Attention and Face Processing

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Abstract

This dissertation seeks to unite two major streams of cognitive research that have traditionally proceeded independently (i.e. selective attention, and face processing). It was already well-established that faces convey a great deal of biologically significant information that has direct implications for everyday social behaviour. Moreover, there is substantial evidence that face processing may be qualitatively different from other forms of visual processing, and may even be subserved by face-specific neural systems. If faces are indeed 'special' in these respects, it is possible that their relation to selective attention may also differ from that of other stimulus classes, for which several attentional principles are relatively well understood. To date, however, this possibility has been largely overlooked. The experiments in this thesis addressed the interaction between selective attention and face processing directly, by examining whether faces are particularly difficult stimuli to ignore, and by assessing the consequences of various attentional manipulations for both on-line processing of task-irrelevant faces, and for subsequent incidental memory of these faces. The main findings indicate that faces may be particularly strong competitors for attention, such that they typically capture more attention than competing nonface objects when spatial competition for attention arises. Moreover, they seem to draw on a highly face-specific capacity with its own (face-specific) capacity limits. Despite being special in these two senses, however, face processing may be subject to more general attentional constraints at some stage, since task-irrelevant faces are later recognised less well if attentional capacity was exhausted by a nonface task at exposure. These findings are discussed in relation to the ongoing debate over 'modularity' for face processing. The results may also have practical implications, for example in assessing the reliability of eyewitness testimony.

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Chapter 1

Selective Attention And Face Processing: General Introduction

1.1 How does face processing relate to attention?

Although the brain is fed a constant stream of information from the senses, only a small fraction of this information enters our awareness (e.g., Broadbent, 1958; Cherry, 1953; Sperling, 1960). Selection of information for further processing is contingent upon at least two factors: firstly, the relevance of that information in terms of current behavioural goals, and secondly its ability to capture attention regardless of such priorities. Thus, selective attention often results in task-relevant stimuli receiving more processing than task-irrelevant, unattended stimuli (e.g., Broadbent, 1958; Treisman, 1960); but irrelevant yet salient stimuli may undergo considerable processing, despite observers' attempts to ignore them, when they are capable of capturing attention (e.g., Moray, 1959; Yantis & Jonides, 1990). To date, studies of visual selective attention have focused almost exclusively on the processing of fairly neutral stimuli such as letters, neutral words, or abstract shapes (e.g., Posner, 1978; Sperling, 1960; Stroop, 1935; Treisman, 1993; Eriksen & Eriksen, 1974). Stimuli of intrinsic biological significance, such as faces (e.g., Fantz, 1961, 1963, 1966; Johnson, Dziurawiec, Ellis & Morton, 1991; Morton & Johnson, 1991), have seldom been presented as irrelevant distractors. This is unfortunate because although a great deal is known about both attention (e.g., Pashler, 1998; Styles, 1997) and face perception (e.g., Bruce, 1988; Young, 1998), rather little is currently known about their interaction.

This thesis explores the interaction between attention and face processing by examining whether faces are particularly difficult distractors to ignore, and the conditions under which they can be successfully ignored. Since much of the information faces carry is of adaptive importance (e.g., sex, identity, emotion), it is possible that distractor faces might still be processed even under conditions that are optimal for the rejection of other classes of distractor. Moreover, it has often been argued that there are dedicated neural systems for the processing of faces in particular (e.g., Farah, 1995; Kanwisher, 2000; Farah, Levinson & Klein, 1995; Farah, Wilson, Drain & Tanaka, 1995; Kanwisher, McDermott & Chun, 1997). If faces are indeed 'special' in this sense, their relation to attention may differ from that of other stimulus classes. I begin with a short review of some principles of selective attention already known to influence and delimit distractor processing for the much-studied case of irrelevant letters and words. I then consider the possible implications of such studies for the ability to ignore salient biological stimuli, such as faces. The few studies that have attempted to relate face perception and attention are then discussed. I end this introductory chapter by describing the general methodologies used in the current work.

1.2 Early versus late selection

A central question in selective-attention research is whether irrelevant distractors can ever be fully ignored. In particular, whether distractors are excluded only from responses (late selection), or can also be excluded from perceptual processing (early selection), has been the subject of much debate (e.g., Broadbent, 1958; Deutsch & Deutsch, 1963; Eriksen & Eriksen, 1974; Miller, 1987; Pashler, 1998; Treisman, 1969; Yantis & Johnston, 1990). Numerous psychological paradigms have been developed to assess the level of distractor processing. Many of these are variations of the classic Stroop paradigm (Stroop, 1935), in which distractor processing is measured indirectly via its effects on target reaction times (RTs). Standard Stroop stimuli conjoin a target dimension to which the subject responds (usually ink colour, e.g., green), and a distractor dimension which can be congruent or incongruent with the response (usually a printed colour name, e.g., "RED"). Distractor processing is then assessed by measuring target RTs as a function of distractor congruency. Typical results show that subjects are unable to ignore irrelevant information (i.e. the identity of the printed word) completely in Stroop-like displays. However, since Stroop stimuli conjoin target and distractor information in a single visual object, it may not be surprising that distractor processing occurs, since subjects are required to ignore information that appears at the focus of their attention. Consequently, many follow-up studies have been devoted to identifying conditions that allow more efficient distractor rejection in Stroop-like displays.

1.3 Principles known to moderate distractor processing

1.3.1 Spatial separation and segregation

The classic Stroop finding suggests that distractor rejection can be rather ineffective when the target and distractor are both parts of the same object. Thus, it is possible that clear target-distractor segregation may be necessary for efficient distractor rejection. Numerous studies have examined this possibility, either by manipulating the spatial separation between the target and an incongruent distractor (e.g., Gatti & Egeth, 1978; Merikle & Gorewich, 1979; Hagenaar & Van der Heijden, 1986), or by assigning them to different perceptual groups (e.g., Driver & Baylis, 1989; Baylis & Driver, 1992; Kramer

& Jacobson, 1991). Such studies have typically found that while Stroop-like interference cannot usually be eliminated merely by increasing spatial separation (e.g., Hagenaar & Van der Heiden, 1986), it can be significantly reduced by this manipulation (e.g., Gatti & Egeth, 1978; Merikle & Gorewich, 1979; Hagenaar & Van der Heijden, 1986). This finding is also characteristic of other Stroop-like paradigms such as the *flanker* paradigm (Eriksen & Eriksen, 1974), in which a distinct target letter appears centrally at fixation flanked by irrelevant distractor letters. The locational certainty here should in principle allow attention to be focused exclusively on the relevant location in advance of the display onset. Nevertheless, some degree of distractor processing (as evidenced by flanker congruency effects on target RTs) has still been demonstrated in numerous flanker studies, even under conditions of fairly clear spatial separation between target and distractor (e.g., Eriksen & Eriksen, 1974; Miller, 1987).

Although spatial separation between the target and distractors typically reduces distractor processing somewhat, several studies have shown that this reduction can be overcome by arranging displays such that distant distractors fall in the same perceptual group as the target. For example, even distant distractor letters have been shown to produce substantial interference on responses to an incongruent central target letter, when they are perceptually grouped with the target by common motion (Driver & Baylis, 1989), common colour (Baylis & Driver, 1992), or connectedness (Kramer & Jacobson, 1991). Collectively, these results imply that both spatial separation and perceptual segregation may be necessary for efficient distractor rejection. However, reports that some distractor processing can still arise even under these conditions (e.g., Gatti & Egeth, 1978) suggest that clear segregation between targets and distractors is not sufficient on its own to eliminate distractor processing entirely.

1.3.2 Display clutter

The studies described in the previous section typically examined distractor effects for relatively uncluttered displays, in which the target and critical distractor were the only stimuli present. It is possible that some distractor congruency effects continued to be found, even with spatial separation and perceptual segregation, because the critical distractor appeared alone with no other objects. Indeed, studies that have examined distractor processing in displays containing more items have typically found no congruency effects from distractors presented more than 1° of visual angle from the target in cluttered displays (e.g., Eriksen & Hoffman 1972, 1973), or separated from the target by an intervening item (e.g., Eriksen & Hoffman 1972, 1973; Yantis & Johnston, 1990). Such findings imply that processing can be restricted to a relevant location or target quite effectively in cluttered displays.

Since processing of relatively distant distractors has been reliably demonstrated in uncluttered displays (e.g., Gatti & Egeth, 1978), such findings suggest that clutter, in conjunction with spatial separation and/or grouping, plays an important role in determining the extent of distractor processing. In fact, the processing of a critical distractor can be impaired merely by adding one extra item to the display. In a Stroop-like study, Kahneman & Chajczyk (1983) measured RTs to name the ink-colour of a central target colour-patch accompanied by a black distractor colour-word above or below fixation. As would be expected, the distractor influenced target RTs, producing a Stroop-like congruency effect, despite its clear spatial separation from the central target. However, this interference could be substantially reduced (in Kahneman & Chajczyk's terminology, "*diluted*") merely by adding an additional response-neutral word, or even a row of Xs, to the display. Kahneman & Chajczyk (1983) concluded that the additional item disrupted the processing of the critical distractor, thereby diminishing its ability to interfere with the relevant task.

1.3.3 Perceptual load

The preceding experiments suggest that at least three factors have a combined influence in determining the extent of distractor processing: target-distractor spatial separation, grouping, and clutter. Lavie (1995) offered an explanation of how these factors may combine. According to her *perceptual load* theory of selective attention, while a clear physical distinction between relevant and irrelevant information is a necessary condition for efficient distractor rejection, it is not in itself sufficient to prevent irrelevant distractor processing. The major determinant is the *perceptual load* of the relevant task. A central assumption of Lavie's (1995) load theory is that attentional resources cannot be voluntarily withheld. Consequently, distractor processing can only be prevented if the perceptual load of the relevant task is sufficiently high to exhaust available attentional capacity. If the relevant task does not exhaust capacity, the excess capacity will be involuntarily allocated to the processing of irrelevant stimuli. On the other hand, if the relevant task does exhaust capacity, distractor processing will not take place, as a natural consequence of all capacity being consumed. Crucially, this theory can account for the otherwise discrepant findings of the studies outlined above (and also for the many seemingly discrepant results within the long-running early- versus late-selection debate). Those studies that reported distractor processing (apparently supporting 'late selection') even under conditions of clear segregation tended to involve situations of low perceptual load (e.g., small display set sizes). Conversely, those studies that reported no processing of distractors at irrelevant locations (apparently supporting 'early selection') tended to involve cluttered displays containing multiple stimuli, that is, situations of high perceptual load (see Lavie & Tsal, 1994, for a review).

Considerable empirical evidence in support of load theory has now been accumulated (e.g., Lavie, 1995, 2000, 2001; Lavie & Cox, 1997; Lavie & Fox, 2000; Rees, Frith & Lavie, 1997). Although in early studies, perceptual load was always equated with display set size, further support for load theory has since been obtained using load manipulations that are independent of the visual display itself (e.g., manipulation of processing requirements for exactly the same display; Lavie, 1995). The major finding, which holds true for various manipulations of load, is that interference from distant and irrelevant distractors is found only under conditions of low perceptual load in the relevant task, being eliminated under conditions of high perceptual load in the relevant task. Recent evidence from functional imaging is also consistent with these behavioural findings. For example, Rees et al. (1997) asked subjects to perform tasks of high or low load on visual word stimuli presented centrally, while ignoring irrelevant radial motion in the periphery of the display. Using fMRI, they found that motion-related activity in cortical area V5 was reduced (and likewise for the duration of psychophysical motion aftereffects) when subjects were engaged in the high load central task, again supporting the view that irrelevant perceptual processing (here for the surrounding motion) depends on the relevant processing load (Lavie, 1995).

However, with the exception of Rees et al.'s (1997) fMRI study of irrelevant motion processing, all of these studies have been concerned solely with distractors that are of no intrinsic biological significance (e.g., letters, words). Such studies cannot address the issue of whether distractors of particular biological significance, such as faces, can ever be truly ignored. It is possible that some biologically significant distractors may undergo full processing even under conditions that are optimal for ignoring less important distractors. In this respect, faces form a particularly interesting class of stimuli. Almost all of our social encounters involve the extraction of information from faces. Not only do we use faces to recognise familiar people, we also use them to judge the sex and age of unfamiliar people, to infer the emotional states of others via their facial expressions, to infer where others are attending via their direction of gaze, and to assist in the interpretation of speech (e.g., Bruce, 1988; Young, 1998). Faces thus carry a great deal of biologically significant information that has direct implications for everyday social behaviour. Moreover, there is also substantial evidence that face processing may be qualitatively different from other forms of visual processing, and may be subserved by face-specific neural systems (e.g., Farah, 1995; Kanwisher, 2000; Farah, Levinson & Klein, 1995; Farah, Wilson, Drain & Tanaka, 1995; Kanwisher et al., 1997). This evidence comes from several sources, as reviewed next.

Evidence that processing of faces may be 'special'

Many studies have shown that face processing may be mediated by different perceptual sub-systems than nonface (object) processing. There is psychological, neuropsychological, and neural evidence for this. I begin with the psychological evidence.

1.4.1 Psychological evidence

Face processing seems to be especially dependent on *configural* information (possibly in the form of information about the spatial relations between component parts; see Hancock, Bruce & Burton, 2000), rather than *featural* information about the parts themselves. For example, Young, Hellawell & Hay (1987) constructed 'chimeric' face stimuli by combining the top halves and bottom halves of different famous faces (see Figure 1.1).

Figure 1.1 An example of the 'chimeric' face effect demonstrated by Young et al. (1987). The top and bottom halves of famous faces are typically harder to identify when closely aligned (left) than when misaligned (right). The faces in this example belong to Rowan Atkinson (top) and Pierce Brosnan (bottom).

They found that when the two halves were closely aligned, subjects experienced great difficulty in naming the separate halves. However, their performance was much better when the two halves were not closely aligned. Presumably, close alignment produced a new configuration, making it difficult to process the two halves independently. Importantly, this effect disappears when the stimuli are inverted. The effect that of inversion on face processing has been studied extensively (e.g., Eimer, 2000; Valentine, 1988; Yin, 1969; Carey & Diamond, 1977; Farah, Wilson, Drain & Tanaka, 1995; Valentine & Bruce, 1986). There is clear evidence that upside-down faces are more difficult to recognize than upright faces (e.g., Goldstein, 1965; Hochberg & Galper, 1967; see Figure 1.2).

Figure 1.2 An example of the particularly disruptive effect of inversion on face perception. Face processing is often found to be more orientation sensitive than nonface object processing (e.g., Yin, 1969; Valentine & Bruce, 1986). The face in this example belongs to Harrison Ford.

However, a number of studies have made the stronger claim that inversion affects face recognition disproportionately compared to recognition of other objects that are usually only seen in one orientation (e.g., Yin, 1969; Carey &

Diamond, 1977; Valentine & Bruce, 1986). For example Yin (1969) found that when photographs of faces, houses, aeroplanes and schematic men in motion were presented and tested upright, recognition was better for faces than for the other classes of objects, but when presented and tested inverted, faces became the most difficult stimuli to recognize. This effect has generally been interpreted as evidence that faces engage processes that are not engaged by other stimuli, probably configural processes (but see Gauthier & Tarr, 1997; Gauthier, Behrmann & Tarr, 1999 for an alternative view). In support of this interpretation, there is considerable evidence that face processing may be more dependent than nonface object processing on configural representations. For example, in a study of recognition memory for parts of studied faces, Tanaka & Sengco (1997) found that the individual parts were recognized best when presented in the context of the original face configuration, less well in a transformed configuration (e.g., with the eyes slightly further apart), and most poorly in isolation (see Figure 1.3). By contrast, none of their tests with control stimuli (such as scrambled faces, inverted faces, or houses; see Figure 1.4) revealed any advantage for recognizing parts embedded in their studied configurations. This contrast suggests that upright faces may be processed in a more 'holistic' fashion than other objects, and thus may be more sensitive to configural transformations (Farah, Wilson, Drain & Tanaka, 1995; Tanaka & Farah, 1993; Tanaka & Sengco, 1997).

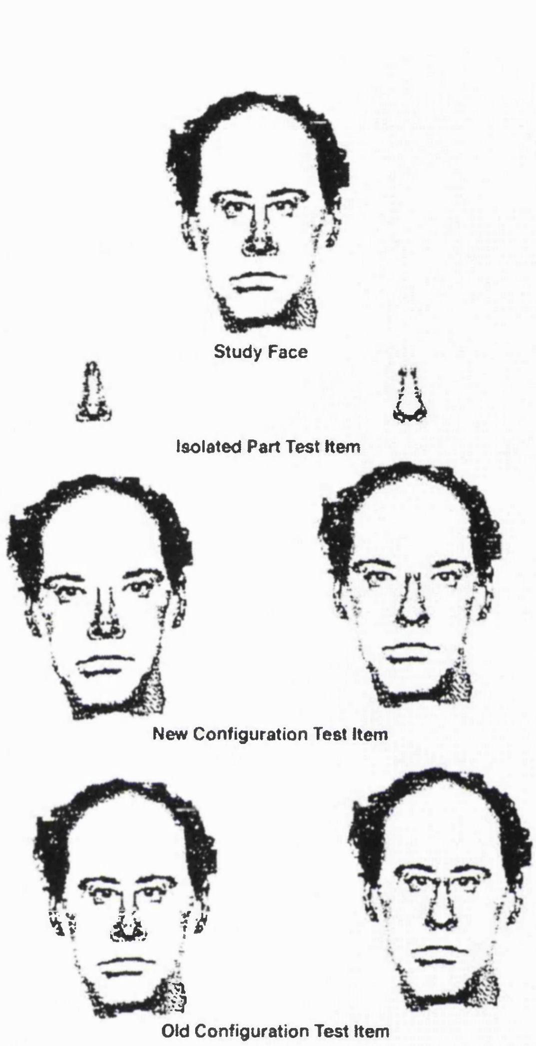

Figure 1.3 Example displays from Tanaka & Sengco (1997; Experiment 1). Note the positioning of the eyes in the study face (top row). In the recognition test, a single feature from the study face (in this case, the nose) is presented in isolation (second row), in a new configuration (third row), or in the original configuration (bottom row). Performance is best when the feature is embedded in the original configuration.

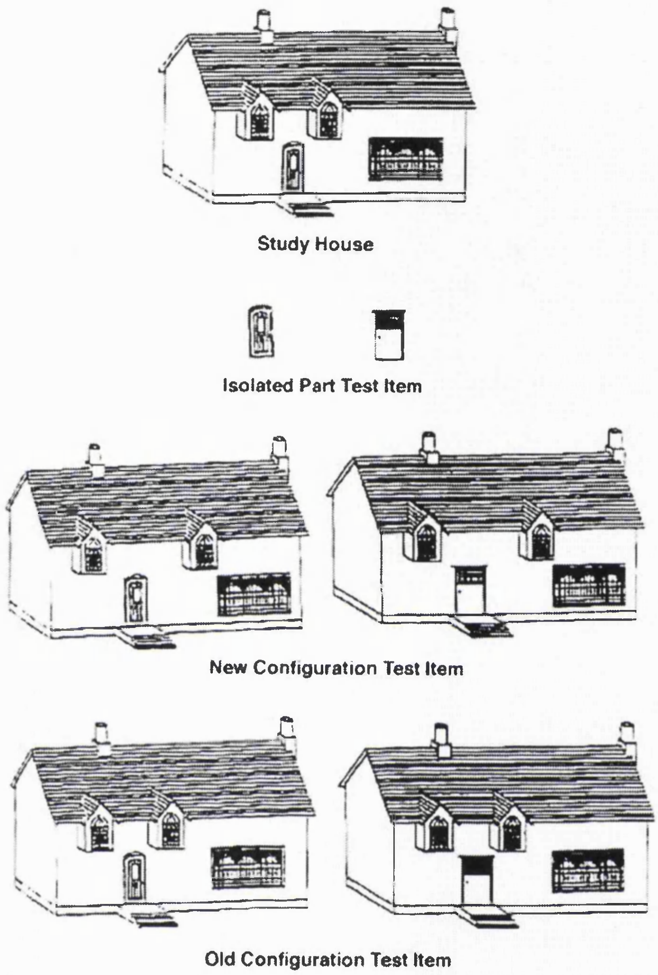

Figure 1.4 Example displays from Tanaka & Sengco (1997; Experiment 2). Note the positioning of the windows in the study house (top row). In the recognition test, a single feature from the study house (in this case, the door) is presented in isolation (second row), in a new configuration (third row), or in the original configuration (bottom row). Performance is equivalent across conditions, unlike the result for face stimuli.

1.4.2 Neuropsychological evidence

These psychological demonstrations of apparently face-specific effects raise the possibility that face processing may be subserved by a specialized neural system that is not shared by other stimulus classes. Several lines of evidence support this view. Firstly, numerous developmental studies of neonatal head and eye movements suggest that some face-specific processes may already be operational at birth. For example, infants reliably demonstrate a preference for face-like patterns over scrambled faces or blank face outlines even within an hour of birth (Goren, Sarty & Wu, 1975; Johnson, Dziurawiec, Ellis & Morton 1991; Maurer & Salapatek, 1976; Morton & Johnson, 1991), and will also track a moving face further than a nonface control (Morton & Johnson, 1991). Such early findings defy explanation in terms of long-term social learning. Rather, they imply that some face-specific processes may be biologically 'hardwired'.

Moreover, many neuropsychological reports have described adult patients with damage to the occipitotemporal region of the right hemisphere (or bilaterally, to both hemispheres) who have selectively impaired face-processing abilities (e.g., De Renzi, 1986; Farah, 1995; Farah, Levinson & Klein, 1995; Farah, Wilson, Drain & Tanaka, 1995; McNeill & Warrington, 1993; Sergent & Signoret, 1992). This condition is known as prosopagnosia. Although prosopagnosic patients are characteristically unable to recognise most familiar human faces, some have little difficulty in recognising familiar nonface objects (or nonhuman faces), even when requiring within-category discriminations of similar subtlety (De Renzi, 1986; Farah, Levinson & Klein, 1995; McNeill & Warrington, 1993, Sergent & Signoret, 1992). For example, McNeil & Warrington (1993) reported a prosopagnosic farmer who had become proficient at recognizing the faces of sheep. They compared his ability to recognize the faces of humans and sheep with that of neurologically normal sheep experts. Although for normal subjects, performance was much worse for sheep faces than human faces, the prosopagnosic showed the opposite pattern. In a logically similar study, Farah, Levinson & Klein (1995) compared the ability of another prosopagnosic patient to recognize particular faces and particular spectacle-frames against normal subjects' performance for the same stimuli (see Figure 1.5). As expected, the normal subjects were considerably better at recognizing the different faces than the different spectacle-frames. However, the prosopagnosic's performance was equally poor for both categories, suggesting a selective face impairment. Although the issue has long been debated (e.g., Damasio, Damasio & Van Hoesen, 1982; DeRenzi, 1986), and remains controversial (e.g., see Kanwisher 2000; Tarr & Gauthier, 2000), such cases suggest that prosopagnosia can be a highly face-specific disorder. Conversely, a few 'pure' object agnosics, whose low-level perception is often remarkably well-preserved, have been reported to suffer impaired object recognition while their face recognition is relatively spared (Humphreys & Rumiati, 1998; Moscovitch, Winocur & Behrmann, 1997; Rumiati & Humphreys, 1997). This pattern of double dissociation is compelling evidence that face and object processing can involve both functionally and structurally separate systems; without some structural distinction, the selective elimination of just one of these two abilities by brain damage would not be possible.

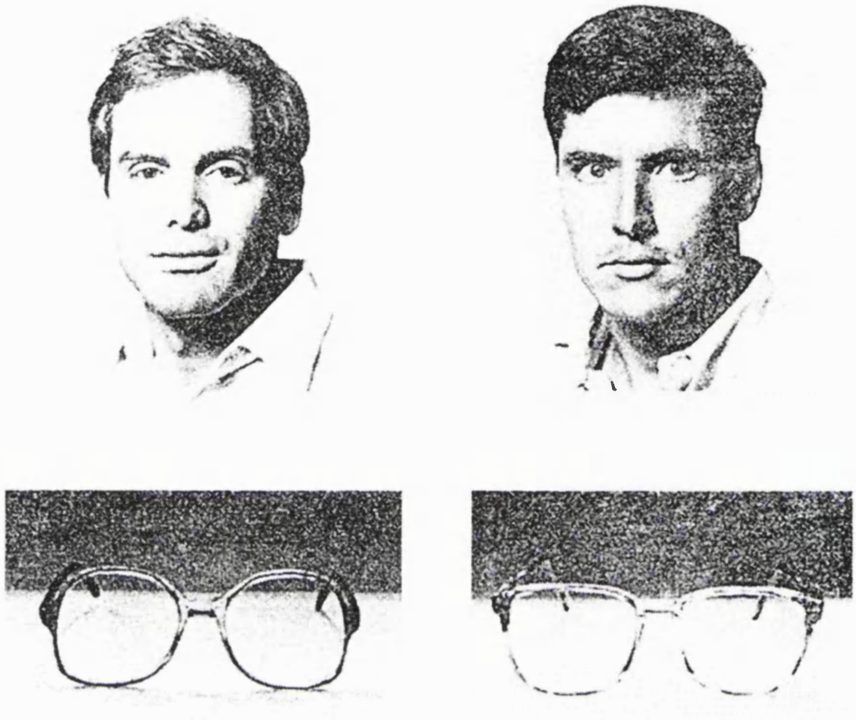

Figure 1.5 Examples of the faces (top) and spectacle frames (bottom) used by Farah, Levinson & Klein (1995) to compare recognition memory for faces versus nonface objects in prosopagnosic and neurologically intact subjects.

