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Self Priming in Face Recognition

Andrew J. Calder

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Abstract

Recently Burton, Bruce and Johnston (1990) have presented an interactive activation and competition model of face recognition. They have shown that this IAC model presents a parsimonious account of semantic and repetition priming effects with faces. In addition, a number of new predictions are evident from the model's structure. One such prediction is highlighted by Burton *et al.* themselves - that for short prime-target stimulus onset asynchronies (SOAs) a face should prime the recognition of a target name (or *vice versa*), 'self priming'. This thesis examined this prediction and found that it held for a design in which items were repeated across prime type conditions (same, associated, neutral and unrelated). Further, cross (face prime/name target) and within-domain (name prime/name target) designs were found to produce equivalent degrees of self and semantic priming (Experiments 1 and 2). Closer examination of the Burton *et al.* model suggested that the effect of domain equivalence for self priming should not hold for a design in which the stimulus items are not repeated across prime type conditions (i.e. subjects are presented with each item only once). This prediction was confirmed in Experiments 3, 4, 5 and 6.

The time courses of self and semantic priming were investigated in two experiments where the interstimulus interval (ISI) between prime and target, and prime presentation times were varied. The results proved difficult to accommodate within the Burton *et al.* model, but it is argued that they did not provide a sufficient basis on which to reject the model.

Finally, the self priming paradigm was applied to the study of distinctiveness effects. Faces judged to be distinctive in appearance were found to produce more facilitation than faces judged to be typical in appearance. Similarly, caricatured representation of faces were found to produce more facilitation than veridical or anticaricatured representations. The results of the distinctiveness studies are discussed in terms of the Valentine's (1991a; 1991b) exemplar-based coding model and Burton, Bruce and Johnston's (1990) IAC implementation.

It is concluded that the results of these experiments lend support to the Burton *et al.* model.

To
my mother
and father with love and thanks

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Finally, thanks to the Medical Research Council for their financial support.

Declaration

This research was carried out by the author between October 1990 and March 1993 at the University of Durham. I declare that the work contained in this thesis is my own and that no part has been previously submitted in candidature for any other degree.

Statement of Copyright

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Table of Contents

List of Tables

List of Figures

1 Repetition and semantic priming in face recognition

1.1 A short historical perspective of priming paradigms in the study of face recognition

Approximately ten years ago Bruce presented a series of papers that called for a different approach to the study of face perception (Bruce, 1979; Bruce, 1981; Bruce, 1983). Bruce noted that the majority of studies within the area examined episodic memory for unfamiliar faces (Bruce, 1983). Further, the high performance generally observed on these laboratory experiments contrasted with the high number of mistaken identities recorded in reviews of eyewitness testimonies (Devlin, 1976). In retrospect, it would seem inappropriate to base the study of verbal memory on tasks that examine subjects' episodic memory for non-words (or words with which they were unfamiliar), yet subjects were being asked to carry out analogous tasks in the study of face perception. To be fair there are obvious ecological applications of studies involving memory for previously unseen (unfamiliar) faces (e.g. eyewitness testimony see Clifford and Bull, 1978; Loftus, 1979; Yarmey, 1979), and Bruce recognized these arguments. Notwithstanding, she argued that face research should adopt a 'systematic and functional approach to facial memory', and suggested that this approach should be founded on the methodological paradigms of the verbal memory literature.

Bruce (1983) was not the first to express concern with the course that face research had followed (Ellis, 1975), nor was she alone in her attempt to gain a greater theoretical insight into the processes of face perception (Hay and Young, 1982). Nevertheless, her directive is seen as a significant contribution to the area for two principal reasons, (i) her suggestion that by studying our ability to recognize the familiar faces that we encounter in

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everyday situations, we would be in a better position to understand episodic memory for unfamiliar faces and, (ii) that plausible methodologies to carry out studies of this type, were to be found in the literature on verbal memory.

Bruce's call for a new approach to the study of face perception was not left unheeded, and has greatly influenced the course of face research over the last decade. This is perhaps most evident in the number of studies that have employed a face familiarity decision task; Bruce's 'face equivalent' of the lexical decision task, where familiar and unfamiliar faces are analogues of words and non-words respectively. The lexical decision and face familiarity tasks are probably most associated with priming effects, of which there are two forms that have been most often studied, repetition priming and semantic priming. The former refers to the speeded recognition of a stimulus on its second or subsequent presentation(s), and the latter refers to the facilitated recognition of a stimulus when it is preceded by a related stimulus. Following Bruce's initiative (1979; 1981; 1983) repetition and semantic priming paradigms have been used extensively in face research, and have contributed significantly to our present understanding of the structure of 'face memory' (Brennen and Bruce, 1991; Bruce, 1986; Bruce, Dench and Burton, 1992; Bruce and Valentine, 1985; Bruce and Valentine, 1986; Brunas, Young and Ellis, 1990; Brunas-Wagstaff, Young and Ellis, 1992; de Haan, Bauer and Greve, 1992; Ellis, Young and Flude, 1990; Ellis, Young, Flude and Hay, 1987; Ellis, Ellis and Hosie, 1993; Flude, Young and Ellis, 1991; Roberts and Bruce, 1989 ; Young, Hellawell and de Haan, 1988; Young, McWeeny, Hay and Ellis, 1986b; Young, Newcombe, Hellawell and de Haan, 1989).

In the remainder of this chapter a review of the face priming literature is presented. The general impetus behind these studies has been the goal of achieving a greater insight into the face recognition system. A number of models attempting to formulate the structure of the recognition system have been proposed (Bruce and Young, 1986; Ellis, 1986; Hay and Young, 1982). Of these models, Bruce and Young's (1986) functional model of face recognition was generally regarded to be the best structural account of face recognition. More recently, however, Burton, Bruce and Johnston (1990) have proposed an interactive activation and competition (IAC) model of face recognition, which seems to present a fuller account of the data. In its most basic form, Burton *et al.*'s IAC model is a computer implementation of Bruce and Young's modular account. It therefore seems pertinent to consider first the structure of the Bruce and Young model before going on to discuss the priming literature and Burton *et al.*'s (1990) computer implementation.

1.2 The Bruce and Young (1986) functional model of face recognition

Figure 1.1 shows a schematic representation of the Bruce and Young (1986) functional model of face recognition. The model is comprised of four parallel processing routes concerned with expression analysis, lip reading, directed visual processing and recognition. The Burton *et al.* model is a computer implementation of the recognition route, and consequently, the other three channels are not considered further.

Bruce and Young suggest that at the initial stages of structural encoding, view-centred descriptions are produced, and that these in turn give rise to expression independent descriptions, which are able to access the face recognition unit (FRU) for a given face. The view-centred descriptions and expression-independent descriptions can be thought of as being analogous to view-centred and object centred representations (Marr, 1982; Marr and Nishihara, 1978) respectively.

The FRUs were originally conceived as analogues to Morton's (1979) logogens, and contained abstract view independent representations of faces, which were activated on an all or none basis (Hay and Young, 1982). However, Bruce and Young (1986) modified this definition and suggested that the FRUs indicate the degree of resemblance between a face input (structural description) and the FRU representation.

The person identity nodes (PINs) are defined as mediators, accessing semantic information relating to a person, and receiving input from a person's face code, name code and voice code etc. (Ellis *et al.*, 1987). Whereas recognition of a person's face is located at the FRUs the recognition of all other input codes, for name, voice etc., are deemed to occur at the level of their corresponding recognition units. Following the PINs is the name generation component where the representation of a person's name is held. Thus name output representations can only be accessed via the PINs.

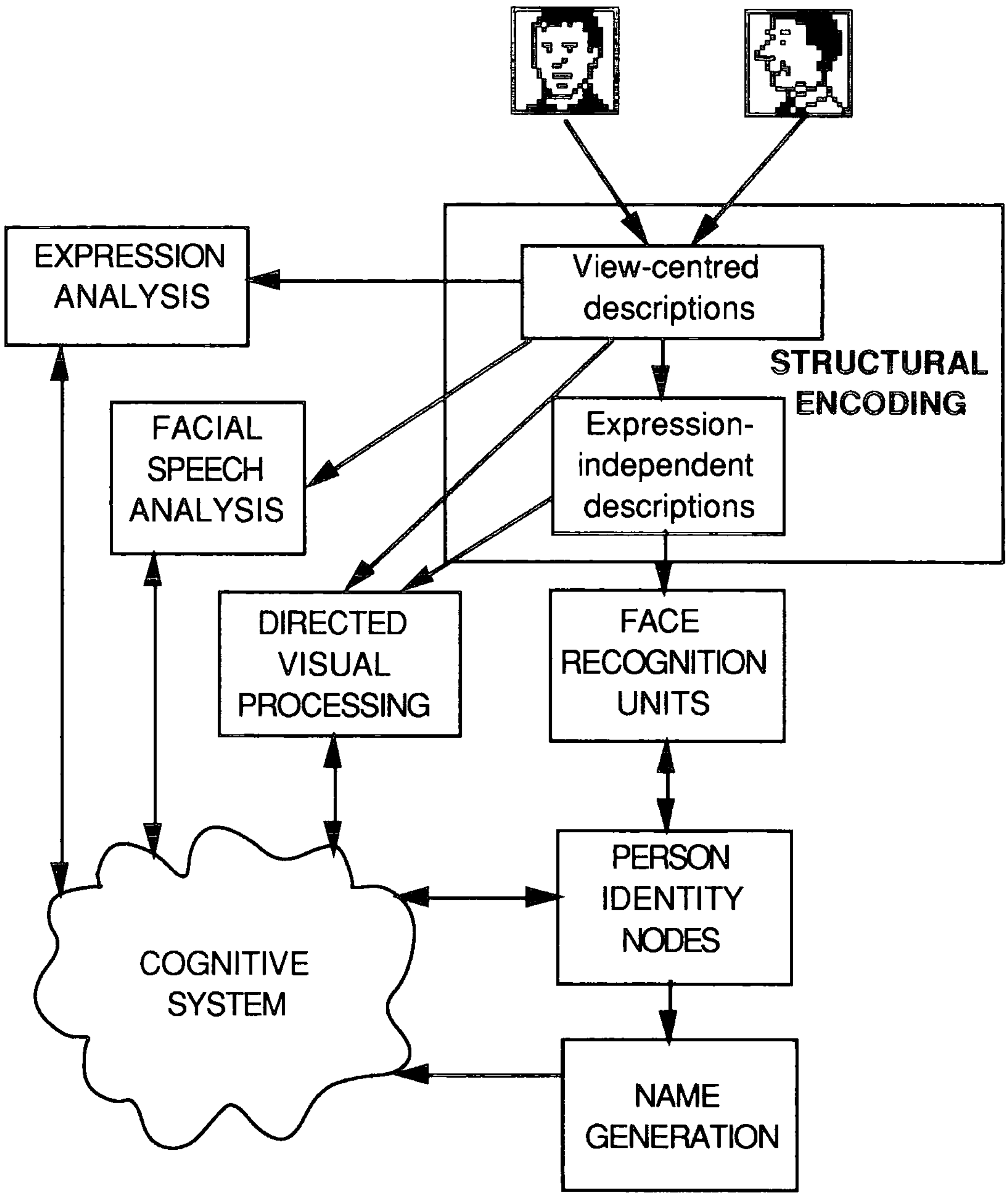


Figure 1.1: The Bruce and Young (1986) functional model of face recognition.

As with any functional model, Bruce and Young's architecture makes a number of predictions regarding its structure, and the nature of the face representations. Priming paradigms have been used extensively to investigate these issues and in the remainder of this chapter, a number of repetition and semantic face priming studies are reviewed.

1.3 A selective review of repetition priming

Scarborough, Cortese and Scarborough (1977) found that in a lexical decision task, subject's response times were faster to the second presentation of a word than its initial presentation. Further, they found that this effect did not diminish over time, nor was it affected when the prime and target were visually dissimilar (upper and lower case font). This is the phenomenon of repetition priming. Both of these observations were significant, as they suggested that repetition priming was long lasting (at least up to 15 intervening stimuli), and that it was not perceptually motivated, as priming persisted across the different font types. Instead, priming appeared to be located at a mnemonic level; a conclusion that was supported by the observation that repetition priming with words and non-words produce different effects (Forbach, Stanners and Hochaus, 1974; Scarborough *et al.*, 1977).

Since these early examples of repetition priming, there has been an explosion in the number of studies investigating the phenomenon. Extensions of the basic paradigm are to be found in word fragment completion tasks (Tulving, Schacter and Stark, 1982), paired recall tasks (Warrington and Weiskrantz, 1970) object decision tasks (Schacter, Cooper, Delaney, Peterson and Tharan, 1991), and neuropsychological studies (for a review of priming in amnesics see Shimamura ,1986 for priming in prosopagnosics see de Haan *et al.*, 1992; Young *et al.*, 1988; Young *et al.*, 1989). A number of authors have suggested that such dichotomous tasks as object decision and familiarity decision have different underlying mechanisms (Monsell, 1991; Tulving and Schacter, 1990). Nevertheless, the results of studies investigating priming with words, objects and faces have produced consistent results and there is strong evidence to suggest that the mechanisms underlying priming in all three domains are very similar (Bruce and Young, 1986).

1.3.1 Domain-specificity in repetition priming

The lexical literature provides strong evidence to suggest that repetition priming does not cross stimulus domains (i.e. visually presented words, orally presented words, semantic definitions, pictures of objects) (Clarke and Morton, 1983; Jackson and Morton, 1984; Morton, 1979; Warren and Morton, 1982; Winnick and Daniel, 1970). Winnick and Daniel (1970) investigated whether reading written words aloud, naming pictures aloud or verbalising words aloud in response to their definitions primed the later presentation of the same words in a written format. They found that subjects' recognition thresholds for written words were lower, if they had earlier seen the word in its written format. Recognition thresholds for words that had been presented as pictures or definitions did not differ from the control condition. Clarke and Morton (1983) replicated and extended this finding by showing that auditory presented words did not prime their later visual presentation. Of more relevance to the study of face recognition, Warren and Morton (1982) demonstrated that the presentation of an object's name in a pre-training phase did not prime the recognition of a picture of the same object in a later test phase. However, priming was found to extend between two pictures of an object, regardless of whether the two pictures were the same. Hence, prior exposure to one breed of dog in a pre-training phase will prime the recognition of a dog in a later test phase, even when the test phase item is a different breed of dog. In an attempt to discover whether the effect of domain specificity also applied to face priming, Bruce and Valentine (1985) carried out an analogous study. Their results showed that a familiarity decision to a person's face was not facilitated by the earlier presentation of the same person's name. Priming was found, however, when either the same picture, or a different picture of the same face was presented, the former producing a significantly greater facilitating effect than the latter. In addition, a post-hoc analysis of the different view pictures showed no correlation between the amount of priming observed and the degree of visual similarity between the prime and the test faces; a result that mirrored Warren and Morton's (1982) findings with object and word stimuli. Bruce and Valentine explained their results in terms of two memory processes, pictorial memory and structural memory. The absence of a correlation between visual similarity and speed of recognition in the different face primed sets suggested that the priming was being generated by view independent 'face centred' units (Marr, 1982), the FRUs (structural memory). They explained the fact that maximal priming was found when the prime and target were the same picture in terms of an additive effect from a pictorial memory representation. This hypothesis is supported further by the observation that rated similarity between prime and target, and the amount of priming are correlated for unfamiliar faces (Bruce, 1982). In the case of unfamiliar face priming, the faces have no FRU representations, As such, any priming effect must be attributed to a pictorial level. On this basis Bruce (1988) has suggested that the pictorial representation should be thought of as an episodic pictorial account of the face that is updated each time the face is encountered.

1.3.2 Instance-based accounts of repetition priming

A. Ellis, Young, Flude and Hay (1987) replicated Bruce and Valentine's (1985) finding that repetition priming does not extend from a person's name to their face. Further, they extended this domain specificity by showing that no priming is observed from a person's body (with the head covered) to their face. These findings point towards the separate storage of a person's face, name and body and any other identity-specific physical attributes. In the same paper, however, they found a graded effect of face repetition priming when the prime and target stimuli were (i) the same, (ii) different, but visually similar, (iii) different, and visually dissimilar (Ellis *et al.*, 1987). Each of the three levels produced significant priming, but all three were significantly different from one another, with condition (i) producing the most priming, and condition (iii) the least. This result conflicts with Bruce and Valentine's (1985) earlier observation that there is no correlation between the degree of similarity between prime and test items and the amount of priming. However, as with Warren and Morton (1982), Bruce and Valentine's correlational study was post-hoc and therefore less sensitive than Ellis *et al.*'s design. Ellis *et al.* conclude that their results are more consistent with instance based accounts of priming (McClelland and Rumelhart, 1985) rather than the logogen type explanations offered by Warren and Morton (1982) and Bruce and Valentine (1985).

1.3.2.1 McClelland and Rumelhart's distributed model of memory

It is important at this point to note the distinctions between logogen and instance based accounts of priming. The logogen accounts dictate that a memory representation for a particular item is stored in a single abstract form. The instance based account, however, argues that a number of specific experiences or encounters with a particular item or event are overlaid to produce its representation in memory (McClelland and Rumelhart, 1985; McClelland and Rumelhart, 1986). McClelland and Rumelhart (1985) go as far as to suggest that a semantic memory representation for an item (e.g. word, object or face) may be thought of as a number of episodic traces, of the same or similar item, superimposed one over the other.

A second feature of the instance based model regards the nature of storage. In instance based models of the parallel distributed processing (PDP) type, an encounter with a particular event or stimulus produces a pattern of activation in the network. This pattern of activation leaves behind a trace; i.e an alteration in the weights of connections between units. When the same pattern is later reinstated, the initial trace enhances the perception of the reinstated pattern, hence, 'recognition' of reinstated patterns is facilitated, i.e. repetition priming. Further, distortions of the initial pattern can also activate the initial pattern's trace, but they take longer to do so. Thus the model can account for the graded priming effect reflecting the visual similarity between the prime and test item (Ellis *et al.*, 1987).

1.3.2.2 Jacoby's perceptual enhancement theory of priming

Jacoby (1983a; 1983b) has shown that the context in which a priming event takes place can have a significant effect on the amount of priming observed. On the basis of these observations Jacoby has suggested that memory representations for a particular word (or object or face etc.) are composed of a number of encounters with that word, where each encounter also includes information relating to the context in which the word occurred. Jacoby's enumeration model is different from the instance based account of memory but the difference is subtle.

Jacoby posits that a memory representation of a word is made up of the total number of perceptual encodings of that word, i.e. it is a multiplex representation. The instance based representation of the word, however, consists of a *single* composite of traces associated with that word, superimposed over each other, each new encounter altering the composite memory trace. Further, memory traces for different words are not stored in distinct composites, but coexist within the same composite memory trace. Both Jacoby's and McClelland and Rumelhart's explanations of repetition priming are instance based accounts, and both would appear to offer a better account of face repetition priming than the logogen type account originally endorsed by Hay and Young (1982).

Ellis *et al.* (1987) were careful to point out that their findings do not render face recognition units obsolete. They suggested that repetition priming effects may be located at the earlier stage of stimulus encoding. Hence, repetition priming might be conceived in terms of the re-affirmation of previously laid down patterns of distributed activation at a pre-FRU level. This is an important point as they suggest that repetition priming for faces might be situated outwith the recognition system. In a second series of experiments, Ellis, Young and Flude (1990) tested this hypothesis. They reasoned that if repetition priming was a 'pre-recognition system' effect then a response to a face should be facilitated on the second presentation of the face, regardless of the nature of the decision task. In a number of experiments Ellis *et al.* (1990) compared the effects of subjects making sex, expression and familiarity decisions in a presentation phase, to faces that were later repeated in a test phase where the nature of the decision task was also varied (one of sex, expression, familiarity). They found that the presence or absence of repetition priming was dictated by the type of the decision task in the *test phase*. Only the subject groups that made familiarity responses in the test phase, produced priming. No facilitating effect was observed for the other two decision tasks. Further, the nature of the decision task in the initial presentation phase had no effect on the amount of priming observed, suggesting that recognition of the stimulus was automatic and unstoppable (Fodor, 1983). Ellis *et al.* (1990) conclude that repetition priming is a phenomenon of the recognition system and that their results are inconsistent with perceptual episodic accounts of priming (Jacoby, 1983a; Jacoby, 1983b). Jacoby's account would predict that priming would be observed regardless of the nature of the decision in the presentation and test phases task. However, it also predcits that priming would be maximal whenever the test and training decisions were the same. Priming in these models is explained in terms of the reinstatement of a previously encoded event, and no constraints are placed on the nature of that event.

Ellis *et al.* (1990) suggest that the FRUs may be constructed on a system comparable to that suggested by McClelland and Rumelhart (1985; 1986). Hence, familiar faces are stored as a composite of superimposed instances (or experiences), in which the most recently laid down instances affect the degree of repetition priming. More recently, Brunas, Young and Ellis (1990) have found further evidence in support of a distributed representation account of face memory. They found that internal portions of faces, external portions of faces and whole faces, all primed whole faces to the same degree. These results are consistent with McClelland and Rumelhart's (1986) demonstration that incomplete inputs of items result in the activation of complete patterns. Further, they are inconsistent with Jacoby's (1983a; 1983b) episodic account of repetition priming, which would predict maximum priming for the condition in which the prime was a whole face (i.e. identical to the target).

It is interesting to note that not all repetition priming studies have produced results consistent with an instance based account. Roberts and Bruce (1989) presented subjects with a serial choice reaction time task in which the second presentation of a face could be one back or two back from the first presentation. Further, the second presentation could be the same or a different view of the face. Their results showed that the amount of priming was independent of the degree of similarity between the first and second presentations. However, they found that, independent of identity, there was an effect of face view, i.e. where a face was presented at a different angle from the one that preceded it, a recognition response to the second was slower. This result points to an effect of face structure (perceptual), as well as face identity (mnemonic) in repetition priming.

Instance-based computer models (McClelland and Rumelhart, 1985; McClelland and Rumelhart, 1986) suggest that an item is represented in memory as a composite of a number of episodic traces. Further, repetition priming is explained in terms of the reinstatement of a recently produced trace. These models are attractive as they are able to account for a number of phenomena in addition to repetition priming (e.g. frequency effects and familiarity effects). Further, they allow us to simulate these effects and produce new testable predictions. However, even the most recent and advanced attempts to model word recognition at a computational level (Seidenberg and McClelland, 1989) offer little in terms of an explanation of semantic priming (Neely, 1991).

1.4 Semantic priming

There is a well established literature on semantic priming effects in word recognition, and these studies have contributed significantly towards our understanding of the structure of verbal memory (for a review see Neely, 1991). However, it is only recently that these paradigms have been applied to understanding the nature and structure of the face recognition system (Brennen and Bruce, 1991; Bruce, 1986; Bruce *et al.*, 1992; Bruce and Valentine, 1986; Young *et al.*, 1988). Neely (1991) presents a selective review of the semantic priming in the lexical literature in which he distinguishes between a number of different sub-types of semantic priming. He cites studies that have examined the differences between associative and non-associative semantic priming (Lupker, 1984; Schreuder, Flores d'Arcais and Glazenborg, 1984; Seidenberg, Waters, Sanders and Langer, 1984). The former refers to facilitation between pairs of items that are associated and from the same semantic category, e.g. bucket - spade, or items that are associated and from different semantic categories, e.g. leaf - rake. Non-associative semantic priming refers to items that are from the same semantic category but are not associated i.e. the two words/objects are not usually encountered together, e.g. prince - boy.

With the exception of Brennen and Bruce (1991), semantic priming studies with faces have concentrated on the investigation of priming between associated pairs (e.g. Morecambe and Wise). Brennen and Bruce failed to find semantic priming effects comparable to those found for associated stimuli. Given their findings and the findings of studies investigating the nature of priming in the lexical literature (Goodman, McClelland and Gibbs, 1981; Lukatela, Kostic, Feldman and Turvey, 1983; Lupker, 1984; Schreuder *et al.*, 1984; Seidenberg *et al.*, 1984), Ellis (1992) has suggested that face 'semantic' priming may be more appropriately referred to as associative priming.

1.4.1 Posner and Snyder's automatic activation theory of semantic priming

A number of investigations of semantic priming have adopted a paradigm developed by Posner and Snyder (1975b). In view of this fact, Posner and Snyder's theory of facilitation and inhibition is discussed before going on to consider the studies themselves.

Posner and Snyder (1975a; 1975b) suggested that semantically related words activate each other by virtue of the fact that they are connected by excitatory pathways. Hence, activation of the word DOG activates the representation of the word CAT. However, semantically unrelated words are not connected by pathways, and hence have no influence on each other. Thus, activation of the word DOG has no inhibitory effect on the word TIN. In short, whereas semantically related words have excitatory effects on each other, semantically unrelated words have no inhibitory effects on each other. They argue that these effects are automatic and unconscious, but that they are altered when the subject consciously attends to the identity of a stimulus (Posner and Klein, 1973). Thus, because the mechanisms of conscious attention are limited, when a subject consciously attends to the word DOG, this has the effect of inhibiting the processing of other items such as CAT or TIN.

Posner and Snyder (1975b) go on to present a series of experiments that measure the facilitatory and inhibitory effects of prime stimuli on targets under a number of conditions. In order to measure the amount of facilitation and inhibition from the prime stimuli, Posner and Snyder (1975b) adopted a design that included a neutral prime condition. The stimuli were presented in pairs, a prime and an array (or target), where the presentation of the prime preceded the presentation of the array. The neutral prime they used was a plus sign (+). However, subsequent studies in the lexical literature have used a row of Xs (XXX) (Becker, 1980; Neely, 1976) or the word BLANK (de Groot, 1984). The requirements of the neutral prime are (i) that it structurally resembles the materials under investigation and (ii) that it conveys no meaning and hence, produces minimum activation in memory. In the face priming literature Bruce and Valentine (1986) have used an unfamiliar face as a neutral prime, on the basis that it has the same structural properties as the familiar face items, while no semantic information relating to the face can be accessed. The neutral prime condition is used as a control condition, relative to which any facilitation from the related prime stimuli can be calculated. In addition, Posner and Snyder (1975b) include an unrelated prime condition, as a measure of subjects' use of conscious strategies, as they predict that as conscious strategies come into play, the processing of target stimuli preceded by an unrelated prime will be inhibited.

In one set of experiments Posner and Snyder (1975b) measure the facilitatory and inhibitory effects of a prime stimulus on a letter array. The letter array consisted of two capital letters. The letters either matched, e.g. AA or did not, e.g. AB. The prime was one of three types, same; e.g. prime = A, array = AA; neutral; e.g. prime = +, array = AA; or unrelated; e.g. prime = B, array = AA. The subjects were instructed to treat the prime as a warning signal and respond only to the array by making a match/mismatch response. Posner and Snyder investigated the effects of varying the probability that the prime was included in the array (20%, 50%, 80% probability), varying the prime presentation time (10, 60, 160, 310, and 350 milliseconds) and varying the prime-array interstimulus interval (ISI) (prime presentation time = 10 milliseconds, prime-array ISI was one of 0, 50, 150, 300, 500 milliseconds). The neutral prime condition was used as a baseline and facilitation was measured by subtracting the response times to the same condition from the neutral prime condition response times. Similarly, inhibition was measured by subtracting the response times to the unrelated condition from the neutral prime response times. They found that all three factors under investigation affected the amount of facilitation and inhibition observed. Both facilitation and inhibition were found to increase with increasing probability of the prime appearing in the array. However, the relative amounts of inhibition and facilitation were not symmetrical; significant inhibition was only found when the probability of the prime appearing in the array was 80%.

The analyses of varying the prime presentation times or prime-target ISIs showed highly similar effects. Facilitation was found in all but the shortest stimulus onset asynchrony (SOA) of 10 milliseconds, while inhibition, was found only at the longer SOAs of 300 and 500 milliseconds. Posner and Snyder (1975b) present a number of other experiments that demonstrate similar results. They conclude that facilitation and inhibition are separate attentional components, a conclusion that is supported by the observations that the two processes are asymmetric and that facilitation can be found in the absence of inhibition. Increasing the prime presentation time and increasing the probability that the prime and target are related increases the amount of inhibition found. Posner and Snyder (1975b) suggest that this is consistent with the observation that priming occurs when the subject's attention is drawn towards the prime. In summary, Posner and Snyder argue that facilitation in the absence of inhibition denotes automatic processing of the prime, while facilitation accompanied with inhibition denotes at least some strategic processing of the prime.

A large number of studies have adopted Posner and Snyder's (1975b) paradigm and as a consequence there is a wealth of data on the facilitatory and inhibitory consequences of priming from different types of prime-target relation, altering presentation times, altering the instructions given to subjects and varying the proportion of related stimulus pairs etc. (for a review see Neely, 1991). For this reason the studies reported in this thesis employ the Posner and Snyder (1975b) paradigm.

1.4.2 The nature of semantic priming with faces

Bruce and Valentine (1986) demonstrated semantic priming with face stimuli using Posner and Snyder's (1975b) paradigm. They investigated the effects of increasing the prime-target inter-stimulus interval (ISI) on semantic priming with a constant prime presentation time of 250 milliseconds. When primes and targets were faces they found significant facilitation from the related primes but no significant inhibition from unrelated primes. Further, there was no significant difference in the pattern of excitatory and inhibitory effects across three prime-target ISIs of 0, 250 and 750 milliseconds. In the same paper they investigated name/name priming and found comparable effects, with the exception that priming with name stimuli produced significant inhibition.

Bruce and Valentine (1986) noted the similarities between face and name priming and examined the hypothesis that face priming is mediated by implicit naming of the faces. They reasoned that if semantic priming is mediated by naming, then the amount of priming observed from Morecambe (prime) to Wise (target) should exceed that found from Wise (prime) to Morecambe (target) because the pair is invariably referred to as Morecambe and Wise. They reported that no difference is observed between the two designs and concluded that the semantic priming was attributed to strong associations between semantic representations, accessed by both names and faces. Further, it was noted earlier that Bruce and Valentine found no repetition priming from a person's name to their face in a familiarity decision task, a result that is also inconsistent with an implicit naming explanation. Bruce and Valentine's hypothesis led them to suggest that semantic priming should also be found for a cross-domain (face/name) design, and Young Hellawell and De Haan (1988) have since confirmed this prediction. Moreover, Young *et al.* (1988) found that both cross and within-domain designs produce the same pattern of semantic priming.

1.4.3 The locus of semantic priming with faces

Bruce and Valentine (1986) also investigated the locus of semantic priming effects. Following a number of studies investigating the effects of stimulus quality on the processing of words (Becker and Killion, 1977; Meyer, Schvaneveldt and Ruddy, 1975; Sperber, McCauley, Ragain and Weil, 1979), they reasoned (with reference to Sternberg's (1969) additive factors theory), that an interaction between stimulus quality and semantic priming would indicate that semantic priming was located at an early encoding stage susceptible to changes in the stimulus quality. Their results confirmed their hypothesis and seemed to suggest that semantic priming, like repetition priming, was located at the FRU stage. In other words, the presentation of a face prime activates its FRU which in turn activates semantic information with which it is associated. Through a process of spreading activation, the semantic attributes of the prime's semantic associate are also activated and subsequently the semantic associate's FRU is activated. Further, given that semantic priming affected the FRUs this implied that a separate similar representational system must exist for names, and that semantic priming with names was located here. However, there was a problem with this explanation. If semantic priming was to be attributed to the same location as repetition priming, then both should show common properties. Using a design adopted from the lexical literature, Bruce (1986) investigated the time courses of semantic and repetition priming.

1.4.4 Investigating the time course of repetition and semantic priming

In a similar study to Scarborough *et al.* (1977), Dannenbring and Briand (1982) attempted to discover the time course of semantic and repetition priming. They measured lexical decision times to target words primed by the same, or semantically related stimuli. In addition, the primes and targets were separated by 0, 1, 5, or 16 unrelated words. Repetition priming was found to persist across all 4 lags (0 - 16) without diminishing, but semantic priming was found only at the 0 lag. Using an analogue of Dannenbring and Briand's (1982) design, Bruce (1983) found that face stimuli show very similar patterns of semantic and repetition priming effects to name stimuli. She replicated their results to the extent that, (i) repetition priming was found at all four stimulus lags (0, 1, 3, 11 in Bruce's (1986) study) and (ii) the semantic priming effect was only significant at the 0 lag. In addition, Bruce replicated her earlier finding that identical prime and test items produce more priming than visually dissimilar prime and test items (i.e different pictures of the same person).

In view of these results, it is difficult to reconcile the suggestion that semantic and repetition priming have the same underlying mechanism (i.e. a reduction in the recognition threshold of an FRU) with the observation that they have very different time courses (Bruce, 1986). Bruce (1986) suggested that her results were consistent with the view that repetition and semantic priming stemmed from different levels of the face recognition system. On the basis of such results, Bruce and Young (1986) suggested that the FRUs be considered not as threshold devices, but as units capable of signalling the degree of resemblance between a face input and its stored representation. Further, they suggested that familiarity decisions would be taken in a separate decision component. Processing within the decision component could be affected by (i) the FRU input (i.e. repetition priming), and (ii) internal effects within the decision component itself (semantic priming). In other words, while the status of repetition priming was for the greater part unaffected, semantic priming was seen in part as a post-access effect, an explanation that has been endorsed by Neely and Keefe (1989) in the lexical literature.

1.4.5 Post-access account of semantic priming

The Posner and Snyder (1975a; 1975b) account of semantic priming was based on a spreading activation theory. That is to say that semantic priming is an automatic effect, and in Fodor's (1983) terms, unstoppable. The post-access explanation however, suggests that the effect is located at a higher decision process level and is a symptom of the task itself, rather than the structure of the recognition system.

Neely and Keefe (1989) present a retrospective semantic-matching model in which they attribute semantic priming effects to a decision process level. They suggest that semantic priming occurs at a stage after the memory representation nodes corresponding to the prime and target have been activated, but before a lexical decision has been made. Their hypothesis draws from the findings of Rosson (1983) who found evidence to suggest that non-words can activate recognition units for words that they resemble visually. Hence, JAT activates the units for CAT, HAT, JAM etc.. Given that non-word targets are constructed so as not to resemble visually a word related to the prime that preceded it, non-word targets do not activate words related to the prime (in the case of face priming, visual resemblance between the semantic associate of a familiar prime face and an unfamiliar target face is unlikely even in the event of this factor not being controlled for). Neely and Keefe argue that a subject is able to use any relationship between the words activated by the prime and target to bias their decision. For a classic semantic priming design such as that employed by Bruce and Valentine (1986), when the prime and target are related, the correct familiarity response to the target must be 'Yes'; because for a semantic relationship to be identified, both stimuli must be familiar. Moreover, because this post-lexical matching process cannot be utilised in the neutral prime condition, a lexical decision response in the related pair condition is facilitated relative to the neutral prime condition. Certainly this seems an attractive explanation of the different time courses of semantic and repetition priming. However, as Neely (1991) points out, it has difficulty in explaining a number of associated phenomena.

The view that semantic priming is a post-access phenomenon is not wholly consistent with the observation that semantic priming effects are affected by stimulus quality (Becker and Killion, 1977; Bruce and Valentine, 1986; Meyer *et al.*, 1975; Sperber *et al.*, 1979). These authors have interpreted this observation through Sternberg's (1969) additive-factor analysis to imply that semantic priming is located at the same point that is affected by the blurring of stimuli; in the case of faces (Bruce and Valentine, 1986) the FRUs. However, perhaps the greatest problem for any post-access account is the subliminal priming literature (for a review see Dixon, 1971). It seems unlikely that a subject can utilise the identity of a prime whose identity (or even presence) he failed to detect, to facilitate his response to a target. In the face literature there have been no demonstrations of subliminal priming, but Young, Hellawell and de Haan (1988) have shown that a prosopagnosic who has lost the ability to recognize familiar faces, shows evidence of semantic priming from faces to names. In terms of a post-access explanation, Young *et al.*'s (1988) patient would seem to be able to access the identity of the face prime for the purposes of using the match strategy, but not to the extent that he can consciously identify the face. This explanation seems highly unlikely, and Young *et al.*'s (1988) findings provide a considerable problem for the post-access account. More recently, de Haan, Bauer and Greve (1992) have shown cross-domain priming from a person's face to their name in another prosopagnosic patient (self priming see Chapter 2). This would also seem inconsistent with a post-access account of priming over short intervals.

1.5 Summary

A number of different face priming studies have been discussed, and from these it is evident that there are distinct parallels to be drawn between priming with faces, words, and objects (Bruce and Young, 1986).

The results of repetition priming studies have shown considerable consistency with the distributed representation accounts (McClelland and Rumelhart, 1985; McClelland and Rumelhart, 1986). Nevertheless, as yet, these distributed models have little to offer in terms of an account of semantic priming (Neely, 1991). A number of attempts have been made to accommodate the results of semantic priming studies in terms of Bruce and Young's (1986) functional model of face recognition. However, these explanations have not proved entirely successful. Burton, Bruce and Johnston's (1990) interactive activation and competition model of face recognition attempts to present an architecture that is consistent with the experimental data on repetition and semantic priming with faces discussed above. Chapter Two discusses the Burton *et al.* (1990) model and its accounts of the experimental data. In addition, Chapter Two considers subsequent modifications of the model that offer explanations of documented phenomena in both the normal and neuropsychological literature (Burton and Bruce, 1992; Burton, Young, Bruce, Johnston and Ellis, 1991).

2 Modelling face recognition

2.1 Introduction

A number of attempts have been made to model face recognition at a computational level. These models fall into two basic categories; (i) computer devices designed to process faces from an early perceptual level through to recognition (Aleksander, 1983; Baron, 1981; Kohonen, 1984), and (ii) those that simulate higher level cognitive function. Models falling in to the former of these two categories (for a review see Bruce and Burton, 1989) are not simulations of the face recognition system and were not designed to address the issues of repetition and semantic priming. Consequently, they are not reviewed here.

Recently, two computer implementations of face recognition have been posited, Schreiber, Rousset and Tiberghien's (1991) FACENET connectionist model and Burton, Bruce and Johnston's (1990) interactive activation and competition model of face recognition. The former will be considered first before going on to discuss the focus of this thesis, the Burton *et al.* (1990) model.

2.2 Schreiber, Rousset and Tiberghien's (1989) connectionist model of face identification: FACENET

Schreiber, Rousset and Tiberghien (1991) present a connectionist model of face identification with the capacity to learn; FACENET. The concept underlying the model is Tulving and Thomson's (1973) encoding specificity principle, which states that traces in memory are contextualised. Schreiber *et al.* (1991; see also Davies and Milne, 1982) argue that despite the large number of studies demonstrating the significant role context plays in the recognition of faces (Baddeley and Woodhead, 1982; Memon and Bruce, 1985; Tiberghien, 1986; Young, Hay and Ellis, 1985), functional models of face recognition have largely neglected the role of context. Figure 2.1 shows a schematic representation of FACENET.

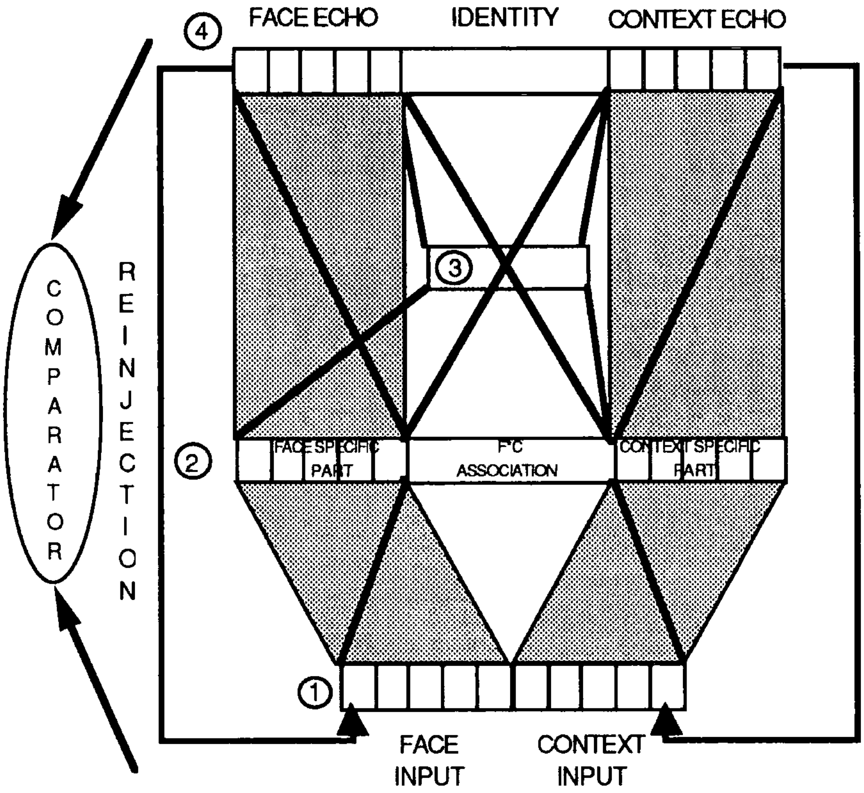


Figure 2.1: Schreiber, Rousset and Tiberghien's (1991) connectionist model of face recognition FACENET.

The model consist of four layers that process two types of input, a face input and a context input. Layer 1 consists of the input units, of which there are equal numbers of face and context inputs (25), each divided into five blocks of five units. Layer 2 is the first of two hidden layers and consists of a face specific part, context specific part and face-context association part. The connections from layer 1 to the lateral regions of layer 2 (face and context specific parts) are arranged in such a manner that the input from the face and context blocks (layer 1) are processed in a hierarchical fashion. This constraint is included to mimic the observation that some features are given greater emphasis than others in the recognition of familiar faces (Shepherd, Davies and Ellis, 1981).

The face-context association units are central to the architecture, and it is here that face and context inputs interact to construct 'identity representations' or episodic associations between faces and contexts. These face-association units connect to layer 3, as do the face specific units; however, the context specific units have no input to layer 3. Schreiber *et al.* point out that this asymmetry is necessary because the model attempts to simulate person identification driven from attending primarily to a person's *face*, and not the context in which it is presented.

The fourth layer is made up of three groups of units; face echo units, context echo units and identity units. Both sets of echo units receive inputs from their corresponding face and context specific units in layer 2 and the face-context association units. Inputs from the face-context association units (layer 2) are necessary, because they can influence the nature of the 'echoes', and consequently an association can be reconstructed at recognition. Thus, the network is able to recall a face from a context input and *vice versa.* The face and context echo units mirror their corresponding input counterparts in terms of number and organisation of units. Further, they feed back to their input units. The outputs from the echo units are intended to denote memory representations of the original inputs, e.g. the face echo units represent a mental image of the face presented at input.

The middle part of layer 4 consists of 25 units, which they suggest are analogues of Bruce and Young's (1986) PINs. Each unit represents a different identity by virtue of the different converging inputs it receives from layers 2 and 3. FACENET therefore has three outputs (i) face echo which denotes familiarity with the face, or as they refer to it, "a feeling of déjà-vu of the face", (ii) an identity output which gives rise to "the feeling of identity" and (iii) context echo, which is contextual information retrieved from memory, or the content of the person's identity.

Schreiber *et al.* (1991) present a number of simulations that demonstrate the model's capacity to account for the effects of context on face recognition. They show that context effects are dependent on the number of contexts in which a face has been encoded (variable/non-variable context), and the number of other faces that share the same context (specific/non-specific context). The identification of a face that has been encoded in variable contexts is unaffected when it is later presented in a novel context, while the identification of a face encoded in a non-variable context is adversely affected; the non-variable, non-specific condition leading to the greatest detrimental effect. This result parallels Thomson, Robertson and Vogt (1982) and Davies and Milne's (1982) findings, that the recognition of previously unfamiliar faces, but not familiar faces, is detrimentally affected by changing the context in which the face appears in the presentation and test phases.

2.2.1 Modelling repetition and semantic priming in FACENET

It is clear from the model's structure that FACENET would have no trouble in accounting for the effects of repetition priming with faces (Bruce, 1986; Bruce and Valentine, 1985; Brunas *et al.*, 1990; Brunas-Wagstaff *et al.*, 1992; Ellis *et al.*, 1990; Ellis *et al.*, 1987; Roberts and Bruce, 1989). Indeed, the model's connectionist structure complies with the comments of Ellis *et al.* (1990; 1987), who suggest that an instance based architecture may be a more suitable environment in which to develop an account of the repetition priming effects in the face literature. Schreiber *et al.* also briefly allude to the suggestion that the model may be capable of accounting for semantic priming, by virtue of the fact that related pairs of faces share the same context. Hence, the presentation of Prince Charles would activate context(s) that he shares with Princess Diana, and as a consequence, her face representation would be primed via the face echo component.

Schreiber *et al.* draw on the results from studies showing that subsequent recognition of unfamiliar faces learnt in a particular context are sensitive to changes in context (Baddeley and Woodhead, 1982; Memon and Bruce, 1985; Tiberghien, 1986).

In addition, they cite a diary study by Young, Hay and Ellis (1985) that noted that subjects' have difficulty in recognising familiar faces associated with a single context in a different context, e.g. seeing your baker at a football match. All of the studies they discuss point to the conclusion that context plays a significant role in face recognition, but for the greater part its effects are restricted to faces that are generally seen in the one context e.g. your baker, or a single encounter with an unfamiliar face (e.g. eyewitness testimony). Recognition of familiar faces that were encoded under a number of different contexts is relatively unaffected by changes in context between one encounter and the next, an observation that is reflected in the simulations with FACENET.

A. Ellis (1992) has suggested that semantic priming may have an associative basis, i.e. related pairs prime one another because they are frequently seen together. This is not inconsistent with Schreiber *et al.*'s position, although Ellis would perhaps argue that for a semantic pair such as Charles and Diana, Charles' 'context' would be Diana and *vice versa*. Indeed there is evidence to suggest that a previously unfamiliar face that was initially presented with a second face is better recognised when it is coupled with its original partner than a new partner (Watkins, Ho and Tulving, 1976; Winograd and Rivers-Bulkeley, 1977). Schreiber *et al.* (1991) do not define what they mean by context, and it is difficult to see how a face (e.g. Prince Charles) can at once be contextual and facial information in FACENET. Nevertheless, it may be worth exploring the role, and nature of context further as a source of semantic priming in future simulations with the model.

2.3 Burton, Bruce and Johnston's (1990) interactive activation model of face recognition

2.3.1 Interactive activation and competition

The Burton *et al.* model was developed from McClelland and Rumelhart's (1988) interactive activation and competition (IAC) program. IAC networks consist of a number of pools of units. Within each pool each units are connected to each other by bidirectional inhibitory connections. Hence, when a unit becomes active it inhibits the activation of all other units within the same pool; this gives the system its 'competitive' property. Connections also extend between units in different pools, and these can be excitatory or inhibitory and unidirectional or bidirectional. Between-pool units are generally bidirectional. Hence, units within any one pool both influence, and are influenced by units in other pools, this gives the system its 'interactive' property (McClelland and Rumelhart, 1988). IAC networks have been applied to the modelling of cognitive function in the past (Grossberg, 1979), but they are perhaps most associated with McClelland and Rumelhart's (1981) (see also Rumelhart and McClelland, 1982) model of context effects in letter identification. McClelland and Rumelhart's (1981) model is analogous to a logogen system (Morton, 1969), in that each word, letter or feature is represented by a single unit, and the 'recognition' of a word is simulated when its activation reaches an arbitrary threshold level. In IAC networks the units themselves hold representations, and not the weights between units, to that extent they are distinct from parallel distributed processing (PDP) networks such as FACENET. Further, whereas PDP networks have the capacity to learn new representations, IAC networks at present do not.

2.3.2 Activation levels

The activation of a unit within the IAC network can fluctuate between defined maximum and minimum activation levels. The activation of any one unit *i* is determined by the current activation of the unit and any input to the unit. