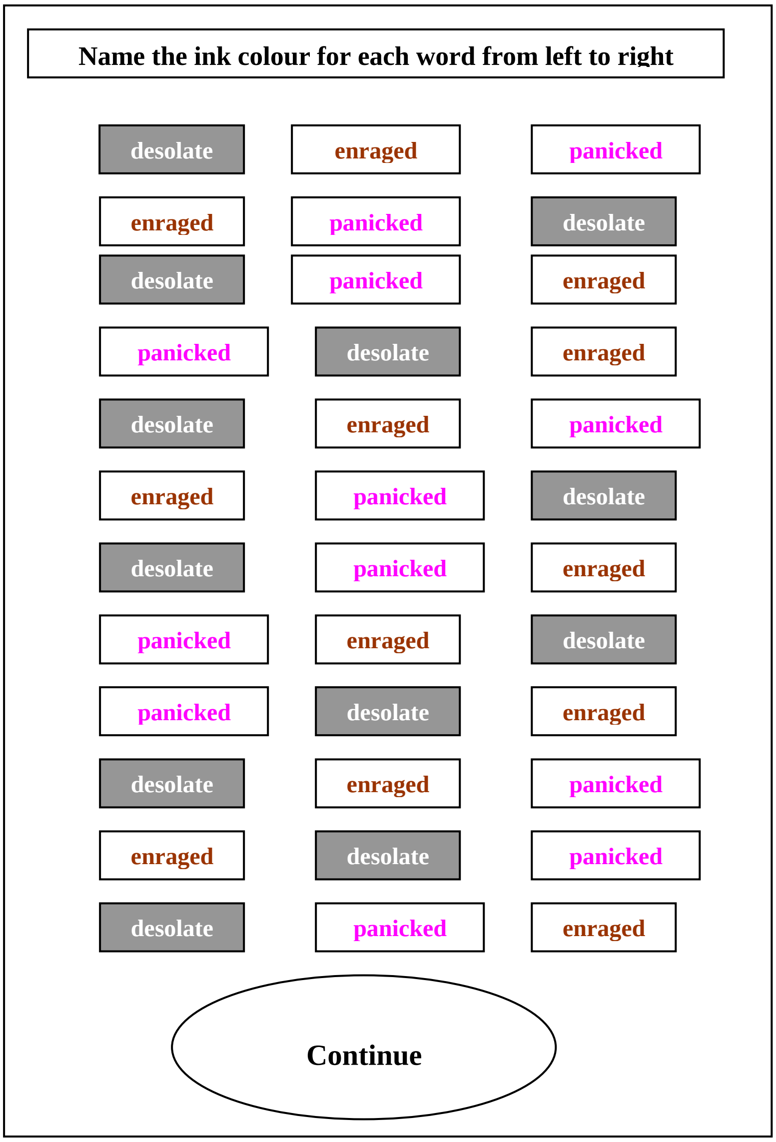
Table 7.1: Sample size per cell for Experiment block 1 (Experiment 4).

	Emotional Words	**Neutral Words**
Appropriate Colour	n = 10	n = 10
Inappropriate Colour	n = 10	n = 10
Total	n = 20	n = 20

Table 7.2: Sample size per cell for Experiment block 2 (Experiment 4).

	Neutral Words	**Non Words**
Appropriate Neutral Colour	n = 5	n = 5
Inappropriate Neutral Colour	n = 5	n = 5
Total	n = 10	n = 10

Figure 7.3: Example of an inappropriate emotional Stroop trial (Experiment 4).



7.3 RESULTS

7.3.1 Standard Stroop Task: the data for colour naming and word reading in the five conditions of each task are shown in Figure 7.4. Plotted are the mean reaction times for each of the ten participants performing in the five conditions of the (blocked design) standard Stroop task. A glimpse at Figure 7.4 reveals that reading coloured words was considerably faster than colour naming, with an overall difference of 8.46 seconds favoring reading, F (1, 19) = 20.38, p = 0.00. Reading black and white words (RBWW) was also significantly faster than naming congruent (NCGC), F (1, 9) = 30.584, p = 0.011, or incongruent (NINCGC) colour words, F (1, 9) = 30.584, p = 0.000. Overall, there were no significant differences among the three reading conditions F (2, 9) = 3.135, p = 0.110, except for the differences between reading congruent versus reading incongruent colour words, which had a mean speed difference of 1.26 seconds , F (1, 9) = 6.99, p = 0.027.

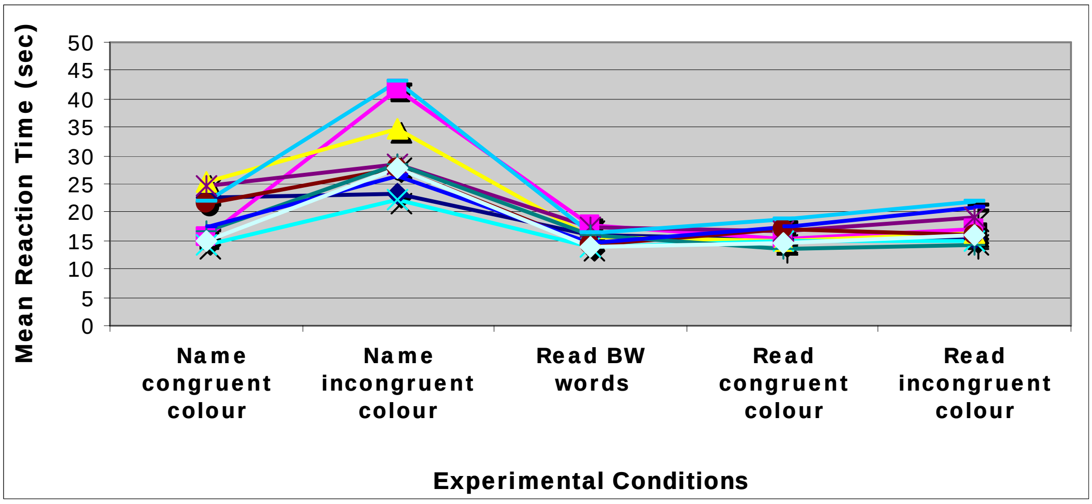


Figure 7.4: Mean reaction as a function of task condition for each of the 10 participants in the Standard Stroop Task (Experiment 4).

The most critical result to emerge from the standard Stroop task is the significant slowdown in colour naming of incongruent colour names compared to all other conditions, with an averaged speed difference of 13.42 seconds, F (4, 9) = 23.915, p = 0.000. Looking at the two naming conditions, the specific speed difference between the congruent and the incongruent colour conditions were also significant, with a mean difference of 10.9 seconds favoring congruent colours, F (1, 9) = 20.378, p = 0.001. Another very important result of the preliminary analysis was the total absence of order effects in the data. A five-way ANOVA for repeated measures with task condition as a within subject factor and order of presentation as a between subjects factor revealed no main effect of order of presentation, F (3, 6) = 3.817, p = 0.077 and no interaction effect between the task condition and the order of presentation, F (3, 6) = 0.857, p = 0.512. The absence of an order effect in our standard Stroop data and the fact that the findings fit with the previous pattern of results commonly shown for the standard Stroop effect (Stroop 1935; Melara & Algom, 2003), allowed us to continue confidently testing the two following Stroop tasks (reported below) that had an identical block design to that used in the standard Stroop task, with the exception that the carrier words were either emotional, neutral or non words, instead of colour names.

7.3.2 Stroop Task for Colour Diagnosticity: the Stroop task for colour diagnosticity consisted of two different Stroop tasks in which participants were assigned randomly to. The first, compared participants' reaction time to emotional words (coloured appropriately and inappropriately, in two different blocks) with their reaction time to neutral words (coloured appropriately and inappropriately in two additional blocks). The second compared the participants' reaction time to neutral words (coloured appropriately and inappropriately, in two different blocks) with their reaction time to non-words (coloured with the same appropriate and inappropriate neutral colours, in two additional blocks). The analyses for these two Stroop tasks are reported separately below.

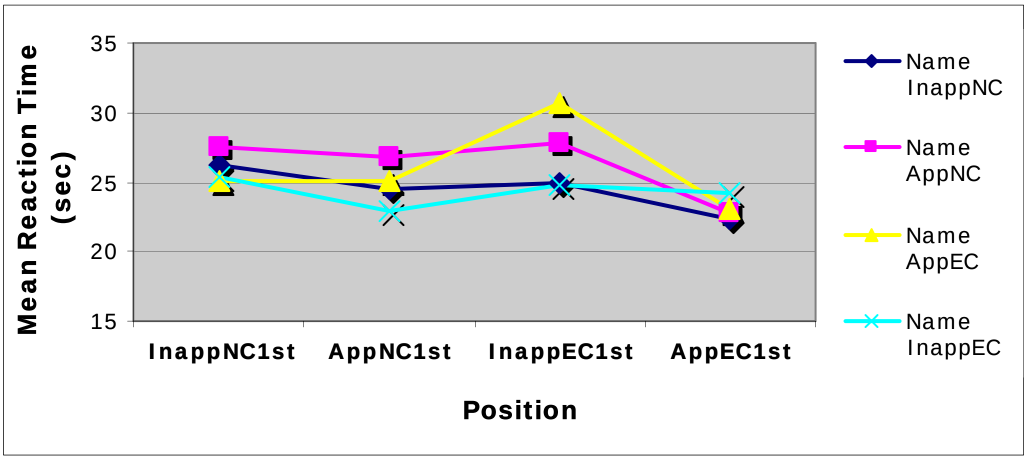


Figure 7.5: Mean reaction for each of the four Stroop tasks as a function of task position, in Stroop Task 1 (Experiment 4). Name InappNC = naming inappropriate neutral colour; Name AppNC = naming inappropriate neutral colours; Name AppEC = naming inappropriate emotional colours; Name InappEC = naming inappropriate emotional colour.

<u>Naming Appropriate and Inappropriate colours of Emotional versus Neutral words:</u> a four-way ANOVA on the reaction time data, was performed as repeated measures with task condition as a within subject factor and order of presentation as a between subjects factor. The analysis revealed a significant main effect of task condition, F (3, 36) = 8.24, p = 0.007 (observed power 0.798), a significant interaction effect of task condition and order of presentation, F (9, 36) = 6.11, p = 0.002, but no significant main effect of order of presentation (observed power 0.94), F (3, 36) = 0.36, p = 0.358. As shown in Figure 7.5 participants' reaction times in each of the four Stroop tasks was not significantly affected by the order of presentation except for cases in which the first Stroop task was to name inappropriate colours of emotional information (Name AppEC).

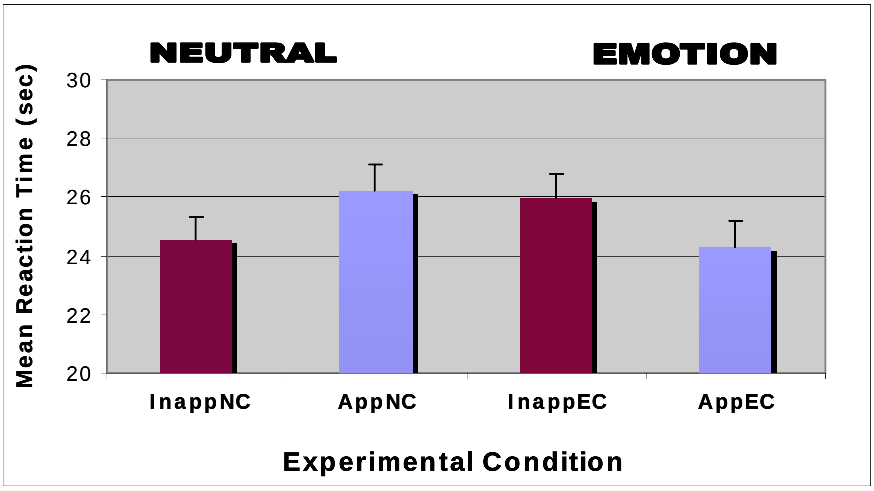


Figure 7.6: Mean reaction for each of the four Stroop tasks conditions, in Stroop Task 1 (Experiment 4). InappNC = naming inappropriate neutral colour; AppNC = naming inappropriate neutral colours; AppEC = naming inappropriate emotional colours; InappEC = naming inappropriate emotional colour.

2 x 2 ANOVA for stimulus type (Emotion vs. Neutral) and colour conditions (Appropriate vs. Inappropriate) revealed significant interaction effect among the four experimental groups F (3, 117) = 5.917, p = 0.02. These findings are demonstrated in Figure 7.6, and show faster naming of appropriate versus inappropriate colours of emotions, with a mean difference of 1.63 seconds in favor of naming appropriate colours, F (1, 39) = 7.663, p = 0.009. Conversely, when the Stroop tasks were to name the colours of neutral words, a significant main effect between naming appropriate and inappropriate neutral colours was in favor of the inappropriate neutral colours, with a mean difference of 1.67 seconds, F (1, 39) = 9.003, p = 0.005. Furthermore, naming appropriate colours of emotional words was on averaged 1.88 seconds

significantly *faster* than naming appropriate colours of neutral words, F (1, 39) = 9.225, p = 0.004, whereas naming inappropriate colours of emotional words was on averaged 1.42 seconds significantly *slower* than naming inappropriate colours of neutral words, F (1, 39) = 7.483, p = 0.009. No significant differences were found between the appropriate emotion and inappropriate neutral conditions, F (1, 39) = 0.326, p = 0.571, or between the inappropriate emotion and appropriate neutral conditions, F (1, 39) = 0.146, p = 0.704.

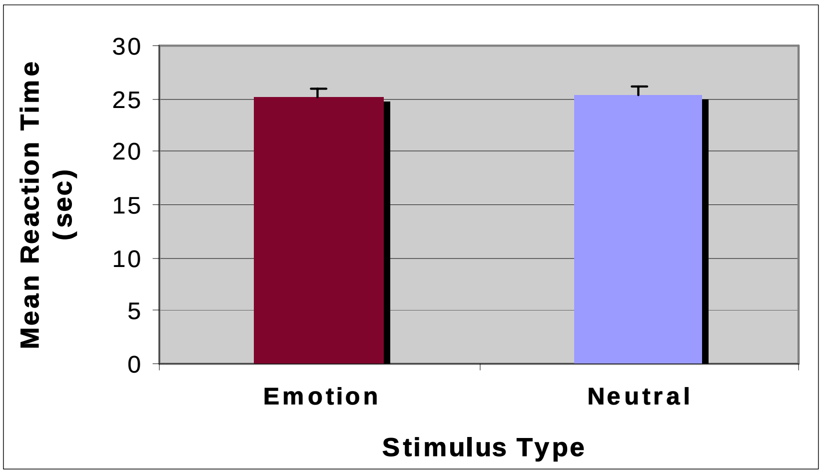


Figure 7.7: Mean reaction for naming emotional and neutral colours, in Stroop Task 1 (Experiment 4).

Finally, Figure 7.7 depicts the overall mean reaction times for naming emotional colours versus naming neutral colours. A repeated measures analysis on the participants' reaction time compared the mean reaction time for naming emotional colours (both appropriate and inappropriate) with the mean reaction time for naming neutral colours (both appropriate and inappropriate). There were no significant differences between the naming latencies of the two stimulus type, F (1, 79) = 0.274, p = 0.602.

Neutral versus Non-word Stroop Task: As the results reported above show, the significant differences between the two colour conditions (naming appropriate colour versus naming inappropriate colours) were reversed between the emotional words and the neutral words. Participants were significantly *faster* to name appropriate emotional colours than inappropriate emotional colours but were also significantly *slower* to name appropriate neutral colours than inappropriate neutral colours. The colours chosen as appropriate or inappropriate colours of the two stimulus type were not random but were based on the participants' individual colour associations. A specific pattern of colour associations was identified for the total collection of neutral colours. Specifically, participants were more likely to choose achromatic colours (e.g. grey, white, brown) as appropriate colours of the neutral and chromatic colours (e.g. pink, orange, red) as inappropriate neutral colours. This trend of colour choices raised the need to exclude the possibility that the significant slowdown in naming appropriate colours of neutral words was not purely due to differences in colour between the two groups of neutral words.

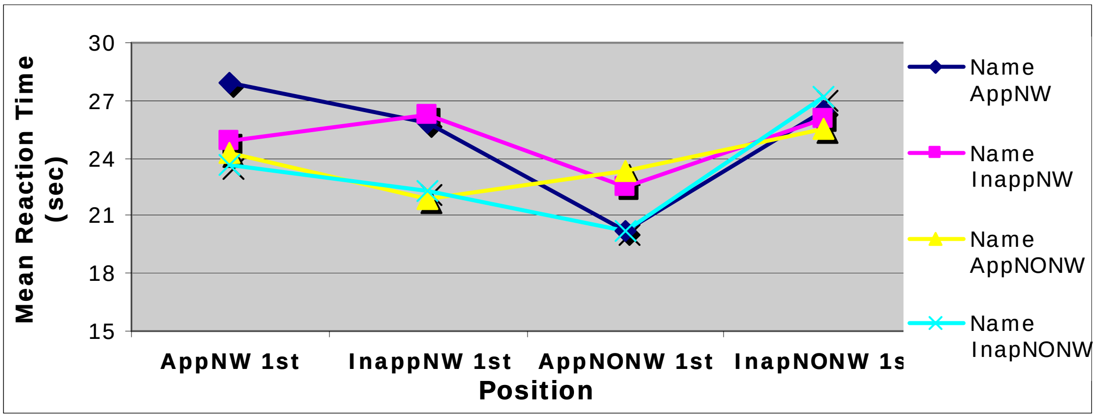


Figure 7.8: Mean reaction for each of the four Stroop tasks as a function of task position, in Stroop Task 2 (Experiment 4). Name AppNW = naming appropriate neutral colour of neutral words; Name InappNW = naming inappropriate neutral colours of neutral words; Name AppNONW = naming neutral appropriate colours of non words; Name InappNONW = naming inappropriate neutral colours of non words.

If this had been the case, than a similar pattern of result should also emerge from a Stoop task that uses non-words coloured in the appropriate an inappropriate neutral colours. Interestingly however, as shown in Figure 7.9, a mix model ANOVA revealed no significant main effects among the four conditions of the second Stroop task, F (3, 48) = 2.42, p = 0.104 (observed power, 0.5), except for the simple effect between the inappropriate neutral words condition and the inappropriate non-words condition, F (1, 19) = 6.51, p = 0.019. Figure 7.9 plots the mean reaction time for each of these 1 four Stroop tasks, which demonstrates that participants were significantly faster (MD= 1.53 seconds) in naming non words coloured in the inappropriate neutral colours than naming neutral words coloured inappropriately, but had even naming speed times among the other conditions. An ANOVA that added order of presentation as a between subject variable, resulted with no significant main effect, F (3, 16) = 1.507, p = 0.251 or interaction effects between order and the four task conditions of the second Stroop task, F (3, 16) = 2.42, p = 0.104. This pattern of result is depicted in Figure 7.8 which plots the mean reaction times for each task condition in four different orders of presentations. Finally, a two way ANOVA on the overall reaction times between neutral words and non words, also yield significance difference in favor of colour naming for non words (MD= 1.45 seconds), F (1, 39) = 5.322, p = 0.026 (Figure 7.10).

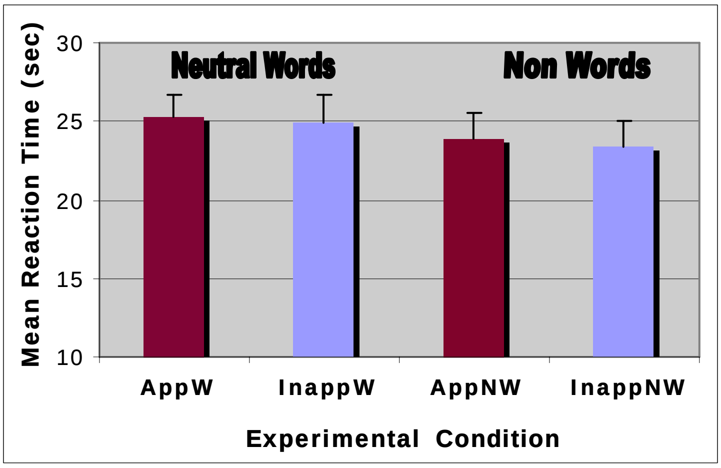


Figure 7.9: Mean reaction for each of the four Stroop tasks conditions, in Stroop Task 2 (Experiment 4). Name AppNW = naming appropriate neutral colour of neutral words; Name InappNW = naming inappropriate neutral colours of neutral words; Name AppNONW = naming neutral appropriate colours of non words; Name InappNONW = naming inappropriate neutral colours of non words.

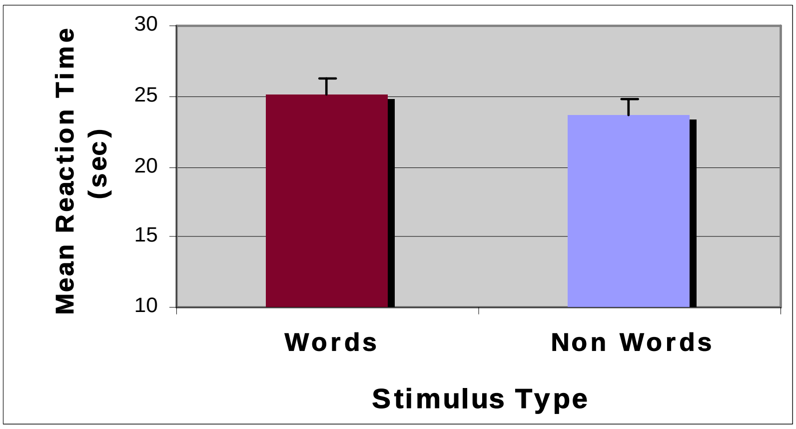


Figure 7.10: Mean reaction for naming neutral colours of words and neutral colours of non words, in Stroop Task 2 (Experiment 4).

7.4 DISCUSSION

The present experiment has succeeded in confirming its main hypotheses. First, from a methodological point of view, the results from the standard Stroop task clearly show the well-studied standard Stroop effect (Stroop 1935; Melara & Algom, 2003; MacLeod, 1991) thus confirming that the method of presentation and the design format may be also suitable for the assessment of other possible Stroop tasks (e.g. Emotional Stroop and Semantic Stroop - see McKenna & Sharma, 2004 for a review). Consequently, we continued to investigate the theory of colour diagnosticity on emotions by using two unique Stoop tasks that, for the first time, utilise individuals' colour emotion associations as the target colours and emotional versus neutral versus non-words as the carrier words.

The findings from the first Stroop task, that show a reversed pattern of colour naming for neutral words (faster naming times for inappropriate colours than for appropriate colours), were not expected and are particularly ambiguous considering that there was no main effect of order (in both Stroop tasks) and that the second Stroop task did not result in a similar pattern of findings for the non-word stimuli, even though the same collection of individual neutral colours was employed for both types of word carrier - neutral and non-words. Thus, the fact that participants in the second Stroop task were not faster to name *inappropriate neutral* colours of non-words compared to *appropriate neutral* colours of non-words, ruled out the possibility that the interference effect for appropriate neutral colours was simply due to the specific collection of the individual colours used for the representation of the neutral category (which, overall, had more chromatic colours for the collection of inappropriate colours than for the collection of appropriate colours). Furthermore, the fact that the second Stroop task did not show significant differences between naming the inappropriate and appropriate neutral colours when the carrier words were neutral may suggest that the interference effect that was found on the neutral carrier words, in the first Stroop task, may be attributed to the persistent (slow) disruptive effects that emotional stimuli can have beyond their presentation. However, since the observed power in the second Stroop task was lower than the first (0.5 and 0.94, respectively) further research should investigate the differences in the two Stroop tasks using equal sets of sample size.   Previous studies that investigated the magnitude of disruption from negative emotional stimuli in Emotional Stroop tasks pointed out that these types of stimulus can have an emotional lingering effect, and thus, a relatively slow effect that operates between trials is in fact stronger than any fast interference effect that may be activated within trials only. This may eventually result in a reversed interference effect – a slow down in naming neutral stimuli compared to negative stimuli or a disappearance of the emotional intrusion effect (McKenna, 1986; McKenna & Sharma, 1995; Sharma & McKenna 2001; McKenna & Sharma, 2004). Indeed, the overall comparison between the emotional and neutral stimuli did not yield a significant difference in the first Stroop task, thus the data provided herein fits with the above findings. It can be argued also that this null finding is due to the presence of another, no less prominent, Stroop interference which unlike the former Stroop effect was found significant - the semantic interference of colour associations (appropriate versus inappropriate) with emotional information. Despite the failure to show the immediate disruptive effects of emotional negative stimuli on information processing this experiment does add substantial weight to the argument that colours are semantically linked to emotions and may therefore be represented together with the emotional conceptual representations. That the findings from both Stroop tasks do not show a similar semantic Stroop for neutral colours as for emotional colours (the pattern was reversed or absent) suggests that any prototypical (conceptual) links that may exist between emotional information and colour information are different from the conceptual links that may exist between neutral information and colour information. This is in line with the findings from our previous experiments which demonstrated that, unlike emotional colour associations, neutral colour associations involve more achromatic colours (Experiment 1) are less stable (Post-Hoc findings of Experiments 2 & 3) and are not as strong as emotional colour associations in their ability to affect recognition memory (Experiment 3).

Finally, considering the mixed results of naming times for appropriate and inappropriate neutral colours, and the fact that the data did not show an Emotional Stroop effect, it interestingly raised the need to resolve a new research question: does a semantic Stroop effect, which involves two types of closely related stimuli, have the ability to fade out another strong and well-known attentional effect, namely, the Emotional Stroop? To provide a full account for such possibility, an expanded block design, similar to what has been used in the present experiment and which consists of five different blocks, should be adopted: (a) Emotional words coloured appropriately and inappropriately vs. Neutral words coloured appropriately and inappropriately (done in this experiment); (b) Emotional words coloured appropriately and inappropriately vs. Non-Words coloured in individuals' appropriate and inappropriate colours of emotions; (c) Emotional words coloured appropriately and inappropriately vs. Non-Words coloured in individuals' appropriate and inappropriate neutral colours emotions; (d) Neutral words coloured appropriately and inappropriately vs. Non-Words coloured in individuals' appropriate and inappropriate neutral colours (done in this experiment); (e) Neutral words coloured appropriately and inappropriately vs. Non-Words coloured in the individuals' appropriate and inappropriate colours of emotions.

CHAPTER 8

General Discussion and Conclusions:

8.1. GENERAL DISCUSSION

Our world is full of colours. Colours surround every part and moment of our lives so that from a very early age humans learn the colours of nature: that the sky is often coloured with shades of blue, the sun is radiant with yellow and a rose glows red. Through evolution humans acquire the knowledge to use colour to identify the location of food and to specifically judge its quality or ripeness (Mollon & Jordan, 1998; Polyak, 1975; Walls, 1972; Gegenfurtner & Rieger, 2000). Lately, research has further proposed that colour plays a critical role in everyday object recognition (Ostergaard & Davidoff 1985; Price & Humphreys 1989; Intraub & Nicklos 1985; Homa, & Viera, 1988, Park & Mason 1982; Suzuki & Takahashi 1997; Olivia & Schyns 2000; Latimer, Palethorpe, Mezey, Ellwood, Raju, & Hicks, 2002; Wichmann, Sharpe & Gegenfurtner 2002). Studies specifically suggest that acquired knowledge of objects, natural objects in particular, includes colour information which under imperfect viewing conditions can act as a diagnostic tool for their recognition (Wichmann, Sharpe & Gegefurtner, 2002; Olivia & Schyns, 2000; Tanaka & Persnell, 1999; Mapelli & Behrmann, 1997; Humphreys, Goodale, Jakobson, Servos, 1994; Price & Humphreys, 1989).

The main objective of this dissertation was to study the possibility that this special role of colour in recognition memory of objects and everyday scenes extends to the memory of our day-to-day emotional experiences and, as such, acts as a diagnostic tool for the recognition memory of emotions. While the diagnostic link between colours and objects strongly relies on the constant and natural appearance of specific colours with certain objects (e.g. yellow banana, blue sky), the appearance of particular colours under specific emotional circumstances is substantially less consistent. As suggested in Chapter Three, colour-emotion associations may be formed through the influence of culture (e.g. white clothing can symbolise, in some cultures, mourning and grief but in others purity and peace), physical appearance (e.g. the redness of an angry face; traumatic exposure to blood) or mere repetition of learning experiences (e.g. a blue dress of ones mother can form into to a colour-emotion association of favouring blue over all other colours). Furthermore, previous research (as well as the current investigation) provides evidence that unlike colour associations with natural objects, the degree to which people associate colours with emotions is highly varied not only across cultures but also within cultures (e.g.

Eysenck 1941; Wexner, 1954; Choungourian 1968; Valdez & Mehrabian 1994; Boyatzis & Varghese 1996; Hemphill 1996; Hupka et al. 1997). Thus, the fact that colour was found to be part of the conceptual representations of objects (Klein, 1964; Naor-Raz, Tarr & Kersten, 2003) does not necessarily mean that it is also part of the conceptual or memory representation of other information types such as emotions. Four different experiments were employed in this dissertation to scrutinise the above research questions. In this chapter I will summarise the main findings and basic conclusions drawn from each of the four experiments and will tie them together to reflect upon potential implications and possible future research directions.

8.1.1. Main Findings and future direction of research

8.1.1.1 Colour is a typical perceptual feature of emotion

Experiment 1 involved the completion of the feature listing task (as suggested by Tanaka, Persenall (1999) and Wurm et al., (1993) for diagnostic colours of objects) to determine whether colour is a diagnostic feature of emotions (e.g. *If 'anger' was an object or something tangible that you can hold in your hands, how would you describe it or what would it look like? Give eight different* ***perceptual features***). The participants were naïve to the specific purpose of the investigation and were given the same task for each of the six basic emotions as well as for a neutral, non-emotional category.

It was found that, more than any other perceptual information (e.g. shape and tactile information); colour information was consistently chosen (in 82% of the lists of features) as a perceptual feature of the seven emotional categories - happiness, sadness, anger, fear, disgust, surprise and neutral. Furthermore, chromatic colours (e.g. red, blue, orange), specifically, were consistently used as typical colours of each of the six basic emotions whereas achromatic colours (e.g. white, grey, transparent) were often mentioned as symptomatic perceptual features for the description of the neutral, non-emotional category.

In line with previous colour-emotion investigations, a wide array of colours which comprise 15 different types of colour features were mentioned as perceptual features that describe the seven emotions (Eysenck 1941; Wexner, 1954; Choungourian 1968; Valdez & Mehrabian 1994; Terwogt & Hoeksma, 1995; Boyatzis & Varghese 1996; Hemphill 1996; Hupka, Zaleski & Tarabrina, 1997; Zenter, 2000; Burkitt, Barrett & Davis 2003; Leichsernring 2004; Ou, Luo, Woodcock & Wright, 2004). Red was the single colour that received more than 50% agreement of the total given colour features (Hupka et al., 1997; Luscher, 1971; Wexner, 1954). Specific colour features that are closely related to the measurement of the colour's brightness were mentioned more often than any other colour features (Barbiere, Vidal, Zellner, 2007; Boyatzis & Varghese, 1996; Valdez & Mehrabian, 1994).

These findings confirm that people do have strong emotional associations with colours (e.g. Barbiere, Vidal, Zellner, 2007; Boyatzis & Varghese, 1996; Hupka, et al., 1997; Zentner, 2001) and imply that colour information may be represented together with, or closely to, the representation of emotions and in a similar fashion to the associative colour representation with objects (Menard-Buteau & Cavanagh, 1984; Klein, 1964; Naor-Raz, Tarr & Kersten, 2003).

8.1.1.2 Colour is diagnostic for recognition memory of emotions

The pattern of results in Experiments 2 and 3 consistently revealed that the presence of diagnostic colours of emotions aids performance in short-term and long-term recognition memory. Participants recognised emotional information coloured with their individual appropriate colour associations significantly better than emotional information coloured inappropriately. Experiment 3 further revealed an overall enhanced memory performance for emotional stimuli (words and faces) over neutral stimuli. These findings confirm two common memory effects that are often documented in the literature. Firstly, the superiority effect of colour on recognition memory (e.g. Olivia & Schyns 2000; Gegenfurtner & Rieger, 2000; Wichmann, Sharpe & Gegenfurtner 2002) was once again replicated and further extended to emotional information. Secondly, the findings also fit with many studies that show a memory enhancement of emotionally laden visual stimuli over neutral stimuli (D'Argembeau & Linden, 2004; Doerksen & Shimamura, 2001; Dolcos & Cabeza, 2002; Kensinger et al., 2002; Kensinger & Corkin, 2003; Margaret et al., 1992; Ochsner, 2000). These two main effects of memory on emotional information were evident in the findings of both memory tests here, strengthening the reliability of our measures and further explicating the existence of an interaction effect between stimulus type (Emotional versus Neutral) and colour type (Appropriate versus Inappropriate - Experiment 2; Appropriate versus Inappropriate versus Random - Experiment 3). Specifically, both experiments consistently show that the facilitation effect of appropriate colours on memory was eliminated for neutral stimuli. Memory performance was enhanced only when stimuli were coloured appropriately and were emotional rather than neutral. This suggests that the powerful effect of colour on memory does not extend to all types of information and is mostly dependent upon a strong associative relationship between the colour cues and the memory items.

The present investigation acknowledged the documented inconsistent tendency of associating colours with emotions among participants (which also exists among cultures). Its empirical strength relies on the fact that each of the above beneficial effects of colour on memory takes into account the individual differences in colour-emotion associations. Thus, although colours and the six basic emotions (e.g. red and anger) do not share as strong an associative relationship as do colours with natural objects and scenes (e.g. red and strawberry), the results shown herein suggest that they are indeed strong and meaningful enough to facilitate recognition memory when presented together with the memory item. Moreover, consistent with the findings of Hupka et al. (1996), the results also revealed that different colour-emotion associations may vary in their strength. This suggests that a particularly strong association like anger-red may have a stronger effect on memory than any other colour-emotion association (a trend that was shown in the post hoc findings). Conversely, inappropriate or simply random colour-emotion combinations are not only different in their level of association with emotions but also different in their effect on memory. Experiment 3, particularly, demonstrated that appropriately coloured stimuli were remembered significantly better than both inappropriately and randomly coloured emotional stimuli. These two types of coloured emotional stimuli were equally impaired in memory compared to appropriately coloured stimuli. As mentioned in Chapter Four, this implies that the memory facilitation that was evident for appropriately coloured emotional information is not the result of a temporary, short-term learning process but reflects a more consistent representation of specific colour knowledge that is part of the representation of emotional information.

Together these findings may have some significant implications for professional settings (e.g. clinical, forensic, education) that value the ease of memory processes for emotional information. Such implications will be discussed in more detail later in this chapter.

8.1.1.3 Association patterns for colour and emotion combinations

Post hoc findings from Experiments 2 and 3 allowed the analysis of two colour-emotion association attributes - the comparison of the consistency levels with which our large student population (n = 210) overall associated appropriate colours versus inappropriate colours with emotions and the evaluation of the different consistency levels among the seven emotional categories. Overall, appropriate colour-emotion associations have received higher agreement levels than inappropriate colour-emotion associations. The emotions happiness and sadness were specifically highly consistent (with an agreement level higher than 50%) regardless of the type of association (appropriate or inappropriate). A reversed consistent colour-emotion association for the two emotionally valenced stimuli (happy-yellow, sad-grey; happy-grey, sad-yellow) illustrates the strong negative correlation that often exists between the two (Green, Goldman & Salovey, 1993; Feldman, Barrett & Russell, 1998). These consistent appropriate colour-emotion associations also fit with studies that show that brighter colours are often related to positive emotions whereas darker colours relate more to negative emotions (Barbiere et al., 2007; Boyatzis & Varghese, 1994; Hemphill 1996; Valdez & Mehrabian, 1994).

In contrast, although the appropriate colour emotion association between anger and red was extremely consistent (93%) and in line with previous studies (Hupka, et al., 1997; Luscher, 1971; Wexner, 1954) no inappropriate colour combination with the emotion anger reached an agreement level higher than 36%. These findings suggest that a consistent associative relationship between colours and emotions is not dependent solely on the type of emotion but rather on the relationship between both colour and emotion information.

A further prominent link between the consistency levels (of appropriate and inappropriate colour-emotion associations and among the emotions) and recognition performance was evident in the data. Emotions that received a high degree of agreement for a specific colour-emotion combination (e.g. anger-red, happiness-yellow, disgust-brown and sad-grey) were more likely to receive a higher percentage of correct responses than emotions that received low level agreement in their colour association. This pattern was less apparent for inappropriate colour-emotion associations than for appropriate colour-emotion associations which discloses a need for future research to explore, more specifically, whether *consistent-appropriate* colour-emotion associations (e.g. happy stimuli coloured in yellow) are remembered better than *consistent-inappropriate* colour-emotion associations (e.g. happy stimuli coloured in grey).

8.1.1.4 Faster naming latencies for appropriately coloured emotional information than for inappropriately coloured emotional information and neutral information

Two novel Semantic-Emotional Stroop tasks were designed in Experiment 4 to assess whether naming *appropriate* colours of emotional carrier words is faster than naming *inappropriate* colours of emotional carrier words. The first Stroop task compared the participants' naming times between appropriately and inappropriately coloured information for carrier words that are emotional as well as neutral. The second Stroop task measured the naming times for appropriate neutral colours and inappropriate neutral colours when the carrier words were either neutral or non-words. The main findings from the first Stroop task confirmed the expectation above, showing significantly faster reaction times for appropriate colours of emotional words over inappropriate colours of emotional words. The findings for neutral words revealed the opposite pattern with significantly faster naming times for inappropriate neutral colours over appropriate neutral colours. The latter finding was not evident however in the second Stroop task for neutral word carriers, which suggests that the advantage of inappropriate neutral colours was due to a disruptive effect from the preceding emotional trials - an effect shown previously in several studies (McKenna, 1986; McKenna & Sharma, 1995; Sharma & McKenna 2001; McKenna & Sharma, 2004).

The fact that the beneficial effect of appropriately coloured emotional stimuli over inappropriately coloured emotional stimuli and neutral stimuli was replicated with two completely different tasks (recognition and Stroop: one that employed an explicit memory system and the other a more automatic, implicit system) strengthens the idea that appropriate colours are part of the conceptual representations of the six basic emotions. In all three of our experiments this beneficial effect of appropriate colours was absent for neutral stimuli. This implies that colour information is not involved in the representation of neutral information, at least not in a similar manner to that of natural objects (Naor-Raz et al., 2003; Klein, 1967) and the six basic emotions. Additionally, the finding from the Stroop tasks specifically suggest that colour may mediate not only explicit (as evident by the results from Experiment 2 and 3) but also implicit memory systems when processing emotional information. Further research should aim at investigating this unconscious retrieval of appropriately and inappropriately coloured emotional stimuli using the measure of repetition priming (Cave et al., 1996; Mecklenbrauker, Hupbach & Wippich, 2001; Vernon & Lloyd-Jones, 2003, 2005). For example, a potential experiment could identify whether a priming effect is observed when participants are asked to identify the emotion expressed by facial expression stimuli whose background is coloured in the individual high diagnostic colours of emotions, low diagnostic colours of emotions or in random colours.

8.1.2 Recognition memory patterns of emotional information are in line with existing models and neurological mechanisms of object recognition

The main objective of this dissertation was to examine the possibility that colour information is a beneficial cue for the recognition memory of other information types than objects and natural scenes (as it has been shown previously in a few studies, e.g. Olivia & Schyns 2000; Tanaka & Persnell, 1999; Wichmann, Sharpe & Gegenfurtner 2002), namely, emotional information. It did not intend to extend our knowledge or understanding of the processing of emotions or colours solely, but on whether the second can contribute to memory of the first. The results from all three experiments support the hypothesis that colour indeed contributes to the recognition memory of emotional information, suggesting that it also takes part in memory representations of emotions and thus is processed not only on a low level (as a sensory attribute) but also on a higher, cognitive level, where it acts as a retrieval cue for memory purposes. There is no study to date that provides such evidence for recognition memory of emotional stimuli. Thus this dissertation strengthens the notion that the effect of colour is not limited to a low level of sensory processing (where it acts as a sensory cue) but is in fact also dominant at a higher level of cognitive processing and it may be represented at the same level as other types of memory cues such as shape, structure and function, which are all activated during recognition processes.

The above findings suggest that the models of object recognition (Davidoff, 1991; Tanaka, 2001) presented in Chapter One are applicable to the domain of emotions. Davidoff (1991) argued that object recognition processes activate two types of memory representations; structure (*hasa*) and functional information of objects (*isa*). Shape information typically activates the first type of representation whereas colour information specifically activates the second. At this high level of representation, appropriate colours are stored as part of the acquired object knowledge and affect recognition of information that is coloured appropriately through a top-down mechanism (Joseph & Proffitt, 1996; Joseph, 1997; Rumelhart, 1986; Tanaka, 2001) but not recognition processes of information that is coloured inappropriately. Correspondingly, since the data from this investigation illustrate a similar pattern of memory enhancement for emotional information coloured appropriately over emotional information coloured inappropriately and over neutral information regardless of colour, this suggests that the diagnostic effect of emotional information on recognition memory engages similar top-down mechanisms to those involved with object recognition. Furthermore, inappropriate colour-emotion associations were found to be less consistent than appropriate colour-emotion associations. These two patterns of results are specifically in line with Bower's *network theory of memory and emotion* which postulates that emotional knowledge and its associative concepts (e.g. colours) serve as memory units that are activated during the processing of emotional information. Consequently, appropriately coloured emotional information results in better memory performance and benefits from more consistent colour-emotion associations since the appropriate colours of emotions (unlike the inappropriate colours of emotions) are part of the acquired emotional information or its associative knowledge.

Neuropsychological studies (Chao & Martin, 1999; Howard, et al., 1998; Martin et al., 1995) provide further evidence that the two different cognitive processes - perceiving a surface colour (e.g. inappropriate colour) and knowing that an item is coloured appropriately - involve distinct neural substrate (left inferior temporal activation by the retrieval of object knowledge but not by colour perception) during the processing of natural objects. Zeki and Marini (1998) showed specific and different neural pathways for naturally coloured observed objects and abnormally coloured observed objects. Observing red strawberries for example activated the fusiform gyrus, hippocampus and ventrolateral frontal cortex (areas that are also activated by other object-colour-knowledge tasks). Participants who observed abnormally coloured objects such as purple strawberries showed activation of the dorsolateral regions of the frontal cortex. This raises the question of whether such neural mechanisms are also involved in the processing of diagnostic colours of emotions. Are these separate neural correlates for appropriately versus inappropriately coloured items specialised for object processing *per se*, or do they reflect more general neural processing that extends to any two types of information that have appropriate and inappropriate relationships?

Finally, the findings also fit with the binding hypothesis (MacKay et al., 2004; MacKay & Ahmetzanov, 2005), which suggests that emotionally charged stimuli trigger binding mechanisms that link the emotion stimulus to salient contextual details (such as colour) that are closely related to the stimuli. According to this hypothesis, since appropriate colour associations are more closely related to emotional stimuli than inappropriate colour associations, the binding mechanism between the two types of information, colour (as a contextual feature of the emotional stimulus) and the emotional stimulus itself may result in better recognition memory for the appropriate (and closely related) colours than inappropriate colours. Although memory performance for these two types of colour was not measured in this thesis, it can be still argued that the memory enhancement effect for the appropriately coloured emotional stimuli was affected by a possible hidden ability of participants to also remember the appropriate colours themselves better than the inappropriate colours.

In summary, the results of the current study fit nicely with various empirical studies and recognition models that have demonstrated the superior role of colour in memory processes. This the question of whether the similarity in the current pattern of results with those found previously for objects is a consequence of the use of a similar brain mechanism that may have been designed originally for survival purposes - to detect and recognise food faster and more accurately. The high level of efficiency in information processing of this object recognition mechanism may make it, by default, the dominate mechanism for processing many other considerably different types of information, including emotions. If this argument can be supported by neurological evidence that shows neural pathways that connect visual processing of colours with emotional processing, it may explain the existence of the human tendency to associate colours with emotions (that is substantially more evident than emotional associations with shapes, different types of fragrances, etc.)

The literature describes a significant amount of work that may be relevant to the above questions. There is evidence from several studies of a connection between the medial geniculate nucleus of the thalamus (MGN) and the amygdala. The role of that pathway in acoustic fear-conditioning may parallel in other emotion-sensory connections (LeDoux, 1995; LeDoux, Cicchetti, Xagoraris, Romanski, 1990a; LeDoux, Farb, Ruggiero, 1990b; Vuilleumier, Richardson, Armony, Driver and Dolan, 2004). Via this subcortical thalamo-amygdalar pathway, sensory information arrives in limbic nuclei before being processed by cortex, thus providing the advantage of making a quick emotional response appropriate to the sensory stimulus. Although most of the studies of the role of amygdala in fear-conditioning use acoustic stimuli (McKernan, Shinnick-Gallagher, 1997; Rogan, LeDoux, 1996; Rogan, Staubli, LeDoux, 1997), it can be assumed that other sensory modalities have access to the amygdala via the thalamus. There are several studies on the emotional content of other sensory modalities (Shi, & Davis 2001; Linke, De Lima & Pape, 1999; Vuilleumier, et al, 2004). Linke et al. (1999) specifically pointed toward a direct projection from colour-coding parvocellular layers of LGN (and perhaps from the superior colliculus) to limbic areas. According to his argument, these subcortical colour pathways may be organized in a similar way to the acoustic pathways from MGN to amgydala. Since the retino-geniculate pathway is topographically organized to preserve colour information, it is not necessary to process that information in cortical areas before having meaningful information to evoke appropriate emotional responses. Additionally, Vuilleumier, et al, (2004) have recently shown evidence for a modulatory influence from the amygdala on visual sensory processing. Their study presented a case where emotional visual stimuli (fearful faces) induced enhanced responses in the visual cortex (fusiform and occipital cortex) for healthy individuals and those with hippocampal damage but not for those diagnosed with an amygdala lesion.

The behavioral findings from our study and the neurological connections suggested above may provide some explanation as to why humans often have a particular favorite colour or a colour that is consistently associated with a particular emotion. Human beings are inclined to process colour information at both high and low cognitive levels of processing to enable us to benefit from fast detection and accurate recognition of the many objects in our environment. For this reason, it may be that any colour information receives priority processing, automatically, in many situations that do not necessarily involve a conscious recognition of objects. Since humans are also blessed with a great variety of emotions, every moment of our lives entails some portion of emotion. Research has further shown that the more meaningful the human experience is, the more easily it is remembered. Thus, the two enhanced memory tendencies, to remember emotionally intense experiences and coloured things (that are naturally part of these situations), may (unconsciously) result in the well-known tendency that is yet to be understood - to associate colours as opposed to shapes or any other visual or sensory information with emotions. Future research that will challenge these assumptions empirically may resolve the current mystery surrounding the formation of colour-emotion associations.

8.1.3 Implications

The findings offer a few possible applications for the use of colour in professional settings as a powerful tool for enhancing memory of emotional information. In this section I will: suggest a way in which colour may aid in the memory reconstruction of people with episodic memory impairment such as the elderly with dementia, describe how it might also increase the accuracy of eyewitness testimonies and the reports of children who have been suspected to have undergone sexual abuse and then suggest ways in which colour may facilitate learning processes especially for those who are diagnosed with learning disabilities.

8.1.3.1. The use of colour as a memory aid for the elderly with Alzheimer's disease

Alzheimer's disease is the most common form of dementia (Evans et al., 1989) and is a group of disorders that impairs mental functioning. Approximately 24 million people worldwide are living with Alzheimer's (Ferri et al., 2006). It is a slowly progressive disease characterised by the loss of cortical neurons and synapses leading to a loss of memory and cognition, accompanied by functional impairment (Burns, 2000). The most significant impairment in the early stages of Alzheimer's disease is a loss of the ability to remember recent events. Previous research which has attempted to assess differences in types of memory impairment has found consistently that recognition or recall of familiar faces among other pictorial and verbal cues significantly deteriorates over the years (Becker, Lopez, & Boller, 1995). However, whether colour perception is also diminished within this population is still an issue of controversy among researchers. On one hand, there is evidence that colour vision disproportionately deteriorates in people with Alzheimer's disease concurrently with other cognitive functions (Cronin-Golomb, Sugiura, Corkin & Growdon, 1993; Kurlyo, Corkin, Dolan, Rizzo & Parker, 1994). On the other hand, Bassi et al., (1993) and Wijk and Sivik (1995) suggested that the impairment of colour vision is not specific to those with Alzheimer's so that they are, in fact, able to discriminate between common colour categories just as the non-demented elderly can.

Recently, Cernin, Keller and Stoner (2003) have specifically addressed the question of whether colour cues can improve object recognition in three elderly groups: those with Alzheimer's, those with other dementias and those cognitively intact. They assessed the use of colour, of form and of combined colour and form cues as a short-term memory aid. Colour cues were better short-term memory aids than form cues alone or combined form and color cues and decreased recognition time equally for all three elderly populations. The authors concluded that colour-coding techniques can be used as an orientational device that may help to interpret the environment and improve independent daily functions. If colour was found beneficial for the recognition memory of objects, our findings suggest that it may also improve recognition memory of emotional information such as relatives' and caregivers' faces.

Consequently, studies should assess whether colour-coding of appropriate colours of emotions may serve as a memory aid for the recognition of patients' relatives and caregivers or alternatively may generally help to reactivate memories of recent emotional experiences. This use of colour-emotion association may be found to be particularly useful for memory recollection of emotionally laden information that may need only a few extra cues to trigger their retrieval as opposed to memory reconstruction of emotional information that the individual has completely forgotten. For example, colours that may signify or match a specific caregiver or relative, as a result of a specific emotional association to this person, may aid in the retrieval of his or her colour-coded identity.

8.1.3.2 The effect of children's drawings and specific colour choices on memory

DiLeo (1970) wrote that children can express their thoughts and feelings graphically with the use of colours thus they naturally tend to draw what they know rather than what they see. Piaget and Inhelder (1956, 1969, 1971) similarly argued that children’s drawings are an expression of their mental construction and not the end product of pure observation. Focusing on the content of drawings, according to the above developmental theorists, may therefore reveal the child's inner self - his traits, attitudes, behaviour characteristics and personality strengths and weaknesses. For this reason, projective drawing techniques were developed as a measurement of personality and emotional states in the analysis of self-concept, body image and sex-role identity (Thomas & Jolley, 1998). As a non-verbal tool, drawing allows children to express feelings they may not be able to express verbally including non-conscious aspects of mental representations (Fury, Carlson & Sroufe, 1997). Nowadays, children’s drawings are used occasionally as evidence of their maltreatment in court cases (Czenner, 1986; Malchiodi, 1990) and are legally accepted as part of a child’s testimony especially in cases where maltreatment is alleged (Cohen-Liebman, 1995). Further, drawings have a long history of clinical use, providing a window into the child’s view of family dynamics and self within the family (Malchiodi, 1998). Empirical research supports clinicians’ assertions that family drawings are also useful in understanding children’s representations of family relationships (Fury et al., 1997; Madigan, Ladd & Goldberg, 2003; Pianta et al., 1999). Not only clinicians, but also teachers, therapists, school psychologists, and other professionals use drawing techniques to assess the child’s level of cognitive development and any possible neurological impairment (Goh & Fuller, 1983; Peterson et al., 1995; Prout, 1983). Of the many aspects of information being assessed in the contents of children's drawings, colour choice is usually among them. For example, the Family Drawing Procedure (Fury, Carlson & Sroufe, 1997; Gullone, King & Ollendick, 2006; Madigan et al., 2003), administered to assess children's mental representational models of attachment relationships, rates global pathology according to the following descriptions: "overall degree of negativity reflected in global organization, completeness of figures, use of colour, detail, affect, and background scene" (Fury et al., 1997, p. 1157). Similarly, Leon, Wallace and Rudy (2007) also developed the Parent–Child Alliances Scale to assess the extent to which children's drawings represent their alliances with their parents. This was indicated by details like separation between figures and differentiation of figures (e.g. the non-aligned parent may be less detailed or colourful).

There is also evidence in the literature of a few attempts to develop personality tests for the diagnosis of children's emotional difficulties through the use of spontaneous drawings or even more specifically through the choices of colours (Vander, 1942; Luscher & Scott, 1969; Scott, 1970). Vander (1942), for example, assessed the possibility that a few formal elements in children's drawing can provide stable and reliable criteria for personality prognosis. These assumptions were based on a large sample of children who were each asked to provide at least six different drawings. The drawing elements that were found potentially systematic for the analysis of personality characteristics were: proportions of the drawing and the shape of the paper chosen, size of the single form elements, distribution of form elements, use of lines or spots, choice of colours, and representation of motion. For example, with respect to colour choices, it has been suggested (Vander, 1942) that normal children use all colours but black and white are used significantly less. Neurotic depressives avoid yellow and red and use a considerable amount of black and some white. Psychotic children often have a definite fear of colour or of certain colours, while dull children are generally apathetic to colour.

Although adults as well as children may indeed have meaningful associations with colours which can be depicted via the tool of drawing (Burkitt, et al., 2003), research has identified difficulties associated with the use of projective tests. For example, interpretations are usually very dependent on the view of the examiner thus test reliability is likely to be low (Torem, Gilbertson & Light, 1990). Further, drawings made by a child may not show the same important features on two different occasions of drawing. To illustrate, although there have been various investigations carried out concerning the significance of the size of topics drawn, Golomb (2004), Joiner, Schmidt and Barnett (1996) were unable to find reliable statistical evidence relating to the assumption that the size of a topic drawn is significant. More recently, Veltman and Browne (2002) conducted a systematic review that aimed to identify studies using drawing techniques with maltreated children and their application to practice. Their review pointed toward a clear massage - "caution should be employed in the use and over interpretation of drawings" (p. 34) which otherwise may result with a high rate of false identification of sexual maltreatment in cases where drawings were the single indicator. The authors summarised their review by urging further research to provide a large-scale controlled investigation of the use of drawings in professional settings. The findings from this dissertation may provide an opportunity for such investigation. I suggest that the use of specific colours in children's drawings may reflect their personal associations with six basic emotions which can be used to trigger an elaborative conversation that may aid in retrieving emotional information that has been suppressed or lost in memory. For example, if a child who associates red with fear and (in a separate setting) has drawn a figure coloured in red, this may imply that the child (consciously or unconsciously) has developed fearful emotions toward the figure drawn. This can be investigated through triggering questions that do not directly concern the child’s emotional attitude toward the figure i.e. “What does red mean to you? Why did you choose red?” The use of colours in such clinical settings concerns the possibility that important emotional information (e.g. details that may help to identify molestation) may be retrieved unwittingly through the development of conversation around the colour choices, rather than the possibility that the content of drawing alone directly indicates whether or not the child has experienced trauma. To support this assumption, Butler, Gross and Hayne (1995) showed children's memory is more complete and accurate when information is given through drawing than through verbal expressions alone. Their study demonstrated that 5- to 6-year-old children who were asked to *draw* what happened in a unique event in which they had participated reported more information than the 5- to 6-year-olds who were asked to *tell* what happened after a one-month delay. The authors postulated that: "…drawing simultaneously provided additional retrieval cues, decreased traditional conversational constraints, and helped children remain on task for a longer period of time." (p. 606), which all contributed to increased memory performance. Todd and Perlmutter (1980) also suggested that children provide a greater amount of information about events when they themselves initiate the retrieval. The results from this dissertation may provide an explanation for the growing body of research indicating that children's drawings are beneficial for assessing memories that have been stored at sensory, perceptual and cognitive levels (but are not always considered important to be retrieved verbally by the child). I specifically suggest that the element of colour choices within children's drawings is at least partly what makes drawing such a powerful memory tool. Since colour details were found significantly effective for the memory of various types of information, colour choices used in drawing need to be assessed more thoroughly and in conjunction with other elements of drawings in order to fully utilise their contribution to memory.

In summary, the specific combination of using drawing techniques and assessing a child's colour choices and their associations with emotions may be found effective as a retrieval tool in clinical and forensic professional settings. Specific ways in which the findings can be applied for eyewitness identification procedures (with older populations) are discussed next.

8.1.3.3 The use of colour in eyewitness memory

Studies examining the role of colour in eyewitness memory are lacking and rather dated. A few studies have investigated the impact of context cues on eyewitness identification responses but resulted in equivocal findings (Maass & Brigham, 1982; Malpass & Devine, 1981; Smith, Glenberg & Bjork, 1978; Sanders, 1984; West & Long, 1993). There are reports (Maass & Brigham, 1982; Malpass & Devine, 1981) that have substantiated the effectiveness of context cues in increasing the probability of identifying a previously seen target in a photo display. Other studies suggested that different categories of context cues operate in dissimilar manners. For example Sanders (1984) demonstrated that reinstating personal appearance context cues (e.g. clothing or hairstyle) had several undesirable consequences such as increasing false alarm rates whereas physical surroundings cues had no discernible effects. Indeed, it seems reasonable to assume that when innocent targets are forced to wear similar clothing or have similar facial hair the similarity between the innocent and the criminal encourages false identification. But it is also well established that people remember events more accurately when the similarity between the conditions surrounding the original experience and those present at the time of recall are greater (Anderson & Bower, 1974; Bower, 198l; Godden & Baddeley, 1975) specifically when the surrounding cues are coloured backgrounds (Vernon & Lloyd-Jones, 2003; 2005).

A review of the literature found only one study specifically interested in the effect of colour on eyewitness identification accuracy (West & Long, 1993). Their participants witnessed an incident with a male actor wearing either all black clothing (control group) or coloured clothing (experimental group) and were asked to act as eyewitnesses by completing a questionnaire pertaining to the characteristics of the person they saw. The questionnaire consisted of six colour related questions (e.g. hair colour, clothing colour); six detail questions (e.g. hair length and style) and five description questions (e.g. age, weight, height). Their findings revealed that those who witnessed the actor wearing colourful clothing were more accurate than the control group on the descriptive questions, less accurate than the control group on the colour related questions and similar to the control group on the detail questions. It was suggested that the disadvantage in the colour related question shown by the experimental group was related to the different amount of colour information given to the two groups and not, as suggested by the above studies, that the colour cue can lead to false identification. Considering that a large number of studies, including this study, have clearly demonstrated a memory advantage of coloured information over non-coloured information, there may be good grounds to hypothesise that colour cues can also be beneficial for eyewitness memory as this specific type of memory involves not only object or scene information but also a great deal of emotional burden.

One option for investigating the above hypothesis is to test the effect on identification accuracy of displaying appropriate colours as the background of suspect facial pictures. These appropriate colours can be associated with the eyewitness's emotional reaction to the crime or with specific colour details that were present in the crime scene (e.g. the colour of the suspect's shirt, the colour of his/her car, etc.) and as such are also likely to be associated with (or induce) the eyewitness's emotional reaction to the crime. Eyewitnesses could be asked on two separate occasions to associate colours with suspect facial pictures (without asking them to identify the suspect). The degree of consistency can be assessed and in a third setting the witness will be asked to identify the suspects from pictures that have the most consistent colours as a background colour. Furthermore, it may be worth checking whether these consistently chosen colours share some similarity with colour details that were evident within the crime scene. If so, these colours may increase the possibility of accurate retrieval in identifying the suspect’s face (or other coloured objects that were in the crime scene).

8.1.3.4 Education

As demonstrated above, the use of colour cues to enhance memory performance has a wide array of possible implications. Since memory facilitation is no less significant in learning processes, the findings of this study can be further applied for teaching and educational purposes especially for those diagnosed with ADD and ADHD. Empirical work has demonstrated that students with ADHD respond differently from their classmates to novel stimulation (e.g. colour, music, classroom activities) in the environment (Zentall, 1975). Their performance can be improved to the same level as (and in some cases even more than) their peers when such stimulations are added to academic tasks (Zentall, 1989). The logic behind this finding is that this type of stimulation allows them to achieve a more optimal level of internal arousal that is necessary for attention and performance (Cooley & Morris, 1990). Thus many researchers have argued that these students do not have an attentional deficit per se but simply show an attentional bias or preference for novelty (i.e. to pay attention to what is bigger, more intense, colourful or moving). Studies that specifically investigated the effect of colour stimulation have almost conclusively yielded supporting results for the effect of adding non-specific colours to reading, handwriting, word-spelling recognition and social tasks (Belfiore, Grskovic, Murphy & Zentall, 1996; Imhof, 2004; Iovino, Fletcher, Breitmeyer & Foorman, 1998; Lee & Zentall, 2002; Zentall, 2005; Zentall & Dwyer, 1989b; Zentall & Kruczek, 1988). Furthermore, Imhof (2004) questioned the exclusive susceptibility of children with

ADHD to colour since their findings revealed that children with speech disorders also responded to colour stimulation (e.g. offering coloured sheets; writing assignments are performed with a coloured pencil) for a spelling and handwriting exercise. This specific contribution of colour cues as a training tool is in line with other empirical evidence which suggests more efficient information processing in the presence of increased stimulation especially through the visual channel (Barkley, 1997; Castellanos, 1999). Changes in cortical activation, which are elicited by colour stimulation, have an influence on behavioural inhibition and facilitate motor coordination, attention regulation (Rockstroh & Elbert, 1990; Zentall, 2005) and the effective monitoring of cognitive functions such as working memory and motivational regulation (Barkley, 1997; Barkley, 1998).

Although the practical implications of the use of colour cues to stimulate learning have been studied quite extensively (particularly for ADHD students), the results from the current study validate these previous findings and add to them in suggesting that not only the use of colour in general, but the specific type of colour, may affect learning performance. An earlier study (Imhof, 1995 as cited in Imhof, 2004) found that ADHD children had a preference for saturated and very bright colours. Thus, identifying a student's specific appropriate (or most favourite) colours which he/she will match individually to a set of tasks can contribute to forming his/her own study aids (in tasks like: reading comprehension, spelling, handwriting, maths problems, etc) which will result in an enjoyable and more meaningful learning process. More importantly, however, having the student use his/her own matched colours may cue the student's memory for the term learned (e.g. spelling of words, memorising and understanding maths facts) and help him/her retain the information even more beneficially than with just any colour (or colours that were chosen for him/her). Thus, it is suggested that this population of students (and potentially students diagnosed with speech disorders as well) should not merely engage in colour-coded training but also actively choose their colour preferences for each task, apply them appropriately (and maybe differently) for each one and be encouraged to add as much meaning as they possibly can to each of the selected colours (e.g. red coloured words are associated with a favourite red coloured cartoon). This procedure is not only based on improving the child's attention by the addition of colour stimulation (as suggested above) but also relies on the findings from this study and others that emphasise colour as a powerful tool for recognition memory of various types of information.

8.1.4 Limitations

As demonstrated so far, the findings of this dissertation are consistent with previous studies in revealing the powerful effect that colour has on recognition memory. Several practical and theoretical implications have also been suggested. Yet, the author also acknowledges some limitations that ought to be mentioned. Firstly, the study did not involve a condition of emotional stimuli coloured in grayscale. Although unpublished work by the author has shown significant memory performance for coloured emotional stimuli over grayscale emotional stimuli (2003 Study) it is important to examine whether the differences in memory of appropriately coloured emotional stimuli are indeed more significant than for both appropriately coloured neutral stimuli and grayscale neutral stimuli. Even more important is to validate the fact that colour is diagnostic for emotional information but not for neutral information by also including a grayscale condition that will enable a specific comparison between the contribution of appropriate colours to emotional stimuli (compared to a grayscale emotional condition) and the contribution of appropriate colour to neutral stimuli (compared to a grayscale neutral condition). To support the above assumption, the improvement in memory between appropriate and grayscale emotional stimuli should be significantly higher than the improvement in memory between appropriate and grayscale neutral stimuli.

Secondly, the ability to compare the independent variables of emotion versus neutral information clearly relies on their being equated. In our study however, there were six different emotions compared to one neutral condition. This forced the design to have an unbalanced quantity of experimental stimuli for each of these conditions. For example, Experiments 2 and 3 had 72 emotional stimuli but only 12 neutral stimuli (words and faces). Experiment 4, however, presented participants with an equal number of word stimuli for each condition. It may be reasonable to argue that this difference is rooted in human nature- humans naturally have more emotional than non-emotional states of mind. It is then left for future research to investigate ways of measuring differences between information processing of emotional versus neutral stimuli while accounting for the natural differences in the variety of each human state.

Finally, since colour was manipulated as a between subjects variable in Experiments 2-4, any replications attempts in future research should also include colour as a within subjects variable.

8.2 CONCLUSIONS

The present dissertation represents a detailed investigation into the effect of colour on recognition memory. In a series of four experiments the study validated and expanded on previous findings that demonstrated the facilitative effect of colour on memory. While this superior effect of colour was shown previously on various types of information categories including faces, textures, everyday scenes, graphs, symbols and animals (Olivia & Schyns, 2000; Latimer et al., 2002; Wichmann, Sharpe & Gegefurtner, 2002) this dissertation is the first to demonstrate that recognition memory also benefits from colour cues when the stimuli are emotional. Furthermore, the findings reveal that colour has the potential to be diagnostic for recognition memory or the description of emotions particularly if it is being consistently and appropriately associated with the emotional item. The study provides evidence that suggests colour and emotion information are not simply closely related and often associated with each other but also conceptually represented together. Altogether, these results offer a few practical implications as well as several directions for further research that should be seriously considered in future empirical and practical applications.

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APPENDIX

Details of colours used in Experiments 1-4.

	Colour number in Supercard 10.4	RGB			HSB		
		R	G	B	hue	saturation	brightness
White	1	255	255	255	60	0	100
Blue	175	0	0	194	359	0	100
Red	72	194	0	0	359	100	76
Yellow	6	255	255	0	60	100	100
Orange	24	255	102	0	24	100	100
Brown	138	128	64	0	30	100	50
Green	230	0	128	0	120	100	50
Purple	104	128	0	128	300	100	50
Grey	250	93	93	93	309	0	36
Pink	32	255	0	218	309	100	100

Experiment 1: An example of the feature listing task

What perceptual features do you have for six basic emotions?

For the following questions you are asked to list **perceptual features** you associate with six different emotions. Please try to limit your answers to one word only, preferably adjectives (e.g. instead of writing 'knife' write 'sharp' etc.).

If *fear* was an object or something tangible palpable that you can hold in your hands how would you describe it, or what would it look like? Give eight different **perceptual features**:

1.____________
2.____________
3.____________
4.____________
5.____________
6.____________
7.____________
8.____________

Diagnostic colours of emotions

If a *neutral* state (non emotional state) was an object or something tangible palpable that you can hold in your hands how would you describe it, or what would it look like? Give eight different **perceptual features**:

1.____________
2.____________
3.____________
4.____________
5.____________
6.____________
7.____________
8.____________

If *surprise* was an object or something tangible palpable that you can hold in your hands how would you describe it, or what would it look like? Give eight different **perceptual features**:

1.____________
2.____________
3.____________
4.____________
5.____________
6.____________
7.____________
8.____________

If *anger* was an object or something tangible, palpable that you can hold in your hands how would you describe it, or what would it look like? Give eight different **perceptual features**:

1.____________
2.____________
3.____________
4.____________
5.____________
6.____________
7.____________
8.____________

If *happiness* was an object or something tangible palpable that you can hold in your hands how would you describe it, or what would it look like? Give eight different **perceptual features**:

1.____________
2.____________
3.____________
4.____________
5.____________
6.____________
7.____________

8.____________

If *sadness* was an object or something tangible palpable that you can hold in your hands how would you describe it, or what would it look like? Give eight different **perceptual features**:

1.____________
2.____________
3.____________
4.____________
5.____________
6.____________
7.____________
8.____________

If *disgust* was an object or something tangible palpable that you can hold in your hands how would you describe it, or what would it look like? Give eight different **perceptual features**:

1.____________
2.____________
3.____________
4.____________
5.____________
6.____________
7.____________
8.____________

Experiment 2:

Mean % Agreement for the distribution of emotional words to six basic emotions and non-emotional words to the neural category (n=9).

Emotional Word	Basic Emotion	% Agreement	% Total Agree-ment	Emotional Word	Basic Emotion	% Agreement	% Total Agree-ment
gleeful	HAPPINESS	100	94.31	repugnant	DISGUST	100	94.44
blissful		88.88		repelled		100	
jovially		100		repulsive		77.77	
gladness		100		revolting		100	
joyfully		100		sickening		100	
ecstatic		77.77		nauseate		88.88	
depressed	SADNESS	100	96.29	fearing	FEAR	100	94.44
grieving		88.88		horrified		100	
desolate		100		worrying		88.88	
miserably		88.88		frightful		100	
sorrowful		100		panicked		100	
gloomily		100		terrorize		77.77	
enraged	ANGER	100	96.3	astonish	SURPRISE	100	96.29
infuriate		100		astound		100	
madness		77.77		stunned		100	
furious		100		amazingly		88.88	
irritated		100		startle		100	
wrathful		100		shocking		88.88	
bombastic	NEUTRAL	88.88	92.59				
immutable		100					
atheistic		77.77					
diligent		88.88					
credible		100					
cosmetic		100					

Experiment 3:

Mean % Agreement for the distribution of emotional words to six basic emotions and non-emotional words to the neural category (n=12).

Emotional Word	Basic Emotion	% Agreement	% Total Agree-ment	Emotional Word	Basic Emotion	% Agreement	% Total Agree-ment
gleeful	HAPPINESS	100	97.22	repugnant	DISGUST	100	98.61
blissful		100		repelled		100	
jovially		100		repulsive		100	
gladness		100		revolting		100	
joyfully		100		sickening		100	
ecstatic		83.33		nauseate		91.66	
depressed	SADNESS	100	94.44	fearing	FEAR	100	92.22
grieving		91.66		horrified		100	
desolate		83.33		worrying		91.66	
miserably		91.66		frightful		100	
sorrowful		100		panicked		100	
gloomily		100		terrorize		83.33	
enraged	ANGER	100	90.28	astonish	SURPRISE	100	97.22
infuriate		100		astound		100	
madness		83.33		stunned		100	
furious		91.66		amazingly		83.33	
irritated		83.33		startle		100	
wrathful		83.33		shocking		100	
impartial	NEUTRAL	100	94.44				
balancing		100					
equalize		100					
abstain		83.33					
unbiased		91.66					
equitable		91.66					