1.4.3 Neural evidence

Recent findings from functional imaging studies appear to corroborate the neuropsychological evidence for 'special' face-processing systems. Several such studies have identified an area in the fusiform gyrus (often right lateralised) that appears to be selectively involved in face processing, responding to a wide range of face stimuli stronger than for other stimuli such as houses, hands, scrambled faces, or everyday objects (e.g., Clark, Keil, Maisog, Courtney, Ungerleider & Haxby, 1996; Haxby, Horwitz, Ungerleider, Maisog, Pietrini & Grady, 1994; Kanwisher et al., 1997; McCarthy, Puce, Gore & Allison, 1996;

Puce, Allison, Gore & MacCarthy, 1995; Sergent & Signoret, 1992; but see Gauthier et al., 1999 for a contrary view; see also recent discussion by Kanwisher, 2000, and Tarr & Gauthier, 2000, for summaries of ongoing controversies on this topic).

This seemingly converging evidence from highly diverse studies has led some researchers (e.g., Farah 1995; Kanwisher et al., 1997) to propose that face-processing may involve a specialized *module* or modules. The concept of modularity may relate to attentional issues - and particularly to the question of whether irrelevant distractors can be ignored - since according to some views (e.g., Farah, 1995), modular processing may proceed independently of attention, and cannot be voluntarily withheld. If face processing is indeed conducted by a specialized module or modules of this type, it is possible that an irrelevant distractor face will always be processed, despite the viewer's intentions to ignore it, even under conditions that are optimal for ignoring other types of distractor (i.e. the words, letters etc. studied in most psychology experiments on attention to date). However, this possibility has not been directly tested before.

1.5 Previous behavioural studies of attention to faces

Possible relations between visual attention and face perception have been examined in past research using several attentional paradigms, including visual search, spatial cuing, and change blindness. It should be noted that none of these paradigms are ideal for measuring distractor processing for faces, in situations where the faces are entirely task-irrelevant (which will provide the empirical theme of this thesis). To date, the most extensively used of these paradigms has been *visual search*. In typical visual search tasks (e.g., Treisman

& Gelade, 1980), subjects are presented with displays containing a variable number of nontarget stimuli (e.g., green Xs). A target stimulus (e.g., a red X) is present on half of the trials and absent on the other half, and the subjects' task is to decide as quickly as possible whether the target is present in the display. Response times are then measured as a function of display set size (i.e. the number of nontargets in which the target may be embedded). Serial search (as indicated by a steeply linear function of RT against set size) implies that the processing of each search item was dependent on focused attention, or at least could not proceed in an efficiently parallel manner. Conversely, parallel search (as indicated by a relatively flat set size function, with little or no increase in RT against set size) implies that the search items could be processed efficiently in parallel, without subjects having to focus attention on each individual item in turn. Thus, if faces can be processed independently of attention, as some proponents of modularity for face-processing might claim, they might be amenable to parallel visual search. This hypothesis has been tested in several recent studies. The results of these studies, however, have not been conclusive.

Nothdurft (1993) asked subjects to detect targets (either faces or specific facial expressions) among a variable number of distractors (either 'nonfaces' i.e. rearranged or inverted faces, or nontarget facial expressions). In all cases, the stimuli were simple schematic drawings. The nontargets were created either by reconfiguring the facial features of the target, or by inverting otherwise intact targets (see Figure 1.6).

Figure 1.6 Demonstration of the failure of an intact schematic face among rearranged faces to 'pop out' (adapted from Nothdurft, 1993; Series 7).

Nothdurft (1993) found no evidence of parallel search for either faces or facial expressions. Parallel search was only observed when the target could be identified on the basis of a unique and salient low-level feature. For example, when the schematic faces included a black chevron for hair (his Series 1), subjects appear to have been able to reduce the search for a face among nonfaces to a simple feature search for an upright chevron among inverted chevrons (see Figure 1.7). This effect was independent of the facial configuration of the stimuli and was equally strong when similar nonface stimuli served as targets (his Series 2).

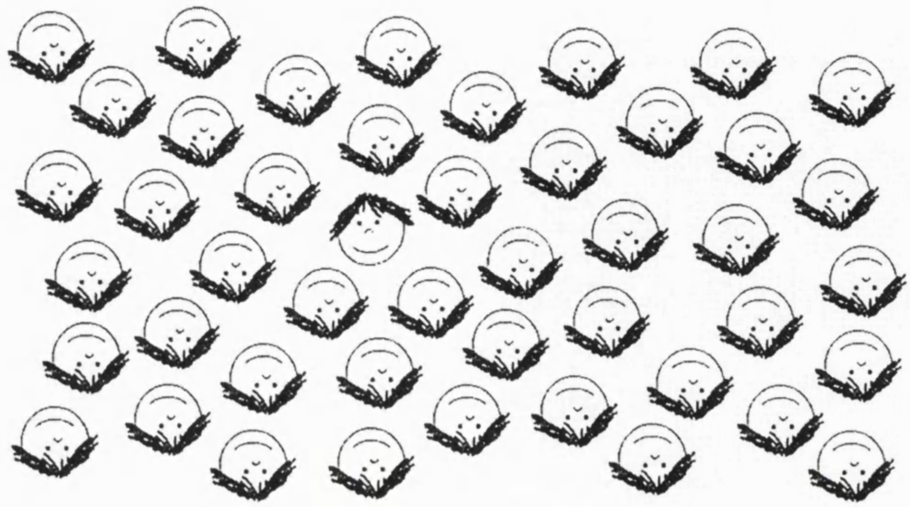

Figure 1.7 An upright schematic face can 'pop out' from an array of inverted faces, but only when the target contains a unique and salient low-level feature (e.g., an upright chevron; Figure adapted from Nothdurft, 1993; Series 1).

More recent visual search studies have also found serial or inefficient search for intact faces among inverted or rearranged faces, using high-quality digitized faces rather than schematic line drawings (e.g., Kuehn & Jolicoeur, 1994; Brown, Huey & Findlay, 1997). However, although faces can fail to pop out as search targets, they may still be particularly difficult to ignore when presented as search nontargets. For example, Suzuki & Cavanagh (1995) found that a cost in feature search (for an upturned 'mouth-like' feature) is incurred if both the target and nontarget features alike are arranged in schematic face-like configurations (see Figure 1.8). This finding suggests that subjects may have been unable to avoid processing irrelevant face configurations even when ignoring them would have improved search efficiency.

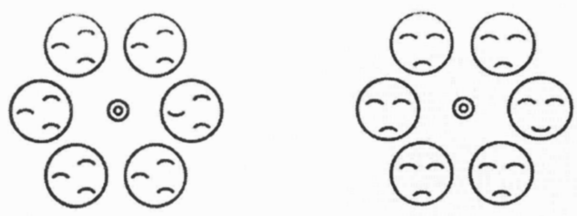

Figure 1.8 Examples of search arrays used by Suzuki & Cavanagh (1995). The left array shows a feature (upturned curve) search without facial configuration. The right array shows a feature (upturned curve) search with facial configuration. Search times were typically slower for targets embedded in a facial configuration.

However, the visual search task may not be the most appropriate test for deciding whether or not face processing can truly proceed independently of covert attention. As the differences between target and distractor items in a visual search array become increasingly subtle (e.g., an upright face among inverted faces as opposed to, say, a red X among green Xs), it becomes increasingly implausible that nonfoveated items can be reliably distinguished. Thus in order to determine whether or not the target is present in a given display, subjects may have to foveate each item in turn. Since foveation is a serial process, it may not be surprising if a serial search function is often obtained for displays containing multiple face stimuli. Such acuity problems are exacerbated when a large set-size enforces small individual items (as in Nothdurft, 1993; Kuehn & Jolicoeur, 1994; Brown et al., 1997).

More recently, several *spatial cuing* studies have shown that the gaze of a centrally-presented schematic face (Friesen & Kingstone, 1998), of a photographic face in frontal view (Driver, Davis, Ricciardelli, Kidd, Maxwell & Baron-Cohen, 1999), or of a photographic face in 3/4 view (Bruce & Langton,

1999) can trigger reflexive attention shifts in the observer. In all three studies, subjects responded more quickly to a peripheral nonface target when it appeared in the location cued by the direction of gaze of a central face, even when they knew the direction of its gaze was completely nonpredictive. In fact, Driver et al. (1999) found that targets on the side that the face gazed towards were processed faster even when subjects knew the direction of gaze was 80% counter-predictive (i.e. when targets were more likely to appear on the side the face gazed away from), suggesting that perceived gaze can induce a corresponding shift in attention even when contrary to the observer's intentions. However, while these studies do suggest that some automatic processes can be triggered by a central face presented in isolation, they did not measure the overall distracting effect of a face, but rather the effect of one specific face component (gaze) when no competing object was present. Thus they have not addressed the current question of whether faces in general are more difficult to ignore than other objects.

One recent study by Ro, Russell & Lavie (2000) compared the attention-capturing properties of faces versus other objects in multiple object arrays, using the 'change-blindness' paradigm (Rensink, Oregan & Clark, 1997). Observers in change-blindness studies are often remarkably poor at detecting large changes between two alternating displays when these are separated by a brief transient across the whole display. Ro et al. (2000) found that changes in upright faces (but not inverted faces) were detected far more rapidly and accurately than changes in other everyday objects (e.g., plants, musical instruments) when all these stimulus types appeared together in multi-item displays, with any item potentially being the changing item. This suggests that faces may be particularly strong competitors for attention compared with other objects. However, the change-blindness paradigm presents a situation in which all the stimuli are potentially task-relevant, since any of the stimuli may contain the change. It therefore offers little insight in to the processing of task-irrelevant stimuli; the fact that a relevant face can summon attention when presented among other relevant items does not guarantee that the same face would summon attention spontaneously when entirely task-irrelevant (i.e. when the observer is trying to ignore faces).

A study by Young, Ellis, Flude, McWeeny & Hay (1986) addressed the possible automaticity of processing for task-irrelevant faces more directly. Young et al. (1986) presented subjects with displays composed of a printed famous name (either a pop-star's or a politician's), presented inside a 'speech bubble' extending from the mouth of a famous face (also either a pop-star's or a politician's). The subjects' task was to categorize the famous name as a pop-star's or a politician's, while ignoring the distractor face, which could be either congruent with the correct response (e.g., Mick Jagger's face for Mick Jagger's name) or incongruent (e.g., Mick Jagger's face for Neil Kinnock's name; see Figure 1.9). They found that target RTs were slower in trials containing an incongruent face (e.g., a popstar's face presented with a politician's name) than in trials containing a congruent face (i.e. a face from the same category as the name).

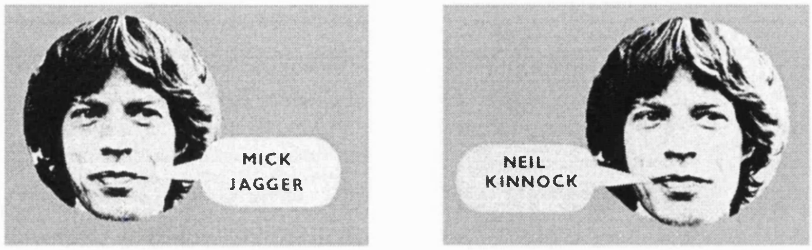

Figure 1.9 Examples of displays from Young et al. (1986). Occupational categorization of the target printed name (pop-star vs. politician) was faster when the distractor face was *congruent* with the correct response (left example here) than when it was *incongruent* with the correct response (right example here).

These results suggest that subjects were unable to prevent semantic categorization of the distractor face under the experimental conditions (i.e. coding of the face in terms of its owner's occupation, presumably via its owner's identity; Bruce & Young, 1986; Burton, Bruce & Johnston, 1990). However, it is not clear from this study whether distractor faces are particularly hard to ignore as compared with other stimulus classes. Similar picture-name semantic interference effects can be obtained with nonface stimuli (e.g., Smith & Magee, 1980). Indeed, even within the Young et al. (1986) study, similar congruency effects from printed names were found when these served as distractors, and the faces as targets. Hence the results to date do not show that distractor faces are any more special than distractor words, or other stimulus types.

In sum, while none of these previous studies on faces in relation to attentional issues demonstrate that the processing of irrelevant faces is strictly mandatory or capacity-free, they at least remain consistent with the idea that faces may constitute a special stimulus from an attentional perspective. For example, the recent findings from visual search and spatial cuing experiments suggest that at least some aspects of face processing may proceed against the observer's will. Thus, Suzuki & Cavanagh (1995) found that subjects seemed unable to ignore irrelevant face configurations, even when ignoring them would have improved their performance in a feature search task. Driver et al. (1999) showed that subjects were unable to avoid orienting in the direction of a seen gaze even when it slowed target reponses (as targets were actually more likely on the side the face gazed away from). Such findings suggest that some information from irrelevant faces may be processed in spite of viewers' intentions to ignore them. Furthermore, recent evidence from the change-blindness paradigm suggests that relevant faces may have a particularly strong capacity to capture attention when competing with other relevant everyday objects (Ro et al., 2000). However, none of these studies have tested whether entirely task-irrelevant distractor faces are particularly difficult to ignore, compared with other irrelevant stimulus types. Although Young et al.'s (1986) pioneering study established that an irrelevant face can be distracting on its own, this finding appears similar to those for other nonface stimulus classes (e.g., Kahneman & Chajczyk, 1983). Thus Young et al.'s study does not reveal whether faces are particularly hard to ignore, producing distractor effects even under conditions that are optimal for the rejection of other types of distractor (e.g., letters, words, nonface objects). This is because the Young et al. study only considered a single distractor face, that was both close to the target name, and grouped with it via the speech bubble. Under these conditions, all stimulus classes studied to date can produce distractor interference (see my earlier review of the attention literature). Whether or not faces are particularly difficult distractors to ignore is the focus of the present work.

To summarize thus far, numerous selective-attention studies have shown that subjects can fail to exclude irrelevant distractors in a visual display from internal processing (e.g., Eriksen & Eriksen, 1974). However, conditions of high load can facilitate the exclusion of distractors. For example, Lavie (1995) has shown that increasing the perceptual load of a display (e.g., by increasing the level of clutter) can eliminate interference effects from irrelevant distractors, provided that the latter are also spatially well separated from the target. But to date, such studies have been concerned primarily with fairly neutral distractors of no direct biological significance (e.g., letters, or neutral words). Little is known about whether stimuli of particular biological significance (e.g., faces) can ever be fully ignored. Given that face processing and nonface object processing seem to be mediated by different perceptual subsystems (e.g., Yin, 1969; Tanaka & Farah, 1993; Tanaka & Sengco, 1997), and perhaps by different neural subsystems (Kanwisher, 2000; Farah, 1995; Kanwisher et al., 1997), it is at least possible that they also follow different attentional principles. Indeed some researchers (e.g., Farah, 1995; Kanwisher et al., 1997) have suggested that face processing may be conducted by a specialized face-processing module (or set of modules) operating in a mandatory fashion in the presence of any face input. Automaticity is often proposed as a characteristic feature of specialized modules (see Fodor, 1983), and there have been many proposals that face processing is strongly automatic in this sense (e.g., Farah, 1995; Farah, Wilson, Drain & Tanaka, 1995). If so, unlike other types of distractor, distractor faces should be processed even when a different target is attended, regardless of the level of clutter or perceptual load in the display.

However, none of these issues have yet been tested directly. Although several recent studies have explored the role of attention in face perception (e.g., Nothdurft, 1993; Ro et al., 2000), only one (Young et al., 1986) has addressed the question of whether faces are still processed even when presented as task-irrelevant distractors. Importantly however, even Young et al.'s study does not reveal whether faces are particularly difficult to ignore, such that they may be processed even under conditions that are optimal for ignoring other types of irrelevant stimuli (e.g., letters, words, nonface objects). Hence the role of attention in the processing of irrelevant distractor faces remains poorly understood. It is not even clear, for example, whether faces are subject to the same principles of selection that apply to other classes of stimuli, or whether irrelevant faces may attract more attention than irrelevant distractor objects that are less biologically significant. The aim of the current dissertation is to address these issues directly, by comparing the processing of face distractors and other types of distractor under varying conditions of perceptual load.

1.6 General methodological approach and overview

The processing of irrelevant distractor faces was examined here using two common psychological measures of distractor processing, namely on-line response-competition (or 'distractor congruency') effects (Chapters 2, 3, and 6), and subsequent recognition memory for previously presented irrelevant distractors (Chapters 4 & 5). Chapter 2 examined the effects of display clutter on irrelevant face processing using a variation of Young et al.'s (1986) face-name interference task. Several modifications to the Young et al. (1986) method were introduced to provide optimal conditions for distractor rejection;

and a suitable adaptation of Kahneman & Chajczyk's (1983) manipulation of additional distractors was used to examine whether additional objects, of various types, could 'dilute' interference from a concurrently presented critical distractor face. Subjects classified a printed famous target name as a pop-star's or a politician's, while trying to ignore a famous distractor face which was always clearly separated from the target name (unlike Young et al.'s (1986) study, in which the target name had been presented close to the face inside a 'speech bubble' extending from the face's mouth; see Figure 1.9). The role of clutter (or 'load') was assessed by examining whether interference effects from the critical distractor face (on reaction times to the printed name, when congruent versus incongruent) could be 'diluted' by adding another item to the display (see Kahneman & Chajczyk, 1983, for such findings with distractor words). To address claims that face-processing may involve face-specific mechanisms (e.g., Farah, 1995; Kanwisher, 2000; Farah, Levinson & Klein, 1995; Farah, Wilson, Drain & Tanaka, 1995; Kanwisher et al., 1997), these experiments also examined whether dilution of distractor effects from a face might require a specific type of clutter, namely the addition of another face stimulus. To determine this, the effects of cluttering the display with an additional face were contrasted with the effects of adding a scrambled face (Experiment 1) or an inverted face (Experiment 2).

In the experiments of Chapter 3, the response-competition task from Chapter 2 was again used, but now to assess any effect of an additional meaningful nonface object on response-competition effects from a distractor face (Experiment 3). This was compared with the converse situation in Experiment

4, which examined the effect of an additional face or nonface distractor on response-competition effects from a critical nonface distractor object in a categorization task for printed object names.

The purpose of these response competition (i.e. distractor congruency) experiments was to explore interactions between particular types of clutter and on-line interference effects on target RTs due to the processing of distractor faces. However, much of the everyday and applied interest in face processing (e.g., as in eyewitness testimony) concerns our ability to remember seen faces. In order to explore possible links between attentional issues and memory for faces, Chapter 4 examined the effect of perceptual clutter (i.e. 'load') at exposure on subjects' later ability to recognize previously unknown faces, that were completely task-irrelevant when first presented. Two experiments assessed the effect of visual clutter at exposure on incidental long-term recognition memory for faces (Experiment 5) and nonface objects (Experiment 6), following exposure as entirely task-irrelevant stimuli in a colour judgement task. As in Chapter 3, the level of clutter was manipulated by adding another face or nonface object to the exposure display. At the end of the experiment, incidental memory for the faces (Experiment 5) and nonface objects (Experiment 6) was assessed using a surprise recognition test. In this way the ability of an additional face or nonface object in the display to 'dilute' subsequent incidental memory for faces (Experiment 5) or nonface objects (Experiment 6) could be compared, analogous to the preceding studies on possible dilution of on-line distractor interference effects.

Chapter 5 examined whether increasing the perceptual load of a nonface task can ever eliminate the formation of incidental memories for a task-irrelevant face presented at fixation. Perceptual load was manipulated in a letter-string task superimposed on a task-irrelevant face. The faces could be presented under conditions of either high load or low load in the relevant letter task. At the end of the experiment, a surprise recognition test was used to compare incidental memory for faces that had appeared under these two load conditions.

The earlier empirical chapters (Chapters 2 & 3) had examined whether perceptual clutter in the display can disrupt the processing of an irrelevant face. In view of recent claims that mental images may have some perception-like properties (e.g., Kosslyn, 1994; Behrmann, Moscovitch & Winocur, 1999), Chapter 6 examined whether face-like clutter 'in the mind's eye' (i.e. an imagined face) is sufficient to dilute the perception of a face that is physically present in the display. To test this possibility, I examined the effect of 'clutter' in visual short term memory (VSTM) on the processing of an irrelevant distractor face, using the response-competition paradigm that was used in Chapter 2. In order to manipulate clutter in VSTM (Experiment 9), the response-competition task was interleaved with a visual short term memory task, in which subjects had to memorize a face or a nonface image presented before the response-competition task and report whether or not it matched another image presented after the response-competition display. This matching task ensured that subjects had to retain the image presented in the VSTM display while performing the interleaved response-competition task. As before, the potential diluting effects of maintaining an image in VSTM were contrasted for face versus nonface images. To further clarify the role of active VSTM in distractor processing, two follow-up experiments assessed the effect of passively-viewed face and nonface images on response-competition effects from distractor faces (Experiment 10) and nonface distractors (Experiment 11).

The general aim of all these experiments was to bring two intensively researched but previously disparate fields together for the first time (i.e. selective attention and face processing). In so doing, the experiments sought to determine whether faces are particularly difficult stimuli to ignore, and also to assess the consequences of various attentional manipulations for both on-line processing of task-irrelevant faces, and for subsequent incidental memory for these faces. Addressing such issues should be of both theoretical and practical significance. For example, one long-standing debate within cognitive science concerns the extent to which the mind may be 'modular' in its functional organization (e.g., see Fodor, 1983; Coltheart, 1998). The debate over modularity for face processing has often been treated as a microcosm of this broader debate (e.g., Kanwisher, 2000; Tarr & Gauthier, 2000). Testing whether face processing can occur without attention should make a substantial contribution to this debate, since mandatory operation (i.e. independence from attention) is widely held to be a characteristic feature of Fodorian modules (e.g., Farah, 1995; Fodor, 1983; Farah, Wilson, Drain & Tanaka, 1995; see also Coltheart, 1998, for a 'neo-Fodorian' account of modularity).

The findings presented in this thesis may also have direct practical implications for the assessment of eyewitness testimony. In legal cases, enormous weight can be given to the testimony of eyewitnesses (Bruce, 1988). Indeed, juries have often convicted suspects solely on the evidence of eyewitness identification (e.g., Devlin, 1976; Wells & Loftus, 1984; see also Wells, 1993; Laughery & Wogalter, 1989; Wells, Malpass, Lindsay, Fisher, Turtle & Fulero, 2000, for reviews of applied eyewitness research). Yet eyewitness identification can often be highly unreliable (Devlin, 1976; Egeth, 1993; Wells, 1993; Hancock et al., 2000; Wells & Loftus, 1984). To date, efforts to improve reliability have typically focused on reducing bias at the time of memory retrieval (e.g., improving the methodology of identity parades; Bruce, Henderson, Greenwood, Hancock, Burton & Miller, 2000; Wells et al., 2000). Attentional factors at the time of encoding have so far received little consideration. The emphasis on facilitating accurate retrieval reflects an assumption that there exists some accurate memory trace (however weak) of the criminal's face, and that the difficulty lies in accessing that veridical memory trace. However, evidence for attentional modulation of face processing may open a further possibility: that no such memory trace exists, even if the criminal's face was in view of the eyewitness, when attention was otherwise engaged.

Chapter 2

Dilution Of Response-Competition Effects From Distractor Faces

Introduction

As reviewed in Chapter 1, there is considerable evidence that face perception may involve some different perceptual principles than other forms of visual perception (e.g., Yin, 1969; Young et al., 1987; Tanaka & Sengco, 1997), and may be conducted by a specialized face-processing 'module' (Fodor, 1983) or set of modules operating automatically in the presence of face input (Farah, 1995; Farah, Wilson, Drain & Tanaka, 1995). If faces are indeed processed in a strongly automatic manner, they should be processed even when a different target is attended, regardless of the level of clutter in the display. In other words, it should be particularly difficult to avoid processing a face in the visual field, even if it is entirely irrelevant in terms of current task priorities. The present experiments examined this possibility by testing whether irrelevant faces are particularly difficult distractors to ignore, and exploring the conditions which may reduce their distracting effects. Although some previous experiments have shown that isolated irrelevant faces can produce distractor effects (Young et al., 1986), these findings alone are similar to those for other classes of stimuli, such as famous names (Young et al., 1986), colour-words (Stroop, 1935), and nonface objects (Smith & Magee, 1980). Thus, Young et al.'s (1986) pioneering study cannot address the issue of whether faces are particularly hard to ignore, producing distractor effects even under conditions that are optimal for the rejection of other types of distractor. To address this, I used a variation of Young et al.'s (1986) task, with several modifications designed to provide optimal conditions for distractor rejection. As in Young et al. (1986), subjects were asked to classify a central printed target name as a pop-star's or a politician's, while ignoring an irrelevant famous distractor face which could be congruent or incongruent with the target name. The target name was now always presented at fixation, while the distractor face was presented in the periphery, clearly separated from the target name. In addition, I examined any effects of presenting other response-neutral objects, to 'clutter' the array and thus increase perceptual load, on the processing of the critical famous face distractor.

If famous face distractors are processed similarly to other classes of distractor stimuli, then any distractor interference found from peripheral face distractors should be 'diluted' when more objects are added to the display (see Kahneman & Chajczyk, 1983, Lavie & Cox, 1997, for such findings with word or letter stimuli as the critical distractors). Such results would be predicted from Lavie's (1995) perceptual load model (unless faces are an exception to this) and would indicate that distractor faces, like other distractors, may be subject to general capacity limits. If however, unlike other stimuli (e.g., letters, words, nonface objects), the processing of faces is automatic in the strong sense of being capacity-free (or independent of general nonface capacities), then distractor faces should continue to produce interference even when other potentially diluting objects are added to the display. Finally, if any capacity limits for faces concern only face-specific processes, then only an additional face distractor should be able to dilute the interference effect from the critical famous distractor face. Adding other nonface objects should not reduce interference from the famous face.

Experiment 1

In Experiment 1 subjects were requested to make a speeded categorization response as to whether a printed name at fixation was a politician's or a pop-star's, while ignoring an irrelevant politician's or pop-star's face presented to the right or left of the name. This famous distractor face could be either congruent or incongruent with the correct response, and congruency effects on target RTs were measured under three conditions. The famous distractor face was either presented: i) alone except for the central target name; ii) with an intact anonymous face on the opposite side of the central target name; or iii) with a scrambled anonymous face on that side (see Figure 2.1). The scrambled anonymous face was intended to serve as a control for low-level visual energies of the intact anonymous face. As stated in the introduction, if face processing is fully automatic not only in the sense that it cannot be voluntarily withheld, but also in that it is capacity-free, then the famous distractor faces should produce congruency effects regardless of the nature and number of any other objects in the display. On the other hand, if faces are processed no differently to other distractor stimuli, in terms of the rules dictating whether they will interfere, then congruency effects from the critical distractor face should arise only when it is the sole distractor; these effects should be reduced once any other object is added to the display (see Kahneman & Chajczyk, 1983). Finally if any capacity-limits are specific to the processing of intact faces, then only an additional intact face should dilute interference from the famous distractor; the scrambled face should have no impact.

Method

Subjects 26 students from University College London, whose ages ranged from 18-28, were paid £3 to participate in the experiment. All subjects had normal or corrected vision by self-report and recognised the famous faces they were to encounter in the experiment, as tested at the beginning.

Apparatus & Stimuli An Apple Macintosh computer attached to a colour monitor was used to present the stimuli and record the responses. Viewing distance was fixed at 60 cm using a chinrest. The experiments were created and run using SuperLab 1.68. The names and faces of 6 male pop stars (David Bowie, Mick Jagger, Elton John, John Lennon, Jim Morrison, and Elvis Presley), and 6 male politicians (Tony Blair, George Bush, Bill Clinton, William Hague, John Major, and Ronald Reagan) were used as targets and critical distractors. A further set of 12 anonymous faces was used in conditions containing additional (response-neutral) distractors as potential diluters. A phase-scrambled version of each of the anonymous faces was also made, by randomly shifting the phase of the component spatial frequencies of each intact anonymous face after Fourier analysis (see McCarthy, Puce, Gore & Allison, 1997). Note that this scrambling procedure preserves the amplitude of the component spatial frequencies across the spectrum in comparison with the original intact face. It is thus a good control for such low-level visual energies. All intact faces were greyscale images derived from photographs, and measured 2.1 cm by 2.8 cm (subtending 2.0° x 2.7° of visual angle at the viewing distance of 60 cm) after being cropped to remove extraneous background. Cropping resulted in some loss of the face outline (see Figure 1), but was done to prevent spatial frequencies present in the surrounding background from contaminating the scrambled face images. Each display contained one name (shown in black 12 point Arial font) centred at fixation, and measuring between 2.3 cm (the shortest name) and 3.4 cm (the longest name) in width (2.2°-3.2° of visual angle). A famous distractor face was presented either to the left or to the right of the name. The nearest contours of the target word and critical distractor face were separated by 1.2 cm (1.1°of visual angle). The concurrent name and famous face in each display were equally likely to be congruent (i.e. a face that matched the target name, e.g., David Bowie's face with David Bowie's name), or incongruent (a face that matched a name from the opposite category, e.g., David Bowie's face with Bill Clinton's name). For the incongruent condition, all 6 potential incongruent faces (i.e. faces from the other category) were equally likely to be paired with each target name, and likewise for the neutral faces. The space on the opposite side of the famous distractor face was equally likely to be blank (in the *Blank* condition), to contain an intact anonymous face (in the *Intact* condition), or to contain a scrambled anonymous face (in the *Scrambled* condition). Combining each of the 12 target names with a congruent or an incongruent famous distractor face under 3 levels of the flanker on the other side resulted in a total of 72 possible displays.

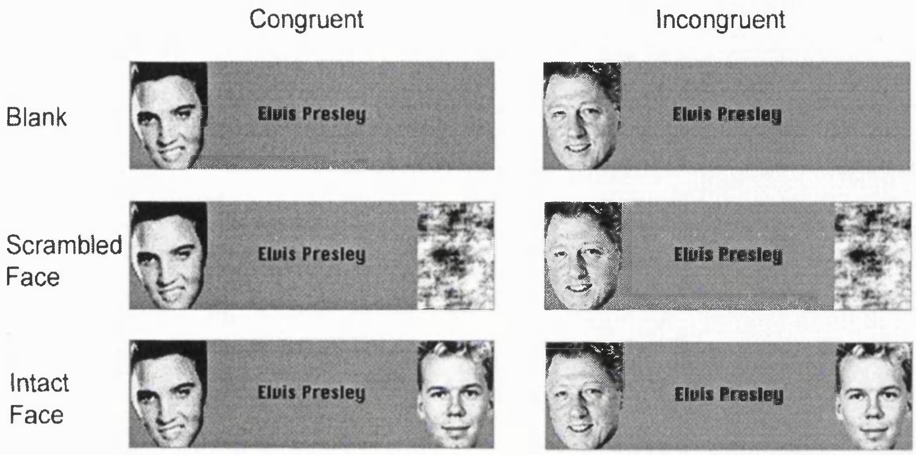

Figure 2.1 Example displays from the six conditions of Experiment 1. The critical distractor face could be either *Congruent* (left column) or *Incongruent* (right column) with the central target name, and was presented alone (*Blank* condition; top row), accompanied by a scrambled anonymous face (*Scrambled* condition; middle row), or accompanied by an intact anonymous face (*Intact* condition; bottom row).

Procedure Prior to the onset of each display, a black fixation point appeared at the centre of the screen for 500 msec. This was immediately replaced by the target-plus-flanker(s) display, which appeared for 200 msec (i.e. too briefly for a stimulus-responsive saccade to be initiated during its exposure) against a light grey background. Subjects made a speeded judgement concerning whether the target name was of a pop-star or a politician. Responses were made with the right hand, using the numeric pad on the right of the standard computer keyboard, pressing the "3" key to indicate a pop-star's name, or the "." key to indicate a politician's name. Feedback for errors was given immediately by a short tone. If no response was made within 3s, feedback was given by the same tone and the next trial initiated. Subjects were emphatically instructed to ignore all the irrelevant distractors and were warned that failure to ignore them could impair their performance. Following a short block of 12 example trials, each subject underwent seven blocks of 72 trials each. All the experimental conditions were randomly intermixed within each block. The example block and the first experimental block were discarded as practice. Subjects were able to rest between blocks, initiating the next block by pressing the space bar.

Results

Incorrect responses and RTs exceeding 2 sec (less than 2% of correct responses) were excluded from the RT analysis. Data from 2 subjects, one whose error rate was 36%, and one whose response latencies were exceptionally slow (1.9 SD from the group mean), were also excluded. Mean correct reaction times (RTs) and percentage error rates were computed for the rest of the group for each level of congruency (i.e. *Congruent* versus *Incongruent*) and display type (*Blank*, *Scrambled*, and *Intact*). The average of these RTs and error rates across subjects is shown in Table 2.1.

Table 2.1 Mean Reaction Times (in msec) and Error Rate (%) across Subjects (n=24) as a Function of Distractor Congruency and Neutral Flanker Type in Experiment 1.

	Distractor congruency				Effect size	
	I		*C*		I-C	
Neutral flanker	RT	%E	RT	%E	RT	%E
Blank	484	11	441	8	43	3
Scrambled	491	11	459	9	32	2
Intact	476	10	458	9	18	1

Note. *I* = Incongruent; *C* = Congruent.

RTs A two-way within-subjects analysis of variance (ANOVA) on the mean RT data, with the factors of distractor congruency (2 levels) and display type (3 levels) showed a main effect of congruency [$F(1,23)=37.9$, $p < .01$], with slower responses to incongruent displays, but no reliable main effect of display type [$F(2,46)=2.55$, $p = .08$]. More importantly, the main effect of congruency was modified by an interaction with display type [$F(2,46)=3.7$, $p < .05$]. As can be seen in Table 2.1, although congruency effects from the critical famous distractor face were found in all conditions ($p < .05$ in each case), one-tailed t-tests showed that these distractor effects were significantly smaller in the condition with an additional intact face as the potential diluter than in the condition with an additional scrambled face [$t(1,23)=1.82$, $p < .05$], or in the *Blank* condition where the distractor appeared alone [$t(1,23)=2.54$, $p < .01$]. There was no difference in the distractor effects between the *Blank* and *Scrambled* conditions [$t < 1$].

Errors Comparable analyses were conducted on the error data. A two-way ANOVA (congruency x display type) found only a main effect of congruency [$F(1,23)=19.38$, $p < .01$]. As can be seen in Table 2.1, *Incongruent* conditions resulted in a small (2% ± 1%) increase in the number of errors under all display conditions. There were no significant effects in the analysis of error rates ($F < 1$ for all), but any trends support the RT pattern.

Discussion

These results extend Young et al.'s (1986) finding that an irrelevant face can interfere with the categorization of a target name, even when the target and distractor are clearly separated, as in the current study. At a general level, this finding corroborates previous claims that spatial separation between a target and an isolated distractor is not on its own sufficient to prevent distractor processing (e.g., Lavie, 1995). The more specific aim of this study was to determine whether the processing of a famous distractor face can be affected by the presence of an additional, response-neutral flanker. The RT results show that face-name interference can indeed be diluted, by adding an anonymous intact face as a further distractor in addition to the critical famous face. This is an important finding since it runs counter to claims that face identification may be fully automatic in the sense of being entirely capacity-free. If identification of famous faces were automatic in this strong sense, the introduction of a second anonymous face in the display ought not to disrupt the influence of the famous face. Finally, these results show that face-name interference cannot be significantly diluted merely by <u>any</u> additional stimulus. Although an upright unknown face produced significant dilution, a scrambled face did not produce any reliable dilution, despite sharing similar low-level energies with the effective intact face. Thus, distractor interference from an irrelevant face may be more robust than other forms of interference (e.g., color-word interference, Kahneman & Chajczyk, 1983), which can apparently be diluted by any additional item, however meaningless it may be (e.g., a row of Xs in Kahneman & Chajczyk's (1983) study).

Experiment 2

The results of Experiment 1 provide initial support for the hypothesis that the distracting effect of a famous face can be diluted, albeit only by the presence of another intact face. The modulation produced by adding an intact face cannot have been due simply to the low-level visual energies of that additional stimulus, as no modulation was found from scrambled faces which preserved the component spatial frequencies and amplitudes of the intact distractors. Thus the reduced effect from the famous distractor face in the presence of another face cannot simply be attributed to the elimination of attention capture by an isolated peripheral object; in statistical terms, the famous face distractor produced as much interference when accompanied by the scrambled face as when alone. However, an objection could be raised as to whether the 'nonface' (i.e. scrambled face) control stimulus was adequate. Although the scrambled faces control for several important low-level features (energy at different parts of the spatial frequency spectrum, overall contrast and size) they do not control for edge or structural information. To assess whether the observed difference in diluting power between neutral faces and nonfaces was due merely to such differences, inverted faces were used as the 'nonface' control in the next experiment. Although inverted faces are identical to upright faces in every respect except orientation (thus preserving many intrinsic stimulus properties), they are poorly perceived and recognised compared with their upright equivalents (e.g., Yin, 1969; Carey & Diamond, 1977; Valentine, 1988). Moreover, the disruption caused by inversion can be greater for faces than for other stimulus classes. It has often been argued that inverted faces undergo less 'configural' processing than upright faces (e.g., Carey & Diamond, 1977; see also Valentine, 1988, for review of face inversion effects). If interference from the critical famous face distractor is unaffected by adding an inverted face distractor, this would provide additional support for the claim that only another intact (upright) face can dilute interference from an incongruent famous distractor face. On the other hand, if an inverted face can also disrupt processing of the critical distractor face, this position would be weakened considerably.

Method

Subjects and Apparatus 26 new subjects (15 female) from University College London, whose ages ranged from 18-30 years, were paid £3 for participating in the experiment. All had normal or corrected vision by self-report and recognised the famous faces they were to encounter in the experiment. The apparatus was the same as for Experiment 1.

Stimuli and Procedure The stimuli and procedure were identical to those of Experiment 1 except for the following changes (see Figure 2.2). The set of scrambled faces was replaced by a set of inverted faces produced by rotating each of the intact anonymous faces through 180°. The original outlines of the famous, anonymous upright, and anonymous inverted faces were now all preserved (i.e. the images were no longer cropped). Consequently, the images were slightly larger than those used in Experiment 1; height was fixed at 3.5 cm (3.3° of visual angle), and width varied slightly between images (2.6-3.0 cm; 2.5°-2.9° of visual angle). Each target-plus-flanker(s) display occupied an imaginary rectangle measuring 11.8 cm x 3.5 cm (11.1° x 3.3° of visual angle). As in Experiment 1, the nearest distractor contours were 1.2 cm (1.1° of visual angle) away from the target name. Following an example block of 12 trials and a practice block of 72 trials, subjects completed seven experimental blocks of 72 trials.

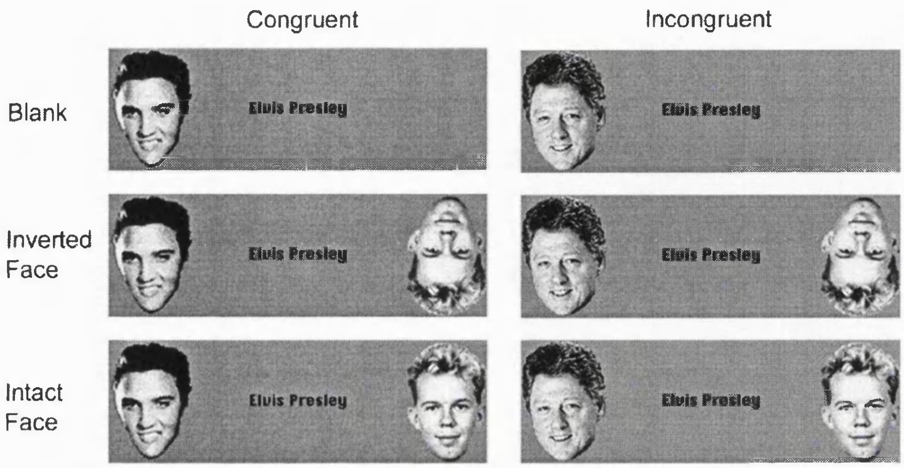

Figure 2.2 Example displays from the six conditions of Experiment 2. The critical distractor face could be either *Congruent* (left column) or *Incongruent* (right column) with the target name, and was presented alone (*Blank* condition; top row), accompanied by a inverted anonymous face (*Inverted* condition; middle row), or accompanied by an intact anonymous face (*Intact* condition; bottom row).

Results

RTs Incorrect responses and RTs exceeding 2 sec (less than 2% of the correct responses) were excluded from the RT analysis. The mean RTs and error rates across subjects are shown in Table 2.2 as a function of the experimental conditions.

Table 2.2 Mean Reaction Times (in msec) and Error Rate (%) across Subjects (n=26) as a Function of Distractor Congruency and Neutral Flanker Type in Experiment 2.

	Distractor congruency				Effect size	
	I		*C*		I-C	
Neutral flanker	RT	%E	RT	%E	RT	%E
Blank	530	22	491	19	39	3
Inverted	533	21	503	20	30	1
Intact	520	20	514	21	6	-1

Note. *I* = Incongruent; *C* = Congruent.

A two-way within-subjects ANOVA [display type (3) x congruency (2)] on the RT data showed a main effect of congruency [$F(1,25)=17.2$, $p < .01$], with slower responses to incongruent trials than to congruent trials, as in Experiment 1. As before, there was no main effect of display type [$F < 1$]. More importantly, the main effect of congruency was again qualified by an interaction with display type [$F(2,50)=3.8$, $p < .05$]. As can be seen from Table 2.2, although the critical famous-face distractors produced congruency effects when they appeared alone [$t(1,25)=12.3$, $p < .01$] or when accompanied by an anonymous inverted face [$t(1,25)=16.0$, $p < .01$], there was no congruency effect when an upright anonymous face was added [$t < 1$]. There was no significant difference in congruency effects between trials containing an inverted face and trials containing no additional flanker [$t < 1$]. An intact face (upright anonymous) produced significant dilution relative to each of the latter two conditions ([$t(1,25)=2.02$, $p < .05$] and [$t(1,25)=2.12$, $p < 0.5$] respectively).

Errors The error rates were analysed in the same way as the RTs. A two-way ANOVA found a main effect of congruency [$F(1,25)=4.51$, $p < .05$], but no effect of display type [$F < 1$]. More importantly there was again a significant interaction between congruency and display type [$F(2,50)=5.71$, $p < .01$]. Similarly to the distractor effects found on RTs, the error rates showed distractor effects in the *Blank* condition [$t(1,25)=16$, $p < .01$], which were significantly reduced by the addition of an upright anonymous face [$t(1,25)=3.98$, $p < .01$].

Discussion

This study replicated the important aspects of Experiment 1, and extended the point that only intact (upright) faces dilute the impact of the famous face. Once again, there was an effect of critical distractor congruency when the famous face was the only distractor present. This effect was significantly diluted by the addition of an intact anonymous face, but not by the addition of an inverted anonymous face, even though the latter is similar to the intact face in all aspects except for the ease of face perception (and probably the extent of 'configural' processing; e.g., Carey & Diamond, 1977; Valentine, 1988). The results are thus consistent with the claim that only another intact, upright face can dilute interference from an irrelevant distractor face. However, one potential criticism of Experiments 1 & 2 is that they both compared dilution effects from meaningful stimuli (i.e. intact faces) against dilution effects from relatively meaningless stimuli (i.e. scrambled or inverted faces). It may be that the intact faces produced more dilution than scrambled or inverted faces simply because they are more meaningful stimuli. This possibility is examined in the next chapter.

Chapter 3

Dilution Of Response-Competition Effects With Meaningful Objects: Testing Face Specificity

Introduction

The experiments in Chapter 2 demonstrated that face-name interference can be significantly diluted by the presence of another intact face, but not by a scrambled face or an inverted face. This finding suggests that the interference produced by a single distractor face is not solely due to the power of an isolated peripheral distractor to summon attention to its location (cf. Kahneman & Chajczyk, 1983; Yantis & Jonides, 1984). If it had been, <u>any</u> additional item with sufficient stimulus energy ought to have eliminated the interference effect, yet scrambled or inverted faces produced no significant dilution when added to the critical distractor. On their own, however, the first two experiments provide only preliminary support for any suggestions that irrelevant distractor faces may be <u>particularly</u> difficult to ignore, with interference from them only being diluted by adding another distractor from the same special stimulus class of faces. It might be instead that intact faces were more effective in diluting the effects of the critical distractor simply because they are more meaningful objects than scrambled or inverted faces. The choice of nonface stimuli (i.e. the scrambled or inverted stimuli) in the previous experiments was constrained by the desire to match faces and nonfaces in terms of low-level visual energies and features. Having established that such low-level properties are not the critical determinant of the observed dilution, any possible influence of 'meaningfulness' may now be isolated, by using meaningful nonface objects as the additional flankers, with less concern over equating low-level visual properties. As before, subjects performed a famous name categorization task (pop-stars versus politicians) while trying to ignore a critical famous face distractor. Now however, any further flanker in addition to the critical famous face was either an anonymous intact face, or a meaningful nonface object (e.g., a musical instrument or a fruit). If the processing of an irrelevant distractor face can be disrupted by the presence of any additional item, provided it is meaningful, then interference effects from the critical distractor face should be eliminated by either an additional intact face, or by an additional meaningful nonface object in the display. Alternatively, if the processing of one famous face can only be disrupted by the presence of another face, then interference effects from the famous face should be observed even when a meaningful nonface object is also present.

Experiment 3

The purpose of Experiment 3 was to compare interference effects from a critical famous face distractor in the presence of either: i) another intact face, or ii) a meaningful nonface object. As mentioned in the introduction to this chapter, although the 'nonface' stimuli used in the previous chapter (scrambled faces in Experiment 1, and inverted faces in Experiment 2) controlled for most low-level visual properties of the intact faces, they did not control for their 'meaningfulness' (nor for the good perception of structure). Thus it remains possible that interference effects from an irrelevant famous distractor face could be as weak in the presence of any meaningful object (with well-perceived structure) as in the presence of another intact face. The current experiment addresses this possibility by using meaningful nonface objects (e.g., musical instruments and fruits) as nonface controls. If the observed differences in dilution between intact faces, versus their scrambled or inverted counterparts, merely reflects a difference in their respective degrees of 'meaningfulness' (or well-perceived structure), then interference from a critical famous face distractor should be equally diluted, whether the additional distractor is another meaningful face or a meaningful nonface object. On the other hand, if only intact faces can disrupt the processing of other intact faces, then interference effects should be significantly smaller in the presence of an additional intact face than in the presence of a meaningful nonface object (e.g., pictures of other types of object, such as fruits or musical instruments).

Method

Subjects The 30 new subjects (20 female) were paid volunteers from University College London whose ages ranged from 18-26 years. All reported normal or corrected vision and recognized the famous faces they were to encounter in the experiment. The apparatus was the same as for Experiments 1 & 2.

Stimuli and Procedure The stimuli and procedure were the same as for Experiment 2 except for the following changes. The set of 12 inverted faces was replaced by a set of meaningful photographed objects (6 items of fruit and vegetables, and 6 musical instruments). By analogy with the anonymous faces of the previous studies, the objects were intended to be difficult to name (e.g., rambutan, durian, zither, dulcimer), while remaining easy to categorize at the basic level. Each block of 72 trials was composed of 36 displays with a nonface object as the additional flanker, and 36 displays with an upright anonymous face as the additional flanker, in a randomly intermixed sequence.

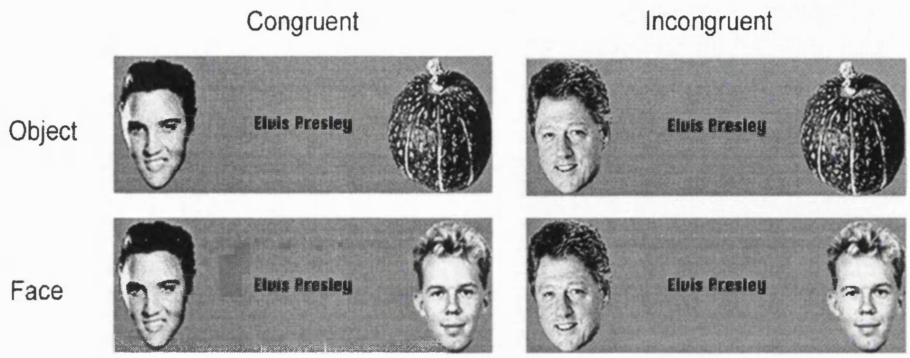

Figure 3.1 Example displays from the four conditions of Experiment 3. The critical distractor face could be either *Congruent* (left column) or *Incongruent* (right column) with the target name, and was accompanied by either a nonface object (*Object* condition; top row) or an intact anonymous face (*Face* condition; bottom row).

Results

As for the previous experiments, incorrect responses and RTs exceeding 2 sec (less than 2% of the correct responses) were filtered from the RT data. Data from one subject whose error rate was 23% (more than 2 SD from the group mean) were also excluded from the analyses. The RTs and error rates (averaged across subjects) for each level of congruency and display type are shown in Table 3.1.

Table 3.1 Mean Reaction Times (in msec) and Error Rate (%) across Subjects (n=29) as a Function of Distractor Congruency and Neutral Flanker Type in Experiment 3.

	Distractor congruency				Effect size	
	I		*C*		I-C	
Neutral flanker	RT	%E	RT	%E	RT	%E
Object	482	12	443	8	39	4
Face	470	10	446	8	24	2

Note. *I* = Incongruent; *C* = Congruent.

RTs A two-way ANOVA [congruency (2) x display type (2)] on the RT data found a main effect of congruency [$F(1,28)=40.65$, $p < .01$], with faster responses to congruent displays. Once again, there was no main effect of display type ($F < 1$), but the main effect of congruency was again modified by a significant interaction with display type [$F(1,28)=3.34$, $p < .05$]. As can be seen from Table 3.1, although some congruency effect was found for both types of additional flanker ([$t(1,28)=4.31$, $p < .01$] for faces; [$t(1,28)=5.25$, $p < .01$] for objects), this effect was significantly smaller in trials containing an anonymous face as the additional distractor than in trials containing a meaningful nonface object [$t(1,28)=1.83$, $p < .05$].

Errors Comparable analyses of the error data revealed a main effect of congruency [$F(1,28)=26.49$, $p < .01$], with a higher error rate for incongruent trials than for congruent trials. There was also a main effect of display type [$F(1,28)=3.45$, $p < .05$], and an interaction between congruency and display type [$F(1,28)=3.66$, $p < .05$]. This interaction had a similar pattern to that found in the RT data; congruency had a significant effect on error rates for both types of additional flanker ([$t(1,28)=2.00$, $p < .05$] for faces; [$t(1,28)=4.31$, $p < .05$] for objects), but the congruency effect was significantly smaller in the added face condition than in the added object condition [$t(1,28)=3.45$, $p < .05$].

Discussion

The addition of an irrelevant anonymous face to the display again caused a significant reduction in interference from the critical distractor face, now relative to the addition of an irrelevant meaningful nonface object. This reduction was observed in both the RT data and the error data. These findings replicate the important aspects of Experiments 1 & 2, and lend further support to the claim that interference effects from an irrelevant famous distractor face can only be reduced by adding another intact face to the display. Moreover, since the nonface controls were now meaningful objects with perceivable structure (cf. Experiments 1 & 2 in which scrambled and inverted faces were used as 'nonface' controls), the present study rules out the possibility that the previously observed differences in dilution between intact faces and their nonface controls merely reflect a difference between their respective degrees of meaningfulness (and/or perceivable structure).

Experiment 4

The preceding experiments showed that interference from a critical famous distractor face can be diluted by the addition of another intact upright face to the display, but is not significantly affected by the addition of other types of object to the display (scrambled faces in Experiment 1, or inverted faces in Experiment 2). Indeed, dilution by intact anonymous faces has even been shown relative to a condition in which meaningful nonface objects, with readily perceived structure, were presented as additional distractors (e.g., musical instruments or fruits; Experiment 3). These results for interference from famous faces appear to contrast with Kahneman & Chajczyk's (1983) results for interference from distractor words, where the interference in a color-naming task was diluted by the addition of any other object to the array.

This apparent contrast between the present results for faces, and Kahneman & Chajczyk's results for words, may suggest that distractor faces are a 'special' class of stimuli for attention. However, Kahneman & Chajczyk's study differed in several ways from the present study. For instance, the different outcomes might reflect a difference between photographed 3D stimuli in general versus 2D printed words as distractors, rather than specifically between faces versus words. Accordingly, the next experiment examined interference from photographed 3D nonface objects when their categories became task-relevant. The purpose was to test whether interference from a critical nonface distractor object (e.g., a musical instrument or a fruit) can be diluted by an additional nonface object (e.g., a scrambled face), even though interference from a critical distractor face can not (as shown in Experiment 1). Such an asymmetry would imply that distractor faces may indeed be 'special' in some sense.

Participants were now asked to categorize printed object names, as fruits versus musical instruments, while again trying to ignore irrelevant flanking distractor photographs. The critical distractor and target could either be congruent (e.g., a photograph of a piano used for the distractor and the word "piano" used for the printed central target) or incongruent (e.g., a photograph of an apple with "piano" as the target name). The displays could either contain: i) no other flanker (in the *Blank* condition); ii) an additional intact (anonymous) face flanker (*Intact* face condition); or iii) an additional scrambled face flanker (*Scrambled* face condition). If response-competition effects from photographed nonface distractor objects can be diluted by any other object regardless of its nature (as is apparently the case for distractor words; Kahneman & Chajczyk, 1983), then any congruency effect in the *Blank* condition should be significantly diluted, not only by the addition of an intact face, but also by the addition of a scrambled face (and to an equivalent extent). Note that such a result would differ from that found for congruency effects from famous faces, where any dilution was highly specific to adding an intact face (see Chapter 2). If congruency effects from nonface objects are only diluted by objects of a similar type, then no dilution should be caused by adding either an intact or a scrambled face. Finally, if distractor faces are always more disruptive to the processing of any other distractors, regardless of the task, then adding an intact face should again produce more dilution than the scrambled face.

Method

Subjects and Apparatus The 25 new subjects (15 female) were paid volunteers from University College London in the age range of 18-30, who reported normal or corrected vision. All subjects were able to name the photographed fruits and musical instruments they were to encounter in the experiment. The apparatus was the same as for the previous experiments.

Stimuli and Procedure The stimuli and procedure were the same as in Experiment 1 except for the following changes. The target set now consisted of 12 common object words. 6 were names of musical instruments (Accordion, Drums, Guitar, Piano, Saxophone, and Violin), and 6 were names of fruits (Apple, Bananas, Orange, Pear, Pineapple, and Strawberry). As in the previous experiments, target words were presented in black 12 point Arial font with all letters except the first in lower case. The shortest name was 1.1 cm wide (subtending a visual angle of 1.1°) and the longest 2.7 cm (2.6° of visual angle). The critical distractors were photographic greyscale images of the twelve objects whose names served as targets. These object images measured between 1.8 cm and 2.8 cm horizontally and 2.8 cm vertically (1.7°-2.7° x 2.7° of visual angle). As in Experiment 1, there were three display types. The target and critical distractor could appear: i) unaccompanied (*Blank* condition); ii) accompanied by an intact flanker face (*Intact* face condition); or iii) accompanied by a scrambled face flanker (*Scrambled* face condition). The additional flankers were the 12 intact anonymous faces and 12 scrambled anonymous faces of Experiment 1. Again, each target-plus-flanker(s) display occupied an imaginary rectangle measuring 10.3 cm x 2.8 cm (9.7° x 2.7° of visual angle), and the nearest distractor contours were 1.2 cm (1.1° of visual angle) away from the central target name. Following an example block of 12 trials and a practice block of 72 trials, subjects completed seven blocks of 72 trials.

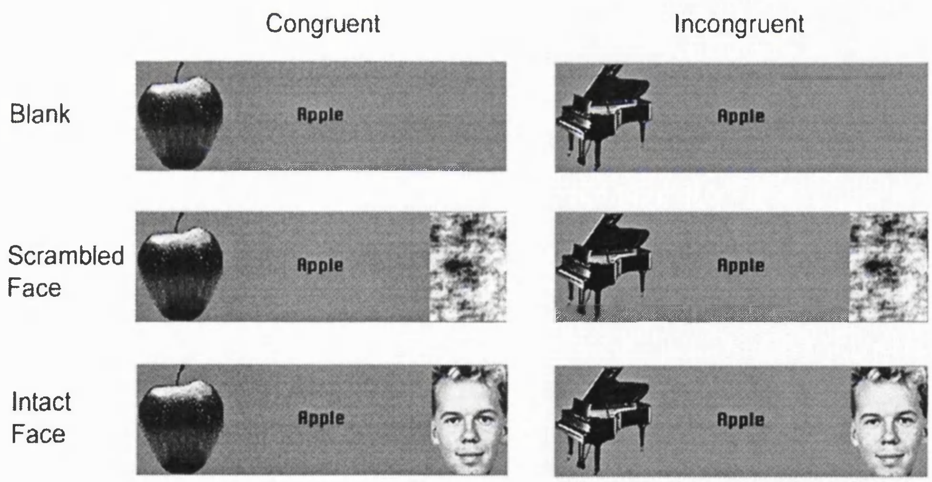

Figure 3.2 Example displays from the six conditions of Experiment 4. The critical distractor object could be either *Congruent* (left column) or *Incongruent* (right column) with the target word, and was presented alone (*Blank* condition; top row), accompanied by a scrambled anonymous face (*Scrambled* condition; middle row), or accompanied by an intact anonymous face (*Intact* condition; bottom row).

Results

Table 3.2 shows the intersubject means for correct RTs and error rates for each level of critical distractor congruency and additional flanker type. Once again, incorrect responses and RTs exceeding 2 sec (less than 2% of the correct responses) were excluded from the RT data. Data from one subject whose error rate was 34% (2.9 SD from the group mean) were also excluded from the analyses.

Table 3.2 Mean Reaction Times (in msec) and Error Rate (%) across Subjects (n=24) as a Function of Distractor Congruency and Neutral Flanker Type in Experiment 4.

	Distractor congruency				Effect size	
	I		*C*		I-C	
Neutral flanker	RT	%E	RT	%E	RT	%E
Blank	416	12	363	8	53	4
Scrambled	400	11	374	8	26	3
Intact	401	10	368	7	33	3

Note. *I* = Incongruent; *C* = Congruent.

RTs As in the previous experiments, a two-way ANOVA [congruency (2) x display type (3)] on the mean RT data found a main effect of congruency [$F(1,23)=39.25$, $p < .01$], with slower responses to incongruent displays, but no main effect of display type [$F < 1$]. Once again, the main effect of congruency was modified by an interaction between congruency and display type [$F(2,46)=3.65$, $p < .05$]. Planned comparisons on this interaction reveal that although the congruency effect was significant in each of the conditions ($p < .01$ in all cases) it was significantly smaller when either an intact or a scrambled anonymous face was added to the display than when no additional flanker was added ([$t(1,23)=2.29$, $p < .05$] and [$t(1,23)=2.73$, $p < .05$] respectively).

Furthermore, the congruency effects in the *Scrambled* face and *Intact* face conditions were not significantly different from each other [$t < 1$].

Errors Similar analyses of the error rates found only a main effect of congruency [$F(1,23)=22.39$, $p < .01$]. There were no other effects in the analysis of error rates ($p > .10$ for all), but note that any numerical trend is for a larger congruency effect in the *Blank* condition, in agreement with the RT pattern.

Note that this pattern of dilution is qualitatively different from that seen in the preceding experiments. As before, interference from the critical distractor (now a nonface object) was significantly reduced by adding an intact anonymous face to the display; but for the first time, the addition of a nonface (i.e. scrambled) flanker also produced significant dilution, and to an equivalent extent. This pattern of comparable dilution by any additional stimulus is consistent with that found for colour-word interference by Kahneman & Chajczyk (1983), but contrasts with the pattern for face-name interference observed in Experiments 1-3 above.

Discussion

Experiments 1-3 sought to determine the conditions under which an irrelevant but famous face can be successfully ignored, eliminating interference effects on response to a central name, caused by the identity (and occupation) of that famous face. These experiments confirmed that an irrelevant photographed face in the periphery produces response-competition effects in a task (similar to Young et al., 1986) requiring the categorizing of famous names, despite a clear spatial separation between the central name and the peripheral face. These distractor effects from famous faces could only be diluted by the addition of an intact face to the display, which consistently reduced interference, relative to any other conditions that were tested (a *Blank* condition in Experiments 1 & 2; a *Scrambled* face condition in Experiment 1; an *Inverted* face condition in Experiment 2; and a meaningful nonface *Object* condition in Experiment 3). By contrast, in Experiment 4, response competition from an irrelevant photographed object (e.g., a fruit) in a categorization task for object names (i.e. classifying words as fruits versus musical instruments) could be diluted not only by the addition of a distractor face, but also by a scrambled face (and to the same extent). The results for object interference in Experiment 4 thus differ from those found for face interference in Experiments 1-3, but accord with previous findings (Kahneman & Chajczyk, 1983) that interference from distractor words can similarly be diluted by adding any object to the display, even a nonsense stimulus. Thus while distractor interference from nonface stimuli such as words and other objects (e.g., fruits and musical instruments in Experiment 4) can apparently be diluted by the addition of any visual stimulus, interference from famous distractor faces can only be diluted by the addition of another intact (upright) face to the display.

These results have several implications. Although face identification may be 'automatic' in the sense that it may arise involuntarily for a single famous distractor face (Young et al., 1986), such processing is evidently not capacity-free, as adding a second (anonymous) face can dilute the effect of the famous face. Moreover, this capacity limit for faces seems more specific than for other classes of objects, whose interference may be diluted by adding any type of object to the display, whereas only another intact face can dilute the effect of a famous face.

One way to explain this difference between dilution of face interference, versus dilution of interference from other types of distractor, would be to argue that faces are particularly strong competitors for attention compared with other stimulus classes (see Ro et al., 2000 for a similar claim). If so, the famous face would inevitably prove distracting when competing against another type of nonface object, only another intact face being able to compete on equal terms against it. On this view, face processing may only be disrupted by another face because faces are particularly distracting stimuli.

One aspect of the current results, however, may appear somewhat inconsistent with any simple generalization that faces are always more powerful distractors than other classes of stimuli. In Experiment 4, an intact face produced no more dilution than a scrambled face, upon interference from a critical nonface object. It thus appears that while an added intact face produces some special diluting effect upon interference from another face, it may not do so for interference from a nonface object. This could be explained by supposing that the capacity limits revealed by the dilution of interference from famous faces are category-specific. If interference due to the identity of a famous face depends on truly face-specific processes, then only an additional face will load that process. (For instance, a neural system which responded only to faces would be unaffected by adding a nonface object). Viewed from this perspective, the present results provide psychological evidence that may converge with recent proposals in neuroscience and neuropsychology for face-specific processes (e.g., Farah, 1995; Kanwisher, 2000; Farah, 1995; Farah, Levinson & Klein, 1995; Farah, Wilson, Drain & Tanaka, 1995; Kanwisher et al., 1997). The fact that dilution effects for interference from distractor words (Kahneman & Chajczyk, 1983) and distractor objects (Experiment 4) appear less specific to the type of added stimulus implies that limits in their processing depend less on specific capacities, and more on general capacity, than for the identification of faces. This interpretation of the experiments would thus support the idea that face-processing is conducted by a dedicated face-processing system (or systems) with its own capacity limits, so that interference from a distracting famous face will be particularly difficult to eliminate unless other faces are present.

An alternative interpretation would agree that faces have category-specific capacity limits, but could suggest that the same might apply to nonface objects also, which may rely on their own specific capacities. This may at first seem inconsistent with the finding that nonface object interference can be diluted equivalently by adding a face or a scrambled face to the display (Experiment 4). However, it could be that the scrambled stimulus produces dilution by tapping capacity from some specialized nonface object system, whereas an intact face produces dilution of object interference for other reasons (e.g., because faces are particularly potent distractors). Later chapters in this thesis return to this issue.

Chapter 4

Dilution Of Long-Term Incidental Memory For Distractor Faces By Additional Distractors

Introduction

In the preceding empirical chapters, I presented evidence from response-competition experiments (i.e. experiments concerning distractor interference on response to concurrent targets) suggesting that the processing of distractor faces may be subject to somewhat different principles than the processing of nonface distractor objects. Specifically, the processing of distractor faces may suffer primarily from face-specific capacity limits; that is, only adding an additional face may dilute interference effects from distractor faces.

However, these experiments remain open to two potential criticisms that stem from an unavoidable characteristic of the response-competition task. In order for response-competition effects to arise, the distractor stimuli must be either congruent or incongruent with the target response. For example, if the relevant task is to categorize a printed famous name as a pop-star's or a politician's, the critical distractor must also belong to one of those categories. In this sense, the critical distractor in a response-competition paradigm can never be entirely irrelevant and unrelated to the central task. Thus it may be that subjects processed distractors which interfered, even though the task could in principle be performed without processing them, only because they were related to the relevant task. This raises the possibility that irrelevant distractor faces might be successfully ignored, even in the absence of any additional distractor, if they were entirely unrelated to the target (i.e. neither congruent nor incongruent with the target).

A second shortcoming of the previous experiments is that they could only address the issue of distractor processing for famous faces (e.g., Elvis Presley's face), at the level of activating an occupational response-category. Thus it may be that the interfering faces in the preceding experiments were particularly difficult to ignore not simply because they were faces, but because they were famous, as well as being related to the name classification task (although note that additional anonymous faces did produce dilution of interference from famous faces).

In view of these shortcomings, I next sought a means by which to assess the processing of distractor faces that were completely unrelated to the relevant task and were also unknown (i.e. anonymous faces). To this end, anonymous faces were presented inside a coloured frame, while subjects performed a colour categorization task on the frame. Any processing of these completely task-irrelevant anonymous distractor faces was assessed at the end of the experiment using a surprise recognition test. Recognition memory for faces has traditionally been claimed to be particularly good compared with that for other classes of stimuli (although see Hancock et al., 2000). For example, Goldstein & Chance (1971) compared recognition memory for three classes of stimuli - faces, inkblots, and snow crystals. They found that faces were recognized best, although the visual differences in discriminability between these three types of stimuli make direct between-classes comparisons difficult to interpret. Yin (1969) compared the ease of recognizing pictures of faces with pictures of houses, aeroplanes, and schematic men in motion, finding that face recognition was far more accurate than recognition of any of the other classes of stimuli. Similarly, Scapinello & Yarmey (1970) found that faces were better recognized than pictures of dogs or buildings. However, in all these previous studies on recognition memory for faces, the faces were fully attended at exposure. The purpose of the present chapter was to investigate incidental recognition performance for faces versus nonface objects, when the stimuli were completely irrelevant to the target task, and as a function of the presence of additional distractor items. Of specific interest was whether recognition memory for anonymous faces would suffer from the presence of another face or nonface object in the encoding display, by analogy with the 'dilution' of on-line distractor effects by additional items in Chapters 2 & 3.

Note that in addition to its theoretical interest, examining incidental recognition memory for task-irrelevant faces as a function of distractor load may also be of practical interest, for example in assessing the reliability of eyewitness testimony. Police often make public appeals for witnesses who may have seen a criminal, even briefly, and may ask eyewitnesses to try to identify the criminal either from photographs or from an identity parade. Moreover, in numerous legal cases, juries have convicted a suspect even when eyewitness identification is the only evidence of a suspect's guilt (e.g., Devlin, 1976; Wells & Loftus, 1984). This suggests that enormous weight can be given to the testimony of an eyewitness. However, in spite of evidence from numerous studies that the recognition memory for unfamiliar faces can be reliable in laboratory settings (e.g., Goldstein & Chance, 1971; Scapinello & Yarmey, 1970; but see Hancock et al., 2000), eyewitness identification is often far from infallible in practice (Devlin, 1976; Egeth, 1993; Wells, 1993; Hancock et al., 2000; Wells & Loftus, 1984). Given the substantial differences in viewing conditions that typify laboratory experiments versus real-world eyewitnessing, such differences in viewers' recognition performance may not be surprising. In a typical face recognition experiment, subjects study a series of faces, knowing that they must later select, from a longer series of faces, the faces they had originally studied. Observers are thus not only motivated to memorize the faces, but may also view each one without concurrent distractions. On the other hand, an eyewitness may be called upon to identify a face that was originally seen under far less favourable attentional conditions (Devlin, 1976). For example, a witness who had the criminal's face in front of their eyes, but did not see the crime in progress, may have had little incentive to memorize the criminal's face, or even to pay any attention to it at all, especially in the presence of many other potential distractors. Moreover, even in cases where the witness is also a victim, it is possible that little attention may be paid to the criminal's face itself. Instead, as a result of potential threats in the situation, the victim may focus attention on a weapon or some other detail (Clifford & Bull, 1978; Loftus, 1979). Despite these concerns, the role of attention and distractor load in incidental memory for faces has largely been overlooked. The following experiments should provide some insight into this important issue, by examining incidental memory for unfamiliar faces that were entirely irrelevant at the time of exposure, and which appeared either in cluttered or uncluttered displays (i.e. with versus without another, potentially 'diluting' distractor that could increase perceptual load at the time of exposure).

Experiment 5

Experiment 5 examined the effect of perceptual clutter at the time of exposure on subsequent incidental memory for anonymous faces that were completely irrelevant to the ongoing task when exposed. The subjects' task was to discriminate between two possible colours of a rectangular frame, while ignoring any stimuli presented inside the frame. The frame always contained an irrelevant anonymous face which could appear alone (*Blank* condition), accompanied by a nonface object such as a butterfly or a leaf (*Object*-diluter condition), or accompanied by a different anonymous face (*Face*-diluter condition). Note that the use of butterflies and leaves as nonface objects was intended to roughly match several characteristics of the anonymous faces; both the face and the nonface object categories were drawn from two visually discernable subcategories (male vs. female and butterfly vs. leaf) and were composed of unique, animate, 'anonymous' members.

At the end of the experiment, subjects were given a surprise recognition test for the faces that had been presented during the preceding colour task. If subjects fail to exclude an irrelevant face in the display from processing even when it is anonymous and completely unrelated to the relevant task, then faces from the *Blank* condition should be recognized relatively well. If the laying down of memory traces for task-irrelevant faces (or their subsequent retrieval) can be disrupted by any type of additional clutter in the exposure display, then recognition performance should be poorer for faces presented alongside another stimulus, as in the *Object*-diluter and *Face*-diluter conditions. Finally, if recognition memory for newly exposed faces can only be disrupted by the presence of another face at exposure, then recognition performance should be equivalent for faces from the *Blank* and *Object*-diluter conditions, and poorer for faces from the *Face*-diluter condition.

Method

Subjects and Apparatus 12 new undergraduate volunteers from University College London, whose ages ranged from 19 to 26, were paid £4 to participate in the experiment. All had normal or corrected vision. The apparatus was the same as for the preceding experiments.

Stimuli The stimuli in the colour task were composed of an anonymous face presented to the left or right of fixation, inside a central coloured frame. As can be seen in Figure 4.1, the opposite side of the frame was equally likely to be blank (in the *Blank* condition), to contain a nonface object (in the *Object*-diluter condition), or to contain another anonymous face (in the *Face*-diluter condition). The frame measured 6.0 cm horizontally and 3.4 cm vertically (corresponding to 5.7° x 3.2° of visual angle at the viewing distance of 60 cm), and was equally likely to be red or blue. The face and nonface stimuli were all photographic greyscale images measuring between 2.2 cm and 2.8 cm horizontally (2.1-2.7°) and 3.2 cm vertically (3.1°), and were positioned inside the frame as far laterally from fixation as possible. Six sets of 12 anonymous faces (6 male, 6 female, within each set) were used in total. One (different) set was exposed in each of the *Blank* and *Object*-diluter conditions (i.e. two sets in total), and two other sets were used in the *Face*-diluter condition (since each display in the *Face*-diluter condition contained two faces rather than just one). The remaining two sets presented as new faces (i.e. foils) in the surprise recognition test. The 12 nonface objects used in the *Object* condition were 6 butterflies and 6 leaves.

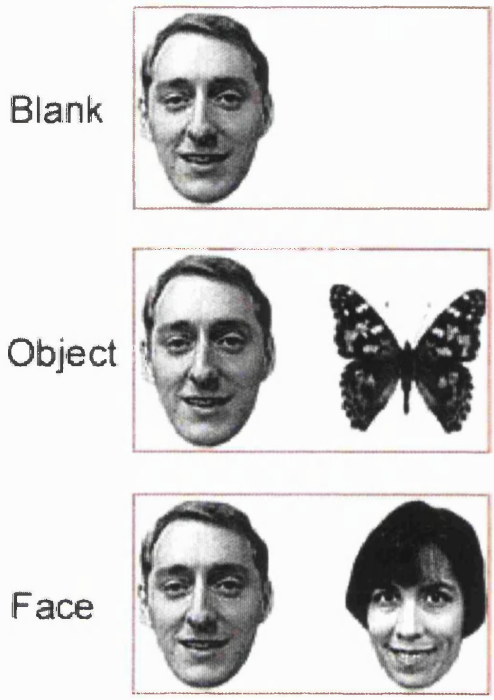

Figure 4.1 Example displays from the three conditions of Experiment 5. In the colour discrimination task, irrelevant and anonymous faces were presented alone (*Blank* condition; top), accompanied by an irrelevant nonface object (*Object*-diluter condition; middle row), or accompanied by another irrelevant anonymous face (*Face*-diluter condition; bottom row). N.B. Each subject saw any particular face in only one of these three experimental conditions; see main text for details of counterbalancing.

For each subject, any given face appeared in the same display condition and the same side of the display each time it was presented. This was to allow incidental memory to be compared for particular faces that had been presented in just one of the display conditions (*Blank*, *Object* or *Face*), and on either side of the display (left or right). However, between subjects, the face sets were counterbalanced across the display conditions, so that when pooling over subjects, each face appeared in all three conditions and on each side of the display an equal number of times, and was equally likely to appear as a memory foil or a target. Presenting each face inside a red frame and a blue frame resulted in a total of 72 possible displays per subject (24 displays per condition).

Procedure Each trial began with a fixation point at the centre of the screen for 500 msec. This was followed by a display composed of a coloured frame plus distractor(s) for 200 msec (i.e. too brief for a stimulus-responsive saccade to be initiated during the display). Subjects were asked to use the "3" and "." keys on the numeric pad to indicate as quickly and accurately as possible which of the two possible colours (red vs. blue) applied to the current rectangular frame, while ignoring the contents of the frame. No mention was made of the memory test to follow. After a short practice block of 12 trials in which empty frames were presented, each subject underwent 6 experimental blocks of 72 trials each in the colour discrimination task. All the display conditions were randomly intermixed within each block. Each of the 72 faces was thus presented 12 times in total. A surprise recognition test was administered immediately after completing all trials of the colour discrimination task. In the recognition test, subjects were presented with a face and were asked to judge whether or not it had been presented during the previous phase (old/new discrimination). Subjects were tested on all 72 faces (48 old, 24 new) in random order.

Results

The probability of responding "yes" to a face in the recognition task was calculated for each subject as a function of the display condition. The intersubject means of these probabilities (or proportions) for each display condition were 0.47 in the *Blank* condition, 0.45 in the *Object*-diluter condition, 0.37 in the *Face*-diluter condition, and 0.32 for new (foil) faces (see Figure 4.2).

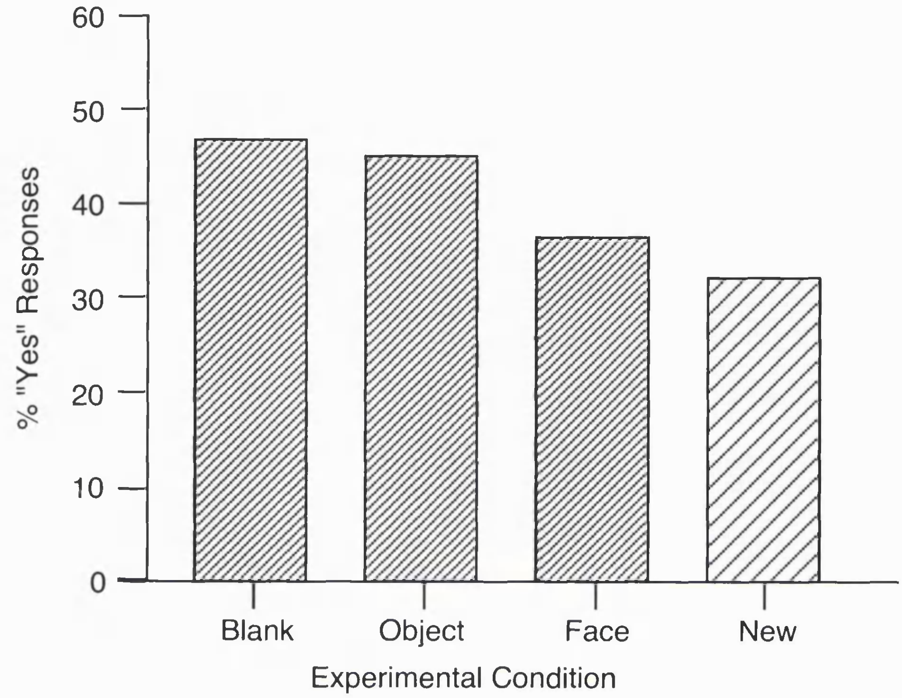

Figure 4.2 Mean percentage of "yes" responses (n=12) in the surprise recognition test for faces in Experiment 5. Memory performance is shown as a function of experimental condition; *Blank*, *Object*-diluter, *Face*-diluter, or *New* (foils).

A one-way ANOVA on these data revealed a significant effect of experimental condition [$F(3,44)=2.88$, $p < .05$]. Planned comparisons showed that, in accordance with the predictions, the probability of responding "yes" was equivalent for faces from the *Blank* and *Object*-diluter conditions [$t < 1$], and was significantly higher for both these conditions than for new (foil) faces ([$t(1,11)=3.00$, $p < .01$] and [$t(1,11)=2.75$, $p < .01$] respectively). By contrast, faces from the *Face*-diluter condition (all 24 of which were tested and analysed) were significantly less likely to be recognised than faces from either the *Blank* condition ([$t(1,11)=2.07$, $p < .04$] or the *Object*-diluter condition [$t(1,11)=1.77$, $p < .05$]. In fact, the difference between the probability of responding "yes" to a face from the *Face*-diluter condition and responding "yes" to a new face did not reach significance [$t(1,11)=1.46$, $p = .08$]. There were no significant effects of display side at exposure on incidental memory for faces ($p > .10$ for all comparisons).

Discussion

The results of Experiment 5 demonstrate that subjects fail to completely ignore a single face in the display even when it is anonymous and completely unrelated to the relevant task, in the sense that incidental memory for such faces can be formed. Moreover, they also show that incidental memory for an irrelevant face can be 'diluted' by the presence of an additional face in the initial display, but not by a meaningful nonface object (e.g., a butterfly or a leaf). These findings are analogous in some respects to the findings of Experiment 3, in which on-line response-competition effects from a distractor face (rather than memory effects, as here) were diluted by the presence of an additional face, but not by a meaningful nonface object. The present results may be taken to indicate that memory for faces might have capacity limits that may concern only faces. One possible reason for reduced memory for distractor faces when other faces were presented concurrently may be because of reduced perception for the face distractors when another is present. This interpretation would seem consistent with the results of Chapter 2. However, given that a memory measure was used here, it is also possible that interference between the faces occurred only at a later stage of processing (e.g., storage or retrieval), with such memory interference showing a degree of category specificity, or some 'similarity' gradient (Baddeley, 1997). The purpose of the following experiment was to examine whether the pattern of dilution found in recognition memory for task-irrelevant faces contrasts with any potential dilution of memory for task-irrelevant nonfaces.

Experiment 6

In the next study, I manipulated perceptual clutter in the initial displays and examined its effects on incidental memory for irrelevant nonface distractors. In order to establish a reasonably high level of incidental memory for the nonface objects, distinct items of household furniture (e.g., a lamp, a telephone, a wardrobe), rather than butterflies and leaves, were used as nonface objects. As in Experiment 5, these objects were presented either alone (*Blank* condition), accompanied by another nonface object (another household object; *Object*-diluter condition), or accompanied by an anonymous face (*Face*-diluter condition). If the processing of nonface objects is subject to general capacity limits, as Experiment 4 had suggested for on-line distractor interference effects, then it should be disrupted by any additional item in the display, even when highly dissimilar. On the other hand, if capacity limits for nonface object processing are category-specific (or similarity based), as may be the case for faces (Experiments 1-3, plus 5), then given that a face falls in a different category to household furniture (and also looks very different), memory for the nonface objects should not be diluted by the presence of an anonymous face in the initial display. Finally, if faces are particularly attention-capturing, they may produce greater dilution of nonface object memory than other nonface objects.

Method

Subjects and Apparatus 12 students from University College London were paid £4 to participate in the experiment. All reported normal or corrected vision and had not participated in the previous experiment. The apparatus was the same as for the preceding experiments.

Stimuli and Procedure The stimuli and procedure were the same as those of Experiment 5, except that each frame now contained an item of household furniture (e.g., a lamp or a wardrobe) rather than an anonymous face. As analogous to Experiment 5, this item could be presented alone (*Blank* condition), accompanied by another nonface object (i.e. another household object; *Object*-diluter condition), or accompanied by an anonymous face (*Face*-diluter condition; see Figure 4.3). The counterbalancing of the objects was similar to that for the faces in Experiment 5. Six sets of 12 household objects were used in total. One (different) set was exposed in each of the *Blank* and *Face*-diluter conditions (i.e. two sets in total), and two other sets were used in the *Object*-diluter condition (since each display in this condition contained two objects). The remaining two sets were presented as new objects (i.e. foils) in the surprise recognition test. 12 anonymous faces (6 male, 6 female) from Experiment 5 were used in the *Face* condition. Each object appeared in the same display condition and the same side of the display each time it was presented for a particular subject, so that incidental memory could be compared for objects from each display condition, and from each side of the display.

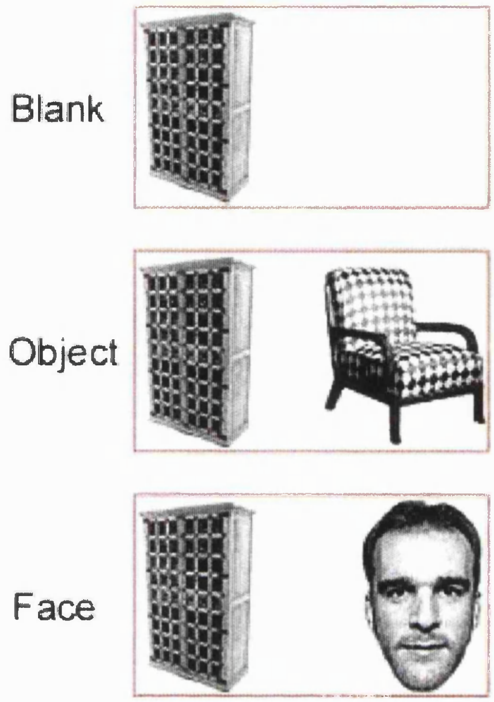

Figure 4.3 Example displays from the three conditions of Experiment 6. In the colour discrimination task (performed on the surrounding frame), irrelevant nonface objects were presented alone (*Blank* condition; top), or accompanied by another irrelevant nonface object (*Object*-diluter condition; middle row), or accompanied by an irrelevant anonymous face (*Face*-diluter condition; bottom row). N.B. Each subject saw any particular object in only one of these three experimental conditions; see main text for details of counterbalancing.

However, between subjects, the 12 sets of objects were counterbalanced fully across the display conditions, so that when pooling over subjects, each object appeared in all three conditions and on both sides of the display an equal number of times, and was equally likely to appear as a memory foil or a target. Presenting each object inside a red frame and a blue frame resulted in a total of 72 possible displays per subject (24 displays per condition). As in Experiment 5, subjects completed a short practice block followed by 6 intermixed experimental blocks of exposure. After the colour task, subjects were given a surprise memory test for the household objects, comprising 72 trials in a random order.

Results

As in Experiment 5, the probability of responding "yes" in the recognition task was calculated for each subject as a function of display condition. The intersubject means of these probabilities for each display condition were 0.56 in the *Blank* condition, 0.43 in the *Object*-diluter condition, 0.35 in the *Face*-diluter condition, and 0.16 for new objects (see Figure 4.4).

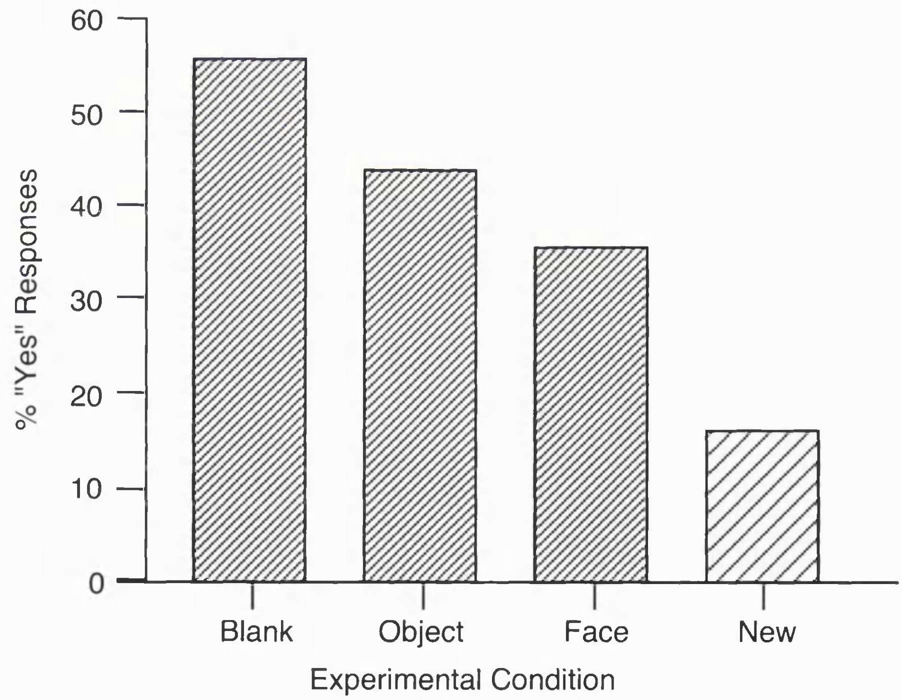

Figure 4.4 Mean percentage of "yes" responses (n=12) in the surprise recognition test for objects in Experiment 6. Memory performance is shown as a function of experimental condition; *Blank*, *Object*-diluter, *Face*-diluter, or *New* (foils).

A one-way ANOVA on the probability data revealed a significant effect of experimental condition [$F(3,44)=9.49$, $p < .01$]. Planned comparisons showed that, in contrast with Experiment 5, the probabilities for responding "yes" to target items from the *Object*-diluter and *Face*-diluter conditions were now both significantly lower than the probability of responding "yes" to an object from the *Blank* condition ([$t(1,11)=2.41$, $p < .02$] and [$t(1,11)=2.44$, $p < .02$] respectively), but were both significantly higher than for new (foil) items ([$t(1,11)=5.67$, $p < .001$] and [$t(1,11)=2.86$, $p < .01$] respectively). Although there was a small numerical trend towards greater dilution of object memory from additional faces than from additional objects, this trend did not approach statistical significance [$t(1,11)=1.20$, n.s.]. There were no significant effects of display side on incidental memory for the household objects ($p > .10$ for all comparisons).

Discussion

The results of Experiment 6 show a clear 'dilution effect' in memory for irrelevant nonface objects. Incidental memory was significantly reduced for irrelevant nonface objects that had appeared either next to an anonymous face, or next to another nonface object, relative to that for nonface objects presented alone. This finding contrasts with the findings of Experiment 5, in which memory for faces was diluted only by adding another face to the display, and not by an additional nonface object. Memory for nonface objects in the present experiment (e.g., a lamp, a wardrobe) could be diluted either by another nonface object (e.g., a telephone), or by a face, neither of which was visually similar to the target. This memory result is consistent with evidence from the response-competition paradigm (Experiment 4) that nonface object distractor processing can be disrupted by any additional item in the display, not just by an object from the same category, whereas effects from faces may only be diluted by an additional face.

It should be noted that there were substantially fewer false positives in the object task of Experiment 6 (16%) than in the face task of Experiment 5 (32%). This may be due to the greater similarity between different faces than between different household objects. Note however, that such differences in similarity cannot, on their own, explain all of the critical memory findings. Although the household objects were very different from the faces, in terms of their appearance, incidental memory for household objects could be disrupted by adding either an object or a face to the exposure display. By contrast, incidental memory for faces could only be disrupted by presenting another face concurrently. Taken together, the results from the recognition memory paradigm of this chapter provide a conceptual replication of the results from the on-line response-competition paradigm of Chapters 2 & 3, but now under conditions where the critical irrelevant faces were always unknown at exposure, and were completely unrelated to the relevant task (which was colour discrimination). Thus while processing of distractor faces seems to be disrupted only by cluttering the display with another face, processing of distractor nonface objects seems to be disrupted by any type of clutter in the display.

As well as their theoretical interest, these findings may also have implications for the practical issue of eyewitness testimony, as mentioned in the introduction to this chapter. Although incidental memory for unfamiliar faces may be less susceptible to disruption by general perceptual clutter (i.e. any type of additional distractor) than incidental memory for nonface objects, some aspects of the current findings nevertheless echo concerns that eyewitness identification may be less reliable than is commonly assumed (e.g., Devlin, 1976). First, the relatively low recognition rates in Experiment 5 suggest that incidental memory for task-irrelevant faces may be considerably less reliable than the high levels commonly claimed for wilfully attended faces (e.g., Goldstein & Chance, 1971; Scapinello & Yarmey, 1970; Yin, 1969), even for faces that were exposed 12 times, and in an uncluttered display. Thus, only 47% of the faces presented in the *Blank* condition of Experiment 5 were correctly recognized, compared with typical hit rates of up to 90% for attended faces in other studies (e.g., Hochberg & Galper, 1967). Second, when the exposure display contained an additional face (as in the *Face*-diluter condition of Experiment 5), the proportion of correct positive responses was reduced almost to the level of false positives to foils (.37 for old faces that had been presented next to another face, compared with .34 for new faces that had not been presented at all). This finding suggests that incidental memory for a visible face may be virtually eliminated by the presence of another face at the time of exposure, at least for the case of brief (albeit repeated) displays.

Chapter 5

Effects Of Relevant Perceptual Load On Long-Term Incidental Memory For Irrelevant Faces

Introduction

Chapters 2 to 4 demonstrated that interference from irrelevant distractor faces (Chapters 2 & 3), plus incidental memory for irrelevant faces (Chapter 4), could be diluted by adding an intact face to the display, but not by adding an additional nonface object (e.g., a scrambled face in Experiment 1; an inverted face in Experiment 2; a musical instrument or a fruit in Experiment 3; a household object in Experiment 5). Collectively, these findings suggest that, unlike effects from other distractor types (e.g., nonface object processing in Experiments 4 & 6; or word processing in Kahneman & Chajczyk, 1983), irrelevant face processing may be relatively impervious to clutter from additional objects of a different type in the display, and thus may be particularly difficult to disrupt unless another face is present.

These apparently face-specific dilution effects appear consistent with the possibility that face processing may suffer only from face-specific capacity limits, and raise the question of whether irrelevant face processing can ever be disrupted by increasing processing load with <u>nonface</u> material. However, the preceding chapters have only considered disruption by an additional <u>distractor</u> in the display. In other words, they have only manipulated task-<u>irrelevant</u> load. They have not examined the effect of task-<u>relevant</u> load on irrelevant face processing. It is thus possible that even nonface stimuli might be capable of disrupting processing of an irrelevant distractor face, as long as they are relevant in terms of the current task. Such a finding would be consistent with Lavie's perceptual load theory of selective attention (Lavie, 1995, 2000), which holds that distractor processing is dependent on the level of <u>relevant</u> perceptual load.

As described in Chapter 1, Lavie (1995) proposes that perception does involve capacity limits, but proceeds automatically within those limits. Thus, the extent to which irrelevant processing takes place may be strongly influenced by the extent to which relevant processing drains available capacity. If the perceptual load of the relevant task is high enough to exhaust all available capacity, then irrelevant stimuli will be excluded from processing, according to Lavie's (1995, 2000) theory. However, if the relevant task is low in perceptual load, any unused capacity will inevitably spill over to the processing of irrelevant stimuli. If some very general resources are involved in visual attention (see Broadbent, 1958; Navon & Gopher, 1979), then increasing load for a relevant task in one domain (e.g., letter processing) should presumably affect distractor processing in another domain (see also Lavie, 2000). Thus, to the extent that irrelevant face processing draws on general processing resources, like other forms of distractor processing it should also be modulated by the perceptual load of the relevant task to some extent, even if that relevant task does not involve faces (e.g., a letter search task; see Lavie, 2000; Rees et al., 1997).

Numerous psychological studies, employing various manipulations of load, have borne out the predictions of load theory to date (e.g., see Lavie, 1995, 2000; Lavie & Fox, 2000; Rees, et al., 1997). However, these studies have typically involved irrelevant distractors that are of little biological significance (e.g., letters or words; Lavie, 1995, 2000; Lavie & Fox, 2000). Thus, little is known about the effects of relevant perceptual load on the processing of task-irrelevant, but biologically significant stimuli. One exception is a functional imaging study conducted by Rees, Frith, and Lavie (1997). They examined the effect of manipulating perceptual load in a relevant linguistic task (judgements on central letter strings) on processing of surrounding motion (dots that moved radially to indicate an expanding optic flow field, versus static surrounding dots), as measured by motion-related activity in V5 using fMRI, and also by a psychophysical motion aftereffect. Subjects were asked to indicate whether a word presented at fixation was printed in uppercase versus lowercase letters (low load task), or to indicate whether it was monosyllabic versus bisyllabic (high load task), while either radial motion or static dots were presented in the surround. The type of radial motion that was used in the surrounding display is thought to contribute much to our perception of motion in the environment (e.g., Gibson, 1950). For example, our own forward motion induces an expanding field of optic flow. Radial motion may thus constitute a highly biologically significant stimulus. Despite this, Rees et al. (1997) found that processing of the irrelevant motion varied as a function of perceptual load in the relevant but unrelated task on the central letter strings, with less motion-related activity in V5, and shorter motion aftereffects, in the high load condition. Note that these effects were found even though the relevant linguistic task was completely unrelated to motion perception. Thus, Rees et al.'s (1997) study demonstrates that the processing of at least some task-irrelevant, but biologically significant stimuli (i.e. motion) can be modulated by the level of relevant perceptual load. However, the role of relevant task load in determining the extent of irrelevant distractor face processing has not yet been examined. It is thus possible that irrelevant face processing could be eliminated by increasing relevant load in an unrelated task to a suitably high level, even though processing of distractor faces seems to be unaffected by increasing general irrelevant load in the form of additional nonface distractors (see Chapters 2-4).

If face processing draws solely on face-specific capacity, as on one interpretation of the previous experiments on distractor load, then an irrelevant face should continue to be processed even when general (nonface) capacity is exhausted by high load in relevant processing. Thus for example, incidental memory for irrelevant faces should be the same regardless of the level of relevant load in an unrelated task at the time of exposure. Such a finding would undoubtedly strengthen the claim that faces are processed by a specialized system subject only to its own highly specific capacity limits, but would contrast with other previous findings that the level of load in a relevant domain can affect irrelevant processing in an entirely different domain (e.g., as when load in a letter-string task affects irrelevant motion processing; Rees et al., 1997). Examining the effect of relevant load on irrelevant face processing thus provides a good test of whether face processing is entirely independent from other forms of visual processing, or instead is subject to some of the usual constraints concerning task-relevant load in an unrelated domain, as outlined by Lavie (1995, 2000), provided the relevant load is made high enough.

In order to manipulate relevant perceptual load in a nonface domain, I used a letter-search task that has been used in previous perceptual load studies, and which is known to be effective in reducing processing for other types of irrelevant distractor (e.g., see Lavie, 1995, 2000). In the low load conditions, subjects merely responded to the colour of the central letter string (red vs. blue). In the high load condition for the same stimuli, subjects searched for a target letter (X vs. N) among other angular letters. Each letter string was superimposed on a task-irrelevant anonymous face. Processing of these anonymous faces was assessed via incidental memory, measured in a surprise recognition test at the end of the experiment, as in Chapter 4. The use of incidental memory as a measure of face processing not only allows the faces to be completely unrelated to the relevant task (unlike Chapters 2 & 3, but as in Chapter 4), but also addresses a practical issue of considerable everyday interest. This concerns whether or not we can recognize a face that had previously appeared directly in front of our eyes, if we were engaged in some other task when that face was present. Although there is a substantial literature on memory for faces, partly because of its practical and legal significance (e.g., Wells & Loftus, 1984; Wells, 1993; Wells et al., 2000), as noted earlier, there has been surprisingly little work on the possible role of attentional factors (e.g., of the relevant load in a nonface task, which the observer may be engaged in during initial exposure to a face) on subsequent incidental memory for the faces encountered. Numerous studies have examined the effects of attention on recognition memory for fairly neutral stimuli such as geometric shapes (e.g., Rock, Schauer & Halper, 1976), line drawings (Goldstein & Fink, 1981) and words (e.g., Gardiner & Parkin, 1990). Such studies have typically reported that recognition performance can be modulated by attention at the time of encoding. However, despite the everyday interest of incidental memory for unattended faces (e.g., for assessing the reliability of eyewitness testimony), the role of attention in face recognition has rarely been examined. Moreover, the few studies that have examined attention and face recognition memory have employed fairly weak attentional manipulations (e.g., mere instructions to attend or ignore stimuli). Such studies cannot establish whether irrelevant face learning still occurs when general capacity is loaded with an unrelated task.

Kellogg (1980) measured incidental memory for faces that had been presented in isolation for approximately 10s. In one condition, subjects were instructed to concentrate solely on the faces. In the other condition, subjects were asked to concentrate on a verbally-presented multiplication task. They were instructed still to look at the faces, but to regard them as distractors. Kellogg (1980) found that subjects recognized the attended faces better than the unattended faces. However, since eye-movements were not monitored in Kellogg's (1980) study, it is possible that in spite of the task instructions, subjects simply spent less time looking at the faces in the secondary task condition than in the single task condition. Indeed, since the multiplication task was presented verbally, subjects had little motivation to look at the visual displays at all in the unattended condition. Thus, the reported difference in recognition performance between the two conditions might reflect different patterns of eye-movement rather than any difference in the availability of attention.

In a more recent study, Reinitz, Morrissey & Demb (1994) tested incidental memory for line-drawn faces that had previously been exposed for 10s under conditions of full or divided attention. In the divided attention condition, subjects viewed a picture of a face while performing a working memory task involving counting dots presented in rapid sequence on the face. The dots could appear in either of two locations on the face; one location was in the top half of the face, and the other was in the bottom half of the face. Nine sequences of varying length alternated between these two locations (e.g., 5 dots at the top, 3 at the bottom, 7 at the top, etc.). The subjects' task was to report the length and location of the longest single sequence (e.g., "7, top" for the above example). These dots were also presented in the full attention condition, but subjects did not perform the counting task. Instead they were asked to attend to the faces and to use the dots as fixation points. Reinitz et al. (1994) found that subjects were better at recognizing fully attended faces than faces presented during the counting task. However, it may not be surprising that the counting task impaired subsequent recognition memory for the faces, since long term memory sometimes depends on the availability of working memory at the time of encoding (e.g., Baddeley & Hitch, 1974). Thus, the finding of reduced memory for faces in the divided attention condition of Reinitz et al.'s study may reflect not a shortage of attention, but a shortage of working memory. Furthermore, in the divided attention condition, it seems likely that the positioning of the dots may have induced more part-based processing of the faces, with attentional focus alternating between the top and bottom halves of the face along with the sequences of dots. In the full attention condition, subjects may have been less motivated to attend closely to just the region of the dots, since they did not have to be counted. Thus, the more holistic aspects of face processing may have been relatively disrupted in the dot-counting condition. Since face recognition is thought to be particularly dependent on holistic processing (e.g., Tanaka & Farah, 1993; Tanaka & Sengco, 1997; see Chapter 1), any such differences in part-based versus holistic processing between the two conditions may also have contributed to the reported effect.

The aim of the present experiments is to clarify the role of attention (and in particular, task-relevant load) in face recognition memory, by examining whether an irrelevant face at fixation will still show incidental learning to the same extent, even when general attentional capacity is exhausted by high versus low load in unrelated relevant processing. These conditions were produced by manipulating the perceptual load of a relevant but unrelated letter-string task superimposed on the face. In the low load condition, subjects simply responded to the colour of the letter string, a task thought to place minimal demands on attention (e.g., Treisman & Gelade, 1980). In the high load condition, subjects had to identify a target letter among similarly-shaped letters in the string, a task thought to demand focused attention (e.g., Treisman & Gelade, 1980; Lavie, 1994, 1995), and shown in previous studies to reduce distractor processing for nonface stimuli (e.g., Lavie, 1995, 2000). Incidental memory for the exposed but task-irrelevant faces was then assessed using a surprise old/new discrimination task, identical to that used for Experiment 5 in the previous chapter.

Experiment 7

The purpose of Experiment 7 was to determine the extent to which irrelevant face processing depends on the general processing capacity demanded by relevant processing, as tapped by the load of an unrelated task. In order to address this question I compared incidental memory for irrelevant faces that had appeared under two conditions of a relevant letter-string task superimposed on the irrelevant face at fixation. In one condition (low relevant load), subjects performed a colour discrimination task in which they indicated which of two possible colours (red vs. blue) applied to the letter string. Since the perception of features such as colour is typically thought to impose minimal attentional demands (e.g., Treisman, 1980), this colour discrimination task was assumed to involve low perceptual load. Note that the processing demands of this task were similar to those of the colour discrimination task used in Chapter 4 in which unaccompanied irrelevant faces were found to be processed to a considerable extent (Experiment 5). It was thus anticipated that irrelevant faces in the colour discrimination condition of the current experiment would also be processed to a similar extent. The new condition of interest was the *High load* condition, in which subjects performed a letter identification task on the same central letter strings. In this task, subjects had to indicate whether the string of angular letters (H, K, M, W, Z) contained a target X versus a target N, a task thought to be considerably more demanding than the processing of a single colour feature (e.g., Lavie, 1995; Treisman & Gelade, 1980). Processing of the irrelevant faces that had been presented during the letter tasks was assessed by measuring explicit recognition memory in a surprise test at the end of the experiment. If face processing draws only on face-specific capacity, then a single irrelevant face should be processed regardless of whether or not general capacity is available. Thus, incidental memory should be equivalent for faces from the *Low load* and *High load* conditions. On the other hand, if face processing draws on general capacity to some extent, then incidental memory for the irrelevant faces should be poorer when general capacity is exhausted by high relevant processing demands in an unrelated task (as in the *High load* condition) than when spare general capacity is available (as in the *Low load* condition).

Method

Subjects & Apparatus 12 students from University College London, whose ages ranged from 18 to 28, were paid £4 to participate in the experiment. All reported normal or corrected vision and had not participated in the previous experiments. The apparatus was the same as for the previous experiments.

Stimuli As can be seen in Figure 5.1, displays consisted of a central letter string superimposed on a face, with the latter positioned so that the middle of the nose (between the bridge and the tip) was at central fixation. The letter strings could be either red or blue, and consisted of a target letter (X or N) and five nontarget letters (H, K, M, W and Z) arranged in a random order. Each letter measured approximately 0.4 cm horizontally and 0.5 cm vertically (subtending approximately 0.4° x 0.5° of visual angle at the viewing distance of 60 cm), and was separated from its neighbours by approximately 0.2 cm (0.2° of visual angle). The whole letter string thus measured approximately 4.2 cm horizontally and 0.5 cm vertically (approximately 4.0° x 0.5° of visual angle). As in the preceding experiments, the faces were photographic greyscale images edited to remove extraneous background. Each face measured between 4.5 cm and 6.5 cm horizontally and 6.5 cm vertically (subtending a visual angle of between 4.3° and 6.2° horizontally, and 6.2° vertically), and was presented against a light grey background. A total of 72 faces were used in the experiment. Of these, 24 were used for the *Low load* condition, 24 were used for the *High load* condition, and 24 served as new faces (foils) in the surprise recognition test. Each set of 24 faces contained 12 male faces and 12 female faces.

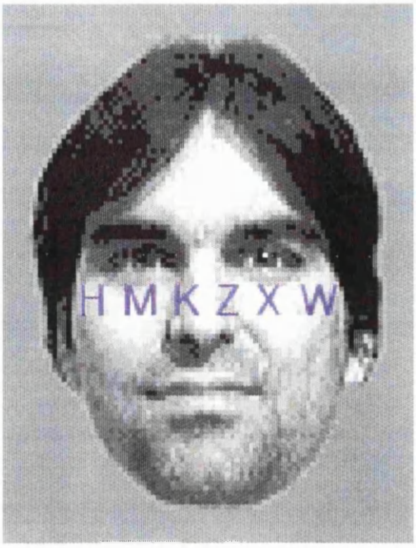

Figure 5.1 Example display from Experiment 7. Subjects responded to a string of letters superimposed on a task-irrelevant unfamiliar face. In the *Low load* condition, subjects responded to the colour of the letter string (red vs. blue). In the *High load* condition, they responded to the identity of one target letter present in the string (X vs. N).

Between subjects, the three sets of 24 faces were counterbalanced across the three experimental conditions (*Low load*, *High load*, and *New*) so that when pooling over subjects, each face appeared in all three conditions an equal number of times. In addition, face identity, target letter identity, target letter position, and string colour were all counterbalanced with respect to load so that across the whole experiment, high and low load displays were identical in appearance.

Procedure

Each trial began with a black fixation point appearing at the centre of the screen for 500 msec. This was immediately followed by the face-plus-string display, presented for 200 msec (i.e. too brief for saccades). Subjects responded to the colour of the letter string in the *Low load* condition, and to the identity of the target letter (an X or an N in the string) in the *High load* condition. Speeded responses were made with the thumb and index finger of the right hand, using the "3" and "." keys on the numeric pad of the computer. In both conditions, feedback for errors was given immediately by a short computer tone. If no response was made within 3s, feedback was given by the same tone and the next trial initiated. The *Low load* and *High load* conditions were presented in alternating blocks, with half of the subjects receiving the *Low load* - *High load* order and half receiving the reverse order. In the *High load* condition, string colour was held constant through each block (either red or blue) to mitigate any possible carry-over effects from the low load task. The experiment began with two practice blocks of 12 trials each, in which the letter strings were presented alone (i.e. with no face present). One practice block was used for practicing the low load task, and the other was used for practicing the high load task. These practice blocks were followed by 6 experimental blocks, each consisting of 48 trials presented in a random order. Subjects were requested to focus on the letter strings and ignore the faces throughout, which were entirely irrelevant to the prescribed letter-string task. A surprise recognition test was administered immediately after completing all trials in the letter-string tasks. In each trial of the recognition test (72 in total), subjects were presented with a single face and were asked whether or not it had been presented in the experiment (explicit old/new discrimination).

Results

Mean RTs and error rates in the letter-string task were significantly higher in the *High load* condition (mean RT 876 msec, 16% errors) than the *Low load* condition (mean RT 422 msec, 2% errors), confirming that perceptual load was effectively manipulated ([t(1,11)=13.99, p < .01] for RTs, [t(1, 11)=8.90, p < .01] for errors).

The probability of responding "yes" in the recognition task was computed separately for faces that had appeared under conditions of *Low load* (.51), faces that had appeared under conditions of *High load* (.28), and new faces (.23); see Figure 5.2.

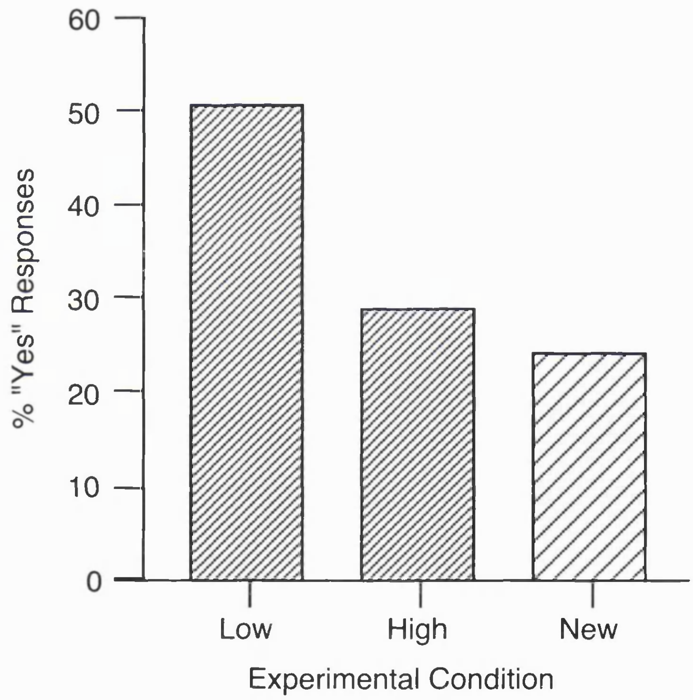

Figure 5.2 Mean percentage of "yes" responses (n=12) in the surprise recognition test for faces in Experiment 7. Memory performance is shown as a function of experimental condition; *Low load*, *High load*, or *New* (foils).

A one-way ANOVA on these probability data revealed a significant effect of experimental condition [F(2,22)=10.7, p < .01]. Planned comparisons showed that, in accordance with the predictions of the load hypothesis, the probability of responding "yes" was higher for faces exposed under conditions of low load than for either new faces [t(1,11)=4.06, p < .01], or faces exposed under conditions of *High load* [t(1,11)=3.01, p < .01]. Moreover, there was no significant difference between responses to faces presented under high load and responses to new faces [t(1,11)=1.13, p > .10]. That is, no reliable explicit memory was found for faces exposed during the high-load letter-string task, although such memory was found for faces exposed during the low-load task.

Discussion

The results of Experiment 7 show a clear effect of task-relevant perceptual load on incidental memory for faces. Explicit recognition for faces that had appeared as irrelevant stimuli during an unrelated visual task was significantly affected by the perceptual load of the relevant task, with poorer performance on faces that had been presented under conditions of high relevant load in the unrelated letter-string task. In fact, increasing load impaired explicit recognition to such a great extent that on average, subjects were no more likely to respond "yes" to a face that had been presented in the *High load* condition than to a face that had not been presented at all. Given that faces seem to be particularly memorable stimuli (e.g., Yin, 1969; Scapinello & Yarmey, 1970), and that in the current experiment, they were presented at fixation twelve times each, it is perhaps surprising that increasing perceptual load in an unrelated relevant task should reduce performance so markedly. However, this is consistent with the idea that attention involves some general resource that is not bound to specific stimulus domains (e.g., Lavie, 1995, 2000), and also accords with previous demonstrations of load effects between domains (e.g., Rees et al., 1997). Moreover, the finding that increased relevant load at the time of encoding reduced explicit memory for the irrelevant faces suggests that processing of irrelevant faces can depend on general capacity to some extent. However, since face processing and the high load task of target letter detection both involved the processing of shape, whereas the *Low load* task of colour discrimination did not, it could be argued that the reduced memory for faces from the *High load* condition reflects not a shortage of general attentional resources, but a shortage of specific resources involved in shape processing (especially given that recognition of greyscale faces may be construed as a primarily shape-based task, rather than colour-based task). To address this possibility, I devised a variation of the above experiment in which both the *High load* and the *Low load* tasks required shape judgements for the letter string (rather than one involving shape and the other involving colour, which might in principle have been responsible for the differential impact on face recognition in Experiment 7).

Experiment 8

The findings of Experiment 7 suggest that incidental explicit memory for an irrelevant face can be reduced by increasing relevant perceptual load in an unrelated nonface task at the time of encoding. The purpose of Experiment 8 was to strengthen the claim that this effect is due to a shortage of general attentional resources, rather than to a more specific interference between the particular demands of the *High load* task and the demands of face processing. To this end, in Experiment 8, I sought to replicate the effects of relevant load on memory for irrelevant faces, but using low load and high load tasks which now both involved the processing of shape. In both load conditions, the subjects' task was to indicate whether an X or an N was present in the letter string. Thus, the target discrimination, and the mapping of letter-string targets to responses, was now strictly matched across the two load conditions. However, in the *Low load* condition, the letter string now consisted entirely of either Xs or Ns. The *High load* task was the same as in Experiment 7. If the poor memory for faces from the *High load* condition in Experiment 7 was simply due to interference at the level of shape processing, then memory for faces from the *Low load* condition should now be poor as well. On the other hand, if the poor memory was due to a lack of spare general capacity at the time of encoding, then the current load manipulation should produce a similar pattern of results to that found in Experiment 7. Specifically, explicit memory should be poorer for faces that were presented in the *High load* condition than for faces presented in the *Low load* condition.

Method

Subjects and Apparatus 12 students from University College London whose ages ranged between 19 and 25 were paid £4 to participate in the experiment. All reported normal or corrected vision and had not participated in the previous experiments. The apparatus was the same as for the previous experiments.

Stimuli and Procedure The stimuli and procedure were identical to those of Experiment 7 except for the following changes. The letter strings in both conditions were now always blue. Letter strings in the *Low load* condition were equally likely to consist of either six Xs or six Ns. In both the *Low load* and the *High load* conditions, the subjects' task was to indicate whether an X or an N was present in the string.

Figure 5.3 Example display from the *Low load* condition of Experiment 8. Subjects responded to the identity of a target letter (X or N), presented in a letter string superimposed on a task-irrelevant unfamiliar face. In the *Low load* condition, the letter string was composed entirely of either Xs or Ns. In the *High load* condition, the target X or N appeared among 5 angular nontarget letters (as in Experiment 7; see Figure 5.1).

Results

The results for Experiment 8 were analysed in the same way as those of Experiment 7. Mean correct RTs and percentage error rates in the letter string task were again significantly higher in the *High load* condition (mean RT 729 msec, 13% errors) than the *Low load* condition (mean RT 460 msec, 2% errors), confirming that perceptual load was effectively manipulated ([$t(1,11)=10.02$, $p < .01$] for RTs, [$t(1,11)=5.45$, $p < .01$] for errors). Note that although these results indicate that the present load manipulation was reasonably strong, a between experiments analysis showed that in terms of RTs, the load manipulation in the previous Experiment 7 was significantly stronger [$F(1,22)=10.15$, $p < .01$]. There was no such significant interaction between experiment and load with respect to error rates [F<1].

The probability of responding "yes" in the recognition task was computed separately for faces that had appeared under conditions of *Low load* (.56), faces that had appeared under conditions of *High load* (.27), and new faces (.17); see Figure 5.4.

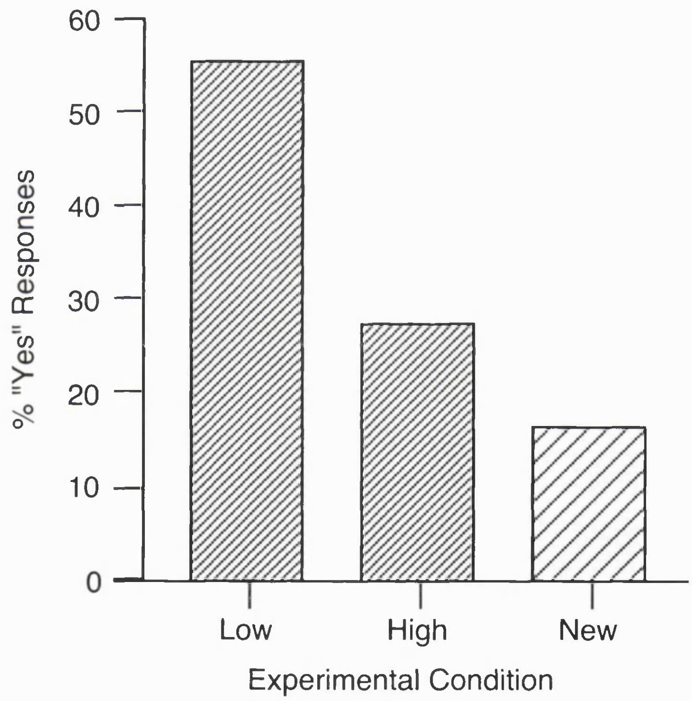

Figure 5.4 Mean percentage of "yes" responses (n=12) in the surprise recognition test for faces in Experiment 8. Memory performance is shown as a function of experimental condition; *Low load*, *High load*, or *New* (foils).

As in Experiment 7, a one-way ANOVA on these probability data revealed a highly significant effect of presentation condition [$F(2,22=28.75$, $p < .01$]. Planned comparisons showed that, as before, the probability of responding "yes" was higher for faces that had been exposed in the *Low load* condition than for either new faces [t(1,11)=5.98,p < .01] or faces from the *High load* condition [t(1,11)=-5.36, p < .01]. Unlike Experiment 7 however, responses to faces presented under high load and responses to new faces were also significantly different [t(1,11)=2.62, p < .05], presumably because the load manipulation was not quite as strong as before (see between-experiments comparison of the load effect on RTs for the letter string tasks, above). Thus, high relevant load in an unrelated letter task again reduced explicit incidental memory for task-irrelevant faces, as compared with low load in the letter task, but on this occasion the high load did not entirely eliminate such memory.

Discussion

The results of Experiment 8 accord with Experiment 7 in showing that incidental memory for irrelevant faces can be affected by the level of relevant perceptual load in an unrelated letter task at the time of encoding. Recognition performance was again significantly better for faces from the *Low load* condition than for faces from the *High load* condition, even though the relevant task in both conditions now involved shape processing (albeit still both in a nonface domain, namely for letters). This suggests that incidental memory for irrelevant faces depends to some extent on the availability of general capacity at the time of encoding. These findings accord with Lavie's (1995, 2000) perceptual load theory, and with previous demonstrations that relevant load in one domain (e.g., for letters) can affect processing of task-irrelevant stimuli in other domains (e.g., for motion in Rees et al., 1997; or for faces here). Finally, whereas the previous chapters had found that an additional task-irrelevant item could only dilute effects from a distractor face when it too was a face, the present chapter shows that face effects can also be reduced by nonface means in the form of increased task-relevant load.

Chapter 6

Dilution Of Interference By Load In Visual Short-Term Memory

Introduction

This final empirical chapter returns to a theme of earlier chapters (2-4), namely factors that can 'dilute' interference effects from irrelevant faces or other types of distractor. The experiments in Chapters 2-4 found that while response-competition effects from a critical distractor face (Chapters 2 & 3) seem to be unaffected by the presence of an additional nonface distractor object in the display (and likewise for incidental memory for task-irrelevant unfamiliar faces; Chapter 4), both can be significantly diluted by the presence of another intact face. The question addressed in the current chapter is whether the additional face must be physically present in order for dilution to occur, or whether merely maintaining a face in visual short-term memory (perhaps akin to imagining it) is enough to disrupt the processing of a critical distractor face in the display.

Many researchers have proposed that a major limit on visual capacity is due to the limits of visual short-term memory (VSTM; e.g., Sperling, 1960; Duncan, 1980). A defining characteristic of VSTM is that the number of visual items it can store is relatively small (e.g., Luck & Vogel, 1997; Lee & Chun, 2001). As the number of items exceeds VSTM capacity, memory for these items deteriorates (Lee & Chun, 2001). Thus, some forms of selection may arise through competition for limited VSTM capacity. If so, it is possible that merely maintaining a face representation in VSTM might be sufficient to disrupt processing of a visually presented distractor face. Indeed, although the extent to which the maintenance of an image in VSTM shares common processes with perceptual visual processing is by no means resolved (e.g., Farah, 1985, 1988; Awh, Jonides & Reuter-Lorenz, 1998; Awh & Jonides, 2001; Behrmann, Moscovitch & Winocur, 1999), numerous studies have demonstrated that images held in VSTM can have various perception-like properties. For example, Kosslyn, Ball & Reiser (1978) found that the time taken for subjects to 'travel' in their mind's eye between two points on a memorized map was proportional to the actual distance between the two points, suggesting that some of the spatial properties of internal visual representations may be analogous to those of the external world (although see Pylyshyn, 1973, 1981; Johnson-Laird, 1983 for possible criticisms). In another well-known set of experiments, Kosslyn (1978) examined the spatial extent of the putative representational medium. He asked subjects to imagine a distant object, and then to 'zoom in' on the object until it filled their mental visual field. Subjects were then asked to estimate how far away the object would have to be for it to appear at that subjective size. Kosslyn (1978) found that the estimated distance increased linearly with the actual size of the imagined object. This linear relationship was interpreted as evidence that the representational medium of imagery, like our field of vision, may have a limited and invariant size.

The potentially close correspondence between imagery and perception is further demonstrated by studies that have found facilitatory interactions between these two processes. For example, Ishai & Sagi (1995) reported that equivalent facilitation was observed in thresholds for the detection of an oriented target patch when there were congruent flankers present in the display, or when experienced subjects merely imagined the presence of congruent flankers. Similarly, Farah (1989) found that when subjects formed a mental image of a letter, this imagined prime facilitated perceptual detection of a subsequent target letter. In addition to this psychological evidence for such interplay between imagery and perception, there is also considerable empirical support for the view that imagery and perception may involve at least some shared neural substrates. In particular, a number of functional imaging studies have shown that early areas of visual cortex that mediate perception can also be active during mental imagery (e.g., Kosslyn, Alpert, Thompson, Malikovic, Weise, Chabris, Hamilton & Buonanno, 1993; Kosslyn, Thompson, Kim & Alpert, 1995; Le Bihan, Turner, Zeffiro, Cuenod & Bonnerot, 1993). Moreover, of particular relevance to the topic of this thesis, O'Craven & Kanwisher (2000) have shown that imagining faces can also activate some of the same brain regions that are activated by actually viewing faces (e.g., the fusiform gyrus; see Kanwisher et al., 1997). Furthermore, visual perceptual deficits in brain injured patients can sometimes be accompanied by a corresponding deficit in visual imagery (e.g., see Farah, Soso & Dasheiff, 1992). Such findings have led some researchers (e.g., Kosslyn, 1994) to propose that visual information in visual short-term memory may be processed in a similar way whether it is generated internally or arrives from the eyes.

If the dilution effects on distractor interference shown in Chapters 2 & 3 were due to capacity limits at a level of internal representation that is common to perceptual processing and visual short-term memory, it is possible that the processing of an irrelevant distractor face could be 'diluted' by the internal representation of another face in VSTM, even when that other face is not physically present, but is merely being maintained in visual short-term memory. The purpose of the current experiments was to test this possibility by examining whether manipulating load in VSTM, rather than within the current visual display, can dilute the effects of a physically present distractor face. As it turned out, these experiments also shed new light on the putative face-specific capacity limits considered in Chapters 2 & 3, as compared with capacity limits for other types of distractor object.

Experiment 9

The aim of Experiment 9 was to examine whether the processing of an irrelevant distractor face could be disrupted (so that distractor interference is 'diluted') merely by maintaining another face, which was no longer physically present, in visual short-term memory. Of particular interest was whether any such potential dilution effects from load at the level of internal mental representation would be face-specific, as seems to be the case for load that is physically present (Chapters 2 & 3). This issue was addressed using a variation of the response-competition task previously employed in Experiments 1-3 to examine the effects of physically present clutter on irrelevant face processing. As in those experiments, the response-competition task required subjects to categorize a central printed famous name as a pop-star's or a politician's, while ignoring a critical distractor face. Unlike Experiments 1-3 however, the target name together with the critical distractor face now always appeared alone in the response-competition display. Since no additional distractors ever needed to be presented in the response-competition displays, the critical distractor face could now be presented at fixation, superimposed by the target name, rather than to the left or right of fixation as it had been in Experiments 1-3. In order to ensure that the target name did not obscure the critical distractor face, these distractors now appeared somewhat larger than they were in Experiments 1-3 (see Figure 6.1). These changes might result in larger overall distractor effects than were observed in the previous experiments. However, the critical question was not the overall size of any distractor effect, but whether it could be diluted by holding an image of another face in VSTM. Load in VSTM was manipulated by interleaving the response-competition task with a VSTM task. For this task, subjects had to memorize an image presented in a 'study' display shortly prior to the response-competition trial, and to indicate whether or not it matched another image presented in a memory test display shortly after the response-competition trial. This matching task should thus ensure that subjects had to retain the memory display in VSTM while performing the response-competition task. The memory displays could contain either: i) a picture of an anonymous face (*Face* condition); ii) a picture of a nonface object (a building; *House* condition); or iii) nothing in the control (*Blank*) condition. In this way the memory displays were somewhat analogous to the additional distractor stimuli presented in Experiment 3 (which had also comprised either an additional face, an additional nonface object, or nothing). The unfamiliar faces and unfamiliar buildings in these memory displays were intended to be difficult to name, in order to minimize the possibility of verbal encoding for the VSTM task. Verbal encoding seems an unlikely strategy to adopt for memorizing anonymous faces, especially when those faces are drawn from a relatively homogenous subset (e.g., clean-shaven adult caucasian males in the present experiments). In order to discourage verbal encoding in the nonface task also, unfamiliar buildings (rather than the unfamiliar musical instruments and fruits used in Experiment 3) were now used as nonface objects. Although the unfamiliar musical instruments and fruits used in Experiment 3 were themselves difficult to name, they nonetheless bore some resemblance to more easily named items, and for this reason may invite verbal labels. On the other hand, the unfamiliar buildings bore little resemblance to any famous buildings, and were all drawn from the same basic level category (i.e. houses). Thus, in the case of such unfamiliar buildings, verbal coding seems a particularly awkward strategy to adopt.

If processing of an irrelevant distractor face can be disrupted by maintaining any image in VSTM, then interference effects from the critical distractor face should be diluted when the 'study' display for the memory task contains an image of a house or a face, relative to when it is blank. Alternatively, if load in VSTM affects irrelevant face processing in the same way as concurrently-presented perceptual clutter (see Chapters 2 & 3), then interference from the critical distractor face should be reduced by another face in VSTM, but not by a nonface object (here a building). Finally, if irrelevant face processing is independent of load in VSTM, then distractor effects from the famous face distractor should be equivalent for all three memory display conditions, with no dilution found.

Method

Subjects and Apparatus The 24 new subjects (15 female) were all UCL undergraduates whose ages ranged from 18-24. All reported normal or corrected vision and were paid £4 for participating. The apparatus was the same as in the previous experiments.

Stimuli The response-competition task was the same as in Experiments 1-3 (i.e. categorization of printed famous names as politicians' or pop-stars') except for the following changes. As can be seen in Figure 6.1, the famous face now appeared at the centre of the display, positioned so that the middle of the nose (between the bridge and the tip) was at fixation. The famous name was superimposed on the face and was also centred at fixation. All names were presented in white and measured between 3.3cm and 5cm horizontally and 0.4cm vertically (subtending a visual angle of between 3.1° and 4.8° horizontally and 0.38° vertically at the viewing distance of 60cm). The faces measured between 4.2cm and 5cm horizontally and 6cm vertically (4.0°-4.8° x 5.7° of visual angle). There were three conditions for the VSTM task: *Blank*, *House*, and *Face*. In the *Blank* condition, the memory displays were always blank. In the *House* and *Face* conditions, the memory displays contained photographic greyscale images whose position and vertical size were the same as for the famous faces in the response-competition display. A set of 24 anonymous male faces of a similar age range to the famous faces was used for the *Face* memory displays. To ensure that the memory displays in the *House* condition were sufficiently memorable, as analogous to those in the *Face* condition, the 24 non-famous buildings were highly distinctive from one another (see examples in Figure 6.1).

Procedure As can be seen in Figure 6.1, each trial started with a black fixation point presented at the centre of the screen for 500 msec. This was followed by a memory study display consisting of either a blank screen (*Blank* condition), a house (*House* condition), or an anonymous face (*Face* condition) presented for 500 msec (see Figure 6.1).

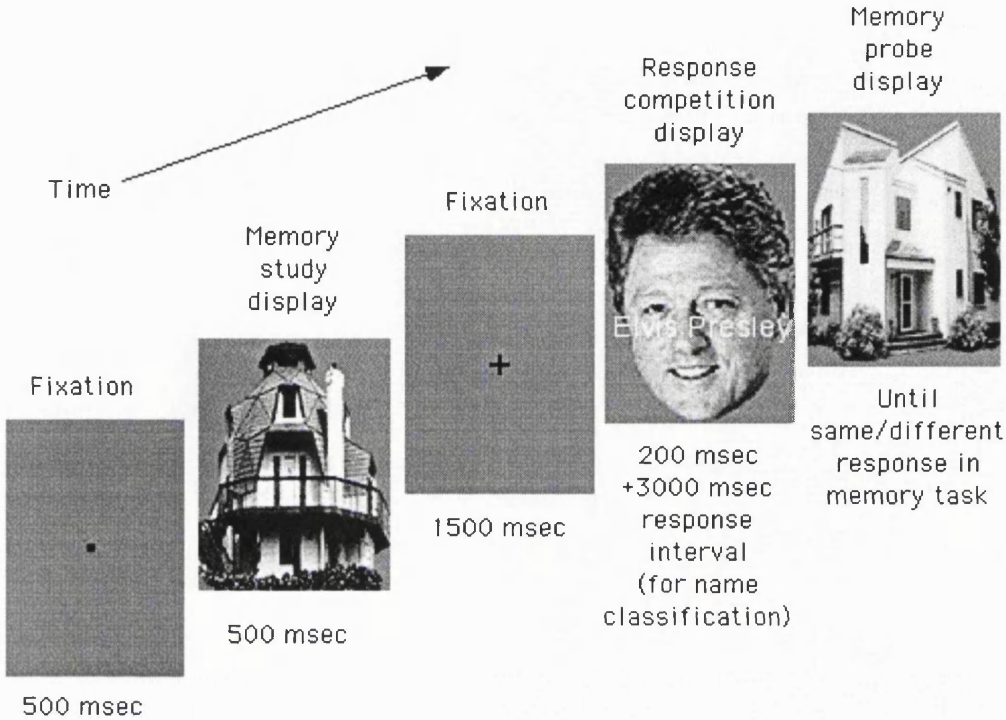

Figure 6.1 Example of a *House* trial from Experiment 9. After a 500 msec fixation, the memory study display (*Blank*, *House*, or *Face*) was presented for 500 msec, followed by a 1500 msec fixation. The response-competition display was then presented for 200 msec, followed by a 3000 msec blank response window for the name classification task. In the response-competition display, the critical distractor face could be either *Congruent* or *Incongruent* with the target name (incongruent in this case). After the name classification response (or after the 3000 msec response window had elapsed), a memory probe display was presented. Subjects were asked to make a same/different judgement to the memory probe display, relative to the memory sample display ('different' in this case).

In the *House* and *Face* conditions, subjects were instructed to memorize this display for a short-term test, and were encouraged to form a mental image and "project" this mental image onto the screen throughout the trial. After an interval of 1500 msec, during which a black fixation cross was present at the centre of the screen, the response-competition display was presented for 200 msec. The procedure for the response-competition task was the same as in Experiments 1-3, with subjects pressing one key for pop-stars' names and another key for politicians' names as quickly and accurately as possible. Following the keypress in the response-competition task, a memory probe was presented at fixation (see Figure 6.1). In the *House* and *Face* conditions, the probe was either the same as the memory display (50% of trials) or a different exemplar from the same house or face category (the other 50% of trials, randomly intermixed). Subjects were instructed to press "s" with the left hand if the memory study item and the memory probe item were the same, and "d" if they were different. In the *Blank* condition, the probe display was always blank, and subjects pressed "s" on each such trial. The memory probe display remained until the subject responded. The three memory task conditions appeared in rotating blocks (e.g., *Blank*, *House*, *Face*, *Blank*, *House*, *Face*) with block order counterbalanced across subjects. In the *House* and *Face* conditions, all 24 different images were presented equally often, each appearing twice per block as the study item, and twice per block as the probe item (once in a 'same' trial, and once in a 'different' trial). Combining each of the 12 famous names with a congruent and an incongruent face in the response-competition display, together with same and different probe items in the memory task, resulted in 48 trials per memory task condition. Following a 6-trial practice block for each memory condition, subjects completed 12 experimental blocks (4 *Blank*, 4 *House*, and 4 *Face* in total), each consisting of 48 trials presented in a random order.

Results

Accuracy in the memory task was equivalent in the *House* condition (79%) and the *Face* condition (78%), suggesting that these two conditions were well matched in terms of overall difficulty. Incorrect responses and RTs exceeding 2 sec (less than 1% of the correct responses) in the response-competition task were excluded from the analysis of latencies for that task. Data from two subjects whose mean name categorization RTs were exceptionally slow (947 msec and 924 msec; 1.9 and 1.8 SD from the group mean of 650 msec), and from one subject whose accuracy in the matching task was below 30% (2.9 SD from the group mean of 79%) were also excluded. Mean correct reaction times and error rates in the response-competition task were computed after these exceptions for each level of congruency (*Congruent* and *Incongruent*), separately for each interleaved memory condition (*Blank*, *House*, and *Face*). The intersubject means of these RTs and accuracy rates are shown in Table 6.1.

Table 6.1 Mean Reaction Times (in msec) and Error Rate (%) across Subjects (n=21) as a Function of Distractor Congruency and Memory Condition in Experiment 9.

	Distractor congruency				Effect size	
	I		*C*		I-C	
Memory cond.	RT	%E	RT	%E	RT	%E
Blank	859	6	781	4	79	2
House	862	5	802	2	60	3
Face	860	5	804	2	56	3

Note. *I* = Incongruent; *C* = Congruent.

A two-way within-subjects ANOVA on the mean RT data in the response-competition task, with the factors of distractor congruency (2 levels) and memory condition (3 levels), found the usual main effect of congruency

[$F(1,20)=131.11$, $p < .001$] with slower responses to incongruent displays, but no main effect of memory condition [$F < 1$]. As can be seen in Table 6.1, the main effect of congruency was modified by an interaction with memory condition [$F(2,40)=4.27$, $p < .03$]. Planned contrasts on this interaction revealed that interference effects from the distractor face were significantly smaller in the *House* and *Face* conditions than in the *Blank* condition ([$t(1,20)=2.35$, $p < .02$] and [$t(1,20)=2.55$, $p < .01$] respectively), but that those for the former two conditions were not significantly different from each other [$t < 1$]. Similar analyses of the error data found only a main effect of congruency [$F(1,20)=15.61$, $p < .001$] with more errors for incongruent trials. There were no other significant effects in the analysis of error rates ($p > .10$ for all comparisons).

Discussion

These results extend the previous findings by demonstrating 'dilution' of face interference effects from stimuli that are not actually present within the same display as the critical distractor face: merely maintaining a house or a face image in visual short-term memory seems to be enough to reduce the interference effect from a distractor face at fixation to some (reliable) extent. This finding is consistent with the emerging view that capacity limits in visual short-term memory (VSTM) may relate to 'attentional' limitations (e.g., Sperling, 1967; Duncan, 1980). Presumably, maintaining an image in VSTM may clutter the mental representations involved in visual perception (Kahneman & Treisman, 1981), thereby producing 'dilution' of distractor processing that is similar in some respects to actual perceptual clutter within a single display.

The short-term memory displays in the *House* and *Face* conditions contained a stimulus, but the memory displays in the *Blank* condition did not. However, it is important to note that visual masking from the preceding or subsequent displays in the *House* and *Face* conditions seems unlikely to explain the dilution of face-interference effects observed in those conditions, since the memory displays and response-competition displays were separated by 1500 msec. Masking usually requires much shorter intervals between successive displays (e.g., Breitmeyer 2000; Enns & Di Lollo, 2000).

Another general difference between the *House* and *Face* conditions and the *Blank* condition was in terms of the task demands. In the *Blank* condition, since the memory displays and probe displays were both blank, subjects were effectively performing only the response-competition task in a single-task situation. In the *House* and *Face* conditions, subjects were performing in a dual-task situation, having to co-ordinate interleaved tasks of visual short-term memory and of perception for word classification. Thus perhaps a general increase in difficulty due to dual-tasking somehow caused reduced distractor effects in those conditions. But this possibility seems unlikely considering other, very recent results concerning the effects of task load on response-competition effects from distractor faces (De Fockert, Rees, Frith & Lavie, 2001). Subsequent to the present studies, De Fockert et al., (2001) used a similar response-competition task to that used here. Their subjects also made speeded classifications of pop-stars' and politicians' names, while ignoring distractor faces that could be congruent or incongruent with the names. They compared congruency effects from these distractors for a condition of high load in short-term memory (subjects had to rehearse the digits 1-4 digits in a different random order on each trial), versus a condition involving no such load on short term memory (the digits to be remembered were always in ascending numerical order i.e. 1, 2, 3, 4). They found that distractor effects were increased by high load in short-term memory, compared to the no load condition. De Fockert et al. (2001) interpreted these findings as evidence for a role of working memory in maintaining the distinction between relevant and irrelevant stimuli for selective attention. The importance of their findings for the current study is that the contrast between the present results and theirs suggests that rather than distractor processing being generally affected by increases in overall task difficulty, it may be very sensitive to the specific type of load in STM that is manipulated. Loading VSTM with a specific visual image, as here (perhaps corresponding to increased load on the visuo-spatial sketchpad in Baddeley's (1986) model) can reduce distractor effects, as the current study shows. However, loading STM by requiring the rehearsal of a list (perhaps corresponding to the phonological loop and/or central executive in Baddeley's (1986) model) can apparently increase them (De Fockert et al., 2001).

Given the suggested interplay between VSTM and visual perception, it is possible that the dilution caused here by maintaining an image in VSTM is due to 'cluttering' the mental representations that are also used for perceiving and classifying stimuli in the response-competition task (i.e. the relevant target as well as the irrelevant distractor). In this way, forcing subjects to maintain a visual display in VSTM (as in Experiment 9) may be somewhat analogous to increasing the actual clutter in the response-competition display (Chapters 2 &

3). But note that the results from Experiment 9 also showed that distractor effects from an irrelevant face could be diluted not only by a memorized face, but also by a memorized nonface object in a VSTM task. This contrasts with findings from the earlier chapters (e.g., Experiment 3) in which a concurrently-presented nonface object produced no significant dilution, with dilution requiring an additional face instead.

This apparent difference might arise because capacity limits in VSTM could be less category-specific than those involved in on-line perception, and thus could be exhausted by any items competing for VSTM, irrespective of their category. Alternatively, it may be due to the fact that in Experiment 9, the additional faces and nonface objects were always relevant to the task (as they had to be memorized), whereas in Chapters 2 & 3 they were always task-irrelevant and had to be ignored. Thus the *House* and *Face* conditions in Experiment 9 might be construed as imposing a higher relevant visual load than the *Blank* condition. Viewed in this way, the finding that response-competition effects were reduced in both of the present memory conditions may be less surprising. Indeed, it could be viewed as consistent with the main finding of Chapter 5, namely that the processing of an irrelevant distractor face can be reduced by increasing the perceptual load of the relevant task, even if that relevant task does not involve face processing. Thus it may be that while faces capture or consume more attention than nonface objects when both stimuli are task-irrelevant, stimuli that are task-relevant (as for the memory displays in Experiment 9) can influence interference effects to a similar extent irrespective of their category. If that is the case, then rendering the additional faces and nonface objects in the memory displays equally irrelevant, by now removing the requirement to perform the short-term memory task, should revert the situation to the faces capturing more attention than the other objects, with faces thus entering VSTM more often than the nonface objects and hence leading to greater dilution. This possibility was tested in the next experiment.

Experiment 10

The purpose of Experiment 10 was to examine whether the memorized houses and anonymous faces in Experiment 9 had produced equivalent dilution simply because they were both relevant in terms of the memory task. To examine this possibility, a variation of Experiment 9 was conducted in which the requirement to actively maintain a mental image of a house or a face during the response-competition task was now withdrawn. As in Experiment 9, displays containing either an image of a house or an image of an anonymous face were presented before and after the response-competition display. However, instead of performing a memory matching task on these displays, subjects now viewed them passively, thus performing the response-competition task in isolation. Since the anonymous faces and nonface objects were now task-irrelevant (as the additional face and nonface flankers had been in Chapter 3), it is possible that the pattern of dilution observed in Chapter 3 may now return, with interference from a critical distractor face being diluted by an irrelevant face in the preceding display, but not by an irrelevant nonface object (here a house). This would support the idea that a face in the display tends to capture attention, even when it is task-irrelevant. Alternatively, it may be that neither a face nor a house in the preceding display dilutes interference from an irrelevant distractor face when passively viewed. Such a finding would suggest that interference from an irrelevant distractor face can only be diluted by another face when it too is physically present.

This study also tests the basic issue of whether the results of Experiment 9 depend on the active task (and consequent 'private mental life' of the subject), or merely on the stimuli shown, which remain the same as before under the new passive-viewing conditions.

Method

Subjects and Apparatus The 24 new subjects (17 female) were UCL undergraduates whose ages ranged from 18-25. All reported normal or corrected vision and were paid £4 for participating. The apparatus was the same as for the previous experiments.

Stimuli and Procedure The stimuli and procedure were the same as for Experiment 9 except that subjects now performed only the response-competition task. The 'memory' study displays were merely viewed passively, and subjects always just pressed "s" to the so-called 'memory' probe display to initiate the next trial. As before, subjects completed a 6-trial practice block for each display condition, followed by 12 experimental blocks of 48 trials.

Results

Incorrect responses and RTs exceeding 2 sec (less than 1% of the correct responses) were excluded from the analysis. Data from two subjects whose mean RTs were exceptionally slow (818 msec and 683 msec; 2.7 and 1.8 SD from the group mean of 541 msec) and one subject whose error rate was 21%

(2.8 SD from the group mean of 8%) were also excluded. Mean correct reaction times and error rates in the response-competition task were computed for each level of congruency (*Congruent* and *Incongruent*) and for each condition of preceding/subsequent displays (*Blank*, *House*, and *Face*). The intersubject means of these RTs and accuracy rates are shown in Table 6.2.

Table 6.2 Mean Reaction Times (in msec) and Error Rate (%) Across Subjects (n=21) as a Function of Distractor Congruency and Display Condition in Experiment 10.

	Distractor congruency				Effect size	
	I		*C*		I-C	
Display cond.	RT	%E	RT	%E	RT	%E
Blank	774	9	707	6	67	3
House	760	9	698	5	62	4
Face	736	9	690	5	46	4

Note. *I* = Incongruent; *C* = Congruent.

A two-way within-subjects ANOVA on the mean RT data found the usual main effect of congruency [F(1,20)=162.86, p < .001], and of display condition [F(2,40)=4.98, p < .02]. These effects were qualified by a marginal interaction between congruency and display condition [F(2,40)=3.09, p < .057]. Planned contrasts on this interaction revealed that congruency effects from the distractor face were significantly smaller in the *Face* condition than in either the *Blank* condition [t(1,20)=2.76, p < .01] or the *House* condition [t(1,20)=1.82, p < .05]. However, the *Blank* and *House* conditions were not significantly different from each other [t < 1]. Thus while in Experiment 9, presenting houses in a preceding display had produced significant dilution when they had to be actively held in VSTM, they produced no such dilution under passive viewing conditions (Experiment 10). On the other hand, faces produced significant dilution in both cases. Direct comparisons of these experiments further strengthen this conclusion. A comparison of the dilution produced by houses in Experiment 9 and Experiment 10 confirmed that houses produced significantly more dilution when memorized than when passively viewed [$t(1,40)=1.77$, $p < .05$]. By contrast, a similar comparison of the dilution produced by faces in Experiments 9 & 10 revealed no significant difference between memorized faces and passively-viewed faces [$t < 1$].

As in Experiment 9, analysis of the error data in Experiment 10 found only a main effect of congruency [$F(1,20)=62.73$, $p < .001$] with more errors for incongruent trials. There were no other significant effects in the analysis of error rates ($p > .10$ for all comparisons).

Discussion

These results show that interference effects from a distractor face were no longer diluted by advance presentation of a house image once the requirement to actively hold the house image in VSTM was withdrawn (cf. Experiment 9). However, advance presentation of an anonymous face still produced the same amount of dilution even in this passive-viewing situation. This is a remarkable finding for two reasons. First, it shows that interference effects from a distractor face can be reduced merely by passively viewing a task-irrelevant face 1500 msec earlier. Second, it shows a degree of category-specificity, in that advance presentation of a face for passive viewing produced dilution, whereas advance presentation of a house did not. This pattern of seemingly category-specific dilution appears consistent with that found in Chapters 2 & 3 for concurrently-presented additional distractors. It is also consistent with the idea that faces may be involuntarily processed even in the absence of instructions to attend to them, either because they are processed by a specialized face processing system with its own face-specific capacity, or because faces have a special ability to capture general attention, even when they are irrelevant to the subject's task (see Ro et al., 2000 for a related claim, but involving task-relevant faces).

Alternatively, it may be that subjects attended to the anonymous faces more than to the nonface objects simply because faces also appeared in the relevant display, albeit as irrelevant distractors. Or faces presented in advance may have diluted interference from the critical distractors not because faces are 'special', but because they were to some extent semantically related to the relevant task of classifying people (albeit in the form of printed names). In order to address such possibilities, the next experiment examined whether a passively-viewed face could also dilute interference effects from nonface objects in an entirely unrelated response-competition task.

Experiment 11

The previous experiment showed that interference from a critical distractor face could be diluted by advance presentation of a passively-viewed anonymous face, but was unaffected by advance presentation of a passively-viewed nonface object (e.g., a house). This finding appears consistent with the proposal that irrelevant faces may be harder to ignore than other types of distractor object (e.g., houses). However, it remains possible that the passively-viewed anonymous faces in Experiment 10 received more processing than the nonface objects because faces were in some way related to the relevant task of categorizing people (albeit by their names). To address this possibility, the present study compared the ability of passively-viewed anonymous faces and houses, presented in advance of the response-competition display, to dilute interference from irrelevant nonface objects when their categories were task-relevant, without people being relevant at all.

Subjects now categorized object names presented at fixation as musical instruments versus fruits (see also Experiment 4 from Chapter 3), while ignoring a critical nonface distractor object (either a musical instrument or a fruit) presented at fixation and superimposed with the target word. As in Experiment 10, subjects also passively viewed houses or anonymous faces presented before and after the response-competition display. If an irrelevant face always captures attention, even when semantically unrelated to the relevant task, then passively-viewed faces may produce a similar extent of dilution on the response-competition effect from the critical nonface distractor object as they did in Experiment 10 for the effect from the critical distractor face. On the other hand, if the anonymous faces in Experiment 10 produced dilution simply because faces were somewhat related to the relevant task of categorizing people (albeit by their names), they should not dilute interference effects from musical instruments and fruits.

Method

Subjects The 24 new subjects (15 female) were all University of London students whose ages ranged from 20-28. All reported normal or corrected vision and were paid £4 for participating.

Stimuli and Procedure The stimuli and procedure were the same as for Experiment 10 except that the response-competition displays were now composed of nonface objects (musical instruments and fruits) superimposed with printed names drawn from these categories. Subjects responded to the words by pressing one key for musical instruments (i.e. the words "Piano", "Guitar", "Accordion", "Violin", "Saxophone", or "Drums"), and another key for fruits (i.e. the words "Orange", "Apple", "Banana", "Pear", "Pineapple", or "Strawberry").

Results

As in the previous experiments, incorrect responses and RTs exceeding 2 sec (less than 1% of the correct responses) were excluded from the latency analysis. Data from two subjects whose RTs were exceptionally slow (718 msec and 703 msec; 1.9 and 1.8 SD from the group mean of 504 msec) were also excluded. Mean correct reaction times and error rates in the response-competition task were computed for each level of congruency (*Congruent* and *Incongruent*) and for each condition of the interleaved displays (*Blank*, *House*, and *Face*). The intersubject means of these RTs and accuracy rates are shown in Table 6.3.

Table 6.3 Mean Reaction Times (in msec) and Error Rate (%) Across Subjects (n=22) as a Function of Distractor Congruency and Display Condition in Experiment 11.

	Distractor congruency				Effect size	
	I		*C*		I-C	
Display cond.	RT	%E	RT	%E	RT	%E
Blank	718	7	658	4	60	3
House	706	7	662	4	44	3
Face	712	7	654	5	58	2

Note. *I* = Incongruent; *C* = Congruent.

A two-way within-subjects ANOVA on the mean RT data in the response-competition task found the usual main effect of congruency [F(1,21)=107.06, p

$< .001$] with slower responses to incongruent displays, but no main effect of display condition [$F < 1$]. The main effect of congruency was modified by an interaction with display condition [$F(2,42)=4.56$, $p < .02$]. Planned contrasts on this interaction revealed surprisingly that interference effects from the distractor face were significantly smaller in the *House* condition than in either the *Blank* condition [$t(1,21)=2.14$, $p < .02$] or the *Face* condition [$t(1,21)=1.79$, $p < .04$]. However, the *Blank* and *Face* conditions were not significantly different from each other [$t < 1$].

As in Experiments 9 & 10, analysis of the error data in Experiment 11 found only a main effect of congruency [$F(1,21=62.73$, $p < .001$] with more errors for incongruent trials. There were no other significant effects in the analysis of error rates ($p > .10$ for all comparisons).

<u>Discussion</u>

The results of Experiment 11 showed surprisingly that interference effects from a nonface distractor object (a musical instrument or a fruit) were unaffected by the advance presentation of a passively-viewed anonymous face, but were significantly diluted by the advance presentation of a passively-viewed nonface object from another category (a house). Note that this is the opposite pattern of dilution to that seen in Experiment 10, in which interference effects from a distractor face were diluted by advance presentation of another face, but not by a nonface object. These results contrast with those of Chapter 3, in which interference effects from a critical nonface distractor object (again, a musical instrument or a fruit) could be diluted by the concurrent physical presence of either an anonymous face or another nonface stimulus (i.e. a scrambled face in

Experiment 4). The current findings thus seem to rule out straightforward attentional capture by faces, regardless of task-relevance, as an explanation for the dilution produced by passively-viewed advance faces in Experiment 10. If a task-irrelevant face always captures attention, regardless of the nature of the relevant task, then the passively-viewed advance faces should have produced equivalent dilution in Experiments 10 & 11, despite the change in response-competition task (as was the case for concurrently presented additional faces in Chapter 3). Surprisingly, despite the lack of dilution from a face presented in advance, a nonface object (a house) presented in advance now produced significant dilution of response-competition effects from a nonface distractor. Experiment 11 thus provides the first instance of a nonface object producing greater dilution than a face. Moreover, this dilution was observed even though the nonface objects in the response-competition displays (musical instruments and fruits) were semantically unrelated to those in the preceding displays (houses), other than falling into the same general domain of nonface objects. Thus, while the dilution effects observed in Experiments 10 & 11 both appear to exhibit some degree of category specificity (whereby interference from a face was diluted by another face but not by a nonface object, and interference from a nonface object was diluted by another nonface object, but not by a face), the categories involved are clearly not straightforward semantic categories. All these points are considered further in the concluding chapter.

The main findings of the present chapter can be summarised as follows. First, interference effects from a critical distractor face can be diluted by actively maintaining an image of a face or a building in VSTM. Second, interference effects from a critical distractor face can be diluted merely by passively viewing a face (but not a building) 1500 msec beforehand. Third, interference effects from a critical nonface distractor (e.g., a musical instrument or a fruit) can surprisingly be diluted by passively viewing a building (but not a face) 1500 msec beforehand.

Chapter 7

General Discussion And

Future Directions

The introduction to this thesis argued that faces might constitute a special class of stimuli for visual attention, due to their inherent biological significance. Specifically, I suggested that faces may be particularly difficult stimuli to ignore, and may be processed even under attentional conditions that allow other types of stimuli to be excluded from processing. A series of 11 experiments examined this possibility by using on-line distractor interference measures, or incidental memory measures, to assess the processing of irrelevant face or nonface distractors. These distractors were presented in situations that either involved potential spatial competition between distractors (i.e. a critical distractor and additional distractor presented simultaneously in different locations; e.g., Chapters 2-4), or involved manipulations in the perceptual load of a relevant task in the absence of such spatial competition (Chapters 5 & 6).

Chapters 2 & 3 examined the conditions under which a task-irrelevant face or nonface distractor can be successfully ignored, to reduce or eliminate interference effects arising from the processing of that distractor. Experiments 1-3 found that a task-irrelevant famous face in the display can produce interference effects (response competition) in a famous name categorization task (i.e. classifying printed famous names as pop-stars' vs. politicians'), even when the target name and distractor face are spatially well-separated (cf. Young et al., 1986). More importantly, although these interference effects from the famous distractor faces could be consistently diluted by the addition of another intact, upright face to the display, they were unaffected by the addition of a 'nonface' object (e.g., a scrambled face in Experiment 1, an inverted face in Experiment 2, or a meaningful nonface object in Experiment 3). By contrast, in Experiment

4, response-competition effects from an irrelevant nonface object (e.g., a fruit or a musical instrument) in a categorization task for object names (i.e. classifying printed words as fruits versus musical instruments) could be diluted not only by the presence of an additional distractor face (i.e. by a distractor which was not from the task-relevant categories), but even by a scrambled face. Thus while distractor interference from nonface objects (such as fruits and musical instruments) can apparently be diluted by the mere addition of any competing visual stimulus, however meaningless, interference from famous distractor faces seems to be diluted only by the presence of another intact, upright face.

Conceptually similar results were obtained in Chapter 4, which used a very different measure to assess the processing of distractor faces. Here the studies compared incidental memory for anonymous faces (Experiment 5) and nonface objects (Experiment 6) that had previously been presented as task-irrelevant items during an unrelated colour categorization task. These task-irrelevant items could appear either alone at exposure, or accompanied by an additional face or nonface object. A surprise recognition test was then used to measure incidental memory for the items, as a function of the class of accompanying clutter at initial exposure (i.e. either a face or a nonface object). Subjects typically exhibited considerable memory for distractor faces that had been presented alone, even though these faces were anonymous, and completely unrelated to the relevant task at exposure. Moreover, while this incidental memory for an irrelevant distractor face could be significantly diluted by the presence of another face in the initial display, it was unaffected by the presence of a meaningful nonface object (e.g., a butterfly or a leaf). By contrast, Experiment 6 showed that incidental memory for task-irrelevant nonface objects (e.g., items of household furniture) could be diluted by adding either another nonface object or a face to the initial display. Chapter 4 thus provides converging evidence that task-irrelevant faces may be harder to ignore than other classes of task-irrelevant stimuli; or at least that the processing of distractor faces may draw on specific capacities, such that it is most 'diluted' by presenting additional face stimuli that draw on the same capacities. Both on-line processing (Chapters 2 & 3) and later memory (Chapter 4) of task-irrelevant faces seem to be relatively impervious to disruption by nonface clutter, since they are diluted only by the presence of another face at the time of exposure. On the other hand, both on-line processing and later memory of nonface objects can be disrupted by adding either a face or a nonface object to the display, as shown in Chapters 3 & 4.

In view of these apparently face-specific effects, the next series of studies sought to establish whether face processing can ever be disrupted by nonface processing. To this end, the two experiments of Chapter 5 (Experiments 7 & 8) examined whether incidental memory for task-irrelevant faces could be affected by the level of relevant perceptual load at the time of encoding, even when unrelated to faces (note that the manipulations of the preceding chapters had all concerned the load imposed by irrelevant distractor items instead). I found that incidental memory for faces could indeed be affected by the level of relevant load, even though the relevant task was completely unrelated to face processing (i.e. target letter detection tasks or colour categorization for a letter string). In both experiments, incidental memory was significantly poorer for faces that had appeared under conditions of high relevant task load during initial exposure, compared with faces from the low load condition. Thus while irrelevant face processing may be less susceptible than other forms of irrelevant visual processing to disruption by perceptual clutter (as Chapters 2-4 seem to show), it can nevertheless apparently be disrupted by relevant processing of sufficiently high load, even if this relevant processing does not involve faces. Note that this finding is not necessarily inconsistent with the claim that faces may be particularly difficult distractors to ignore, since the level of relevant load required to exclude a distractor face from processing might be higher than that needed to exclude other classes of distractor, as future studies could test. However, the result does suggest that task-irrelevant face processing depends to some extent on the availability of general processing resources, and not just face-specific capacity. Given that, in other studies, perceptual load has been shown to modulate activity in relatively early visual areas (e.g., motion-related activity in V5; Rees et al., 1997), one possibility is that faces presented under conditions of high load in Experiments 7 & 8 in the current studies were excluded at some early stage of analysis; that is, before reaching any putative face-specific processing system.

Chapter 6 provided further evidence that task-irrelevant face processing can sometimes be reduced when relevant nonface processing exhausts perceptual resources. Specifically, Experiment 9 found that interference effects from an irrelevant distractor face can be diluted by either a face or a nonface object (e.g., a house) when this is actively maintained in visual short-term memory (VSTM). This result extends the previous findings by demonstrating 'dilution' effects from task-relevant stimuli that are not physically present in the same display as the critical distractor face: merely maintaining an image of a house or an anonymous face in VSTM seems to be enough to reduce the interference effect from a distractor face at fixation. Crucially however, if the house or anonymous face becomes irrelevant to the subject's task, so that it can merely be passively viewed instead of being actively maintained in VSTM, the pattern of dilution of face interference effects reported in Chapters 2 & 3 returns. Thus Experiment 10 showed that interference from a critical distractor face could be diluted by a passively-viewed face in the preceding display, but not by a passively-viewed house. This contrast between Experiments 9 & 10 seems to highlight the central importance of task relevance in determining whether a nonface object can dilute interference from a task-irrelevant face. Although the processing of a task-irrelevant face can be reliably diluted by another face, regardless of whether this additional face is relevant or irrelevant to the subjects' task (as seen in Experiments 1-3, 5, 9, and 10), nonface objects apparently produce no such dilution when task-irrelevant (Experiments 1-3, 5, and 10). Thus, nonface processing can apparently disrupt task-irrelevant face-processing only when it is task-relevant (as in Experiments 7-9).

Finally, Experiment 11 tested whether interference effects from a critical nonface distractor object could be diluted by a passively-viewed anonymous face or nonface object in the preceding display. The surprising result was that while interference effects from a critical nonface distractor object (e.g., a musical instrument or a fruit) were unaffected by the previous presentation of a passively-viewed anonymous face, they were significantly diluted by the previous presentation of a nonface object from another category (e.g., a house). This is the opposite pattern of dilution to that seen in Experiment 10 (in which interference effects from a distractor face were diluted by advance presentation of another passively-viewed face, but not a nonface object). It thus seems to rule out general attentional capture by faces as a sufficient explanation for the face-specific dilution observed in Experiment 10: if a previously presented face always captured attention, regardless of the nature of the relevant task, then faces should presumably have produced equivalent dilution in Experiments 10 & 11 (as was the case for concurrently presented additional faces in Experiments 3 & 4). As it turned out however, Experiment 11 provided the first instance of dilution in a nonface task by a task-irrelevant nonface object (from a different category), without corresponding dilution by a task-irrelevant face. Given that the processing of nonface objects was apparently diluted by faces and nonface objects alike when these were presented as concurrent distractors in Experiments 4 & 6, this seemingly object-specific dilution may at first sight seem somewhat discordant; why should a face dilute an object interference effect in Experiments 4 & 6, but not in Experiment 11? One way to resolve this apparent discord may be to consider the role of spatial competition in each case. Experiments 4 & 6 necessarily involved spatial competition between the critical nonface object and the diluting face, because these stimuli were presented alongside each other concurrently in the same displays. However, such spatial competition cannot have arisen in Experiment 11, in which the critical face and nonface object were presented in successive rather than concurrent displays.

All of the findings in this thesis may be explained if faces are special in two specific senses. First, faces seem to be particularly strong competitors for attention, even when task-irrelevant, such that they will capture more attention than a task-irrelevant nonface object when presented concurrently in the same display. This could explain why both on-line processing (Experiment 4) and later incidental recognition memory (Experiment 6) of a task-irrelevant nonface object could be diluted by adding a concurrent face to the display at exposure. It could also explain why adding a nonface object to the display failed to dilute either online processing of faces in Experiments 1-3, or incidental memory for faces in Experiment 5. In each of these cases, involving spatial competition between a concurrently-presented face and a nonface object, the face seems to have monopolized attentional resources, to the detriment of the accompanying nonface object. This conclusion converges with recent claims of enhanced attention capture for faces, based on studies of change blindness in normals (Ro et al., 2000) and extinction in patients with spatial neglect (Vuilleumier, 2000).

The second sense in which faces may be special, as suggested by the combined results of this thesis, is that they may draw on a highly face-specific capacity with its own face-specific capacity limits. This could explain why processing of a task-irrelevant face could be disrupted by adding another concurrent intact upright face to the display, but not by adding a scrambled face (Experiment 1), an inverted face (Experiment 2), or a concurrent meaningful nonface object (e.g., a musical instrument or a fruit; Experiment 3), assuming that the latter three types of stimulus do not draw on face-specific capacities. It could also explain the similar finding in Experiment 5, in which incidental memory for a face was reduced by the presence of another face at the time of exposure, but not by the presence of a nonface object (e.g., a butterfly or a leaf). Both of these findings can be interpreted as evidence that face-processing involves limited face-specific resources that are not involved in other types of visual processing. If demand for these face-specific resources cannot be met, face processing suffers as a result. Alternatively, one could argue that these findings too might be explained in terms of straightforward attentional capture by faces. Thus, one might argue that the reason face processing is disrupted only by an additional face, and not by other types of clutter, is <u>not</u> that only another face loads the same face-specific capacity, but rather that only another face can compete for general attentional capacity on equal terms.

On the evidence of Chapters 2-4 alone, there seems to be little reason to favour either of these accounts over the other. However, the findings of Chapter 6 may be more decisive. As pointed out in the discussion of Experiment 11, if faces always capture general attention, but do not draw on any more specific capacities, then they should presumably always dilute interference from face and nonface distractors alike. Clearly this is not always the case. As Chapter 6 shows, in the absence of any spatial competition between concurrent items (i.e. with successive rather than simultaneous displays), a 'double dissociation' can emerge whereby an additional face dilutes interference from a distractor face but not an object, while an object dilutes an object but not a face. Double dissociations of this kind are generally taken as evidence that two processes are functionally separable to some extent. Certainly, it would be difficult to account for the pattern described solely in terms of general attention capture always being stronger for faces. Any account based on task-relevance alone would also encounter problems, as there is no reason to suppose that the category of nonface objects that were passively viewed in Experiment 11 (houses) was any more relevant to the task-relevant categories of musical instruments and fruits than are faces. It thus seems unavoidable that to account for the findings of Chapter 6, one has to appeal to the idea that faces load some capacity-limited process that other objects do not load, while conversely, nonface objects may load some other capacity-limited process that is not loaded by faces. These proposals are incompatible with any claim that face processing may be fully automatic in the sense of being capacity-free (i.e. operating regardless of the number of faces present), but is entirely consistent with recent evidence from neuroscience (e.g., Kanwisher et al., 1997; 2000) and neuropsychology (e.g., Farah, 1995; Farah, Levinson & Klein, 1995; Farah, Wilson, Drain & Tanaka, 1995; McNeill & Warrington, 1993) that faces may engage a specialized face-processing system.

Allowing some dichotomy between face processing and nonface processing may also help to explain one aspect of Experiments 4 & 6 that a 'capture' model alone cannot accommodate, namely the finding that faces and nonface stimuli disrupt object processing to a similar extent when presented in the same displays. Introducing the notion of separable capacity-limited systems for faces and nonface objects seems to provide some leverage here, as it opens the possibility that faces and nonface objects may disrupt the processing of nonface objects for different reasons. For example, a nonface object may disrupt object processing because it taps some specialized nonface processing system, whereas an intact face may disrupt it because faces are particularly powerful distractors.

Clearly, this point is somewhat speculative, being based largely on post-hoc reasoning. Moreover, it may seem somewhat unsatisfactory to attribute two similar effects to two different causes. It is not logically inconsistent to do so however, and in this case, it is difficult to see how any more parsimonious interpretation could be squared with the corpus of data taken together.

So far, this discussion has been concerned with the processing of task-irrelevant distractors presented under conditions of low relevant load, while the number and type of any additional distractors was manipulated. However, as Experiments 7-9 show, irrelevant face processing can be disrupted by task-relevant load, even in a nonface task, provided the load of that task is high enough. These findings suggest that although faces may interact with attention in special ways, as described above, face processing may nevertheless be constrained by some general attentional principles. In particular, face processing, like other forms of visual processing, seems to depend on the availability of general attentional resources to some extent. In view of Rees et al.'s (1997) finding that even relatively low-level visual processing (i.e. processing of task-irrelevant radial motion) can suffer if attentional resources are not available, this may be less surprising. After all, specialized face-processing can presumably only follow face detection, which in turn presumably depends on relatively low-level visual processing. However, this raises the interesting possibility of a potential 'bottleneck' in face processing at some relatively early stage. It may yet be that, subsequent to face detection, face processing is conducted by a capacity-limited, face-specific system that does not require general attentional resources for its operation. However, if any processing prior to face detection relies on general attentional resources, then a shortage of such resources will inevitably affect later stages of face processing as well. Thus, the finding that irrelevant face processing suffers if general attentional resources are unavailable does not guarantee that specialized face processing *per se* draws directly on those resources. It may be that face processing itself is independent of general attention, but follows stages of processing that are not.

According to the interpretation advanced in this discussion, faces may be particularly strong competitors for attention, such that they typically capture more attention than competing nonface objects in concurrent displays that induce spatial competition. Moreover, they seem to draw on a highly face-specific capacity with its own (face-specific) capacity limits. Despite being special in these two senses however, face processing is evidently subject to perceptual load at some stage, since task-irrelevant faces undergo less processing (at least, as evidenced by less subsequent memory) during a high load relevant task that is unrelated to faces.

Quite apart from their theoretical interest, these findings and conclusions have several potential implications for face processing in the real world. Consider the conditions that were found here to disrupt the processing of an irrelevant face presented clearly on the retina: i) concurrent presence of another irrelevant face; ii) recent presence of another irrelevant face that is no longer visible; and iii) active maintenance of a stimulus in VSTM. In addition, consider the conditions shown to impair subsequent incidental memory for irrelevant faces: i) concurrent presence of another irrelevant face; or ii) performing some unrelated but perceptually demanding task at the time of initial exposure. It seems plausible that at least some of these conditions are encountered fairly frequently in everyday life. For example, situations in which several faces are visible simultaneously are presumably quite common. Indeed, in some settings, such as the densely populated city where this thesis was generated, seeing a single face in spatial and temporal isolation might be a relatively rare occurrence! The impact of internal imagery and/or perceptual load on face processing in everyday life is clearly harder to assess, but an exploration of how these factors affect practical performance might help to predict breakdowns in face perception and face recognition more accurately, and may even suggest practical strategies for overcoming such difficulties. At the very least, the current findings urge caution in assessing the reliability of eyewitness testimony (Wells, 1993; Wells et al., 2000); it seems that for faces viewed under any of the conditions described above, eyewitness identification would not be very reliable at all.

Despite the progress made in the current research, several theoretical issues remain unresolved. Perhaps the most pressing of these issues is whether spatial competition does indeed play a critical role in determining whether a face disrupts the processing of a nonface object, as suggested above. Recall that in Experiment 4, interference based on the processing of a nonface distractor object could be diluted by adding either an intact face or a scrambled face to the display. However, in Experiment 11, interference from the same distractor objects was unaffected by an intact face in the preceding display, despite showing the expected dilution from a preceding nonface object of an unrelated category. The foregoing discussion suggested that the reason for this discrepancy may be that Experiment 4 involved spatial competition between the irrelevant face and nonface stimuli when presented concurrently in the same displays, whereas Experiment 11 involved no spatial competition because the face and nonface stimuli were presented singly in successive displays.

However, a possible alternative would be to attribute the discrepancy to some special property of houses that is not shared by other nonface objects. For example, it may be that houses are more attention-grabbing than the other classes of nonface object tested, although this seems unlikely. One way to test this possibility would be to devise a variation of Experiment 4 using critical distractor houses. If faces generally capture more attention than concurrently-presented nonface objects, they should dilute interference even from critical distractor houses. On the other hand, if houses behave differently to other classes of nonface object, interference effects based on their processing might be diluted by adding another nonface object to the display, but not by adding a face.

A related issue concerns the apparently object-specific capacity limits seen in Experiment 11. If objects as diverse as houses, musical instruments, and fruits all tap into some common nonface system, then clearly this must be fairly broad in scope. By testing whether other classes of nonface stimuli (e.g., other categories of meaningful object; 2D shapes; words) also load this system, it should be possible to determine its function more precisely. In particular, if the observed split between faces and objects reflects an underlying split between configural versus part-based processing (as proposed by Farah, 1995), then one strong prediction is that words may disrupt interference from objects more than they disrupt interference from faces, since according to Farah's (1995) model, words rely most heavily on part-based processing. This prediction could be tested quite easily using variations of the designs used here, in which printed words could be used as additional distractors.

Similarly, although the putative face-specific system seems to be remarkably finely tuned to intact faces (e.g., it is apparently not engaged by inverted or scrambled faces), it is still not clear exactly what counts as a face in terms of the dilution effects observed. It might be interesting to examine whether various degraded face stimuli, such as distorted photographic faces or schematic faces, or even nonface stimuli that resemble faces in terms of their configuration (e.g., frontal views of cars, face-like patterns in clouds or woodgrain etc.) produce similar effects to intact photographic faces (see Tong, Nakayama, Moscovitch, Weinrib & Kanwisher, 2000).

Another issue which merits further investigation is whether the level of task-relevant perceptual load required to disrupt irrelevant face processing is higher than that required to disrupt other types of irrelevant processing (e.g., processing of task-irrelevant nonface objects). The present research provides the first demonstration that sufficiently high load in relevant nonface processing can reduce the effect of irrelevant face distractors. However, given that faces seem to be particularly difficult distractors to ignore, in as much as they are less easily affected by 'clutter' in the visual scene (see Chapters 2-4), it is possible that they may also be somewhat more resistant to increases in relevant perceptual load, suffering less than other, nonface distractor objects. This possibility could be examined using an adaptation of the flanker paradigm used in Chapters 2 & 3. By varying the load of the central name categorization task (e.g., by presenting the target name alone versus embedded in a list of unfamiliar names), one could measure interference effects from a critical distractor face in the periphery as a function of relevant load. Contrasting results from this condition with a control condition in which subjects categorize single versus embedded words while ignoring a critical nonface distractor object (whose congruency is manipulated) should allow the impact of relevant load on face and nonface distractor processing to be compared directly.

Any differential effects of relevant perceptual load on incidental memory for faces and nonface objects could also be assessed, again by using variations of experiments reported here. For example, as long as care was taken to match 'baseline' performance in the low load condition, one could directly compare the effects of increased relevant load on incidental memory for task-irrelevant faces (as observed in Experiments 7 & 8) versus task-irrelevant nonface objects. Such a comparison could reveal whether faces may be special in the further sense that face encoding suffers less than object encoding when attentional resources are scarce.

One general way to extend this line of research would be to explore possible cross-modal interactions between attention and face processing. For instance, it may be that distractor faces only affect the processing of other visually-presented distractors, and would not affect the processing of auditory distractors. Moreover, irrelevant face processing may be completely unharmed by increased perceptual load in an auditory task. Testing such possibilities may help to clarify whether the 'general' attentional resources involved to some extent in face processing are modality-specific, despite generalizing across a wide variety of tasks within that modality; or whether instead they are truly general in the sense that they transcend modality altogether.

Regardless of whether or not the attentional capacity limits involved turn out to have some modality-specific component, the present claim that face processing taps some general attentional capacity, as well as face-specific capacity, is subject to the following caveat. As discussed earlier, a relevant task may need only to disrupt the visual processes that precede initial face detection in order to disrupt face-processing as a whole. That is, anything that modulates initial processing of input which later feeds into specialized face processing will necessarily have some effect on the latter. It does not follow from this that specialized face-processing proper (as distinct from early analysis of a scene that contains an as-yet-undetected face) also draws on general attentional resources.

Perhaps one way of disentangling any role of general attention in face processing from its role in earlier visual processing would be to examine whether manipulating the perceptual load of a relevant task modulates more implicit effects, such as priming, from a task-irrelevant face in the display. The memory studies in this thesis measured only explicit recognition memory for faces. Since priming can provide a measure of more implicit processing, it is possible that some priming might be obtained even from previously exposed faces that cannot be explicitly recognized as being previously exposed. A dissociation of this kind could suggest that increasing perceptual load does not disrupt face processing simply by starving early visual processes of attention; it is difficult to see how a photo of, say, Madonna's face in one display could prime a different photo of her face in a later display if the prime face had never even been extracted from the initial image.

In summary, this thesis demonstrates that attentional paradigms can be fruitfully applied to the topic of face processing, and establishes several new facts about face processing that may have both practical and theoretical implications. In doing so, it takes some steps towards uniting two major fields of cognitive research (namely, attention and face processing) that have traditionally proceeded independently. It also identifies specific directions for future research. The present results already show that we will never understand face processing fully unless we take attentional principles into account, as they demonstrate that both on-line face processing and later memory for faces can be substantially modulated by attentional factors.

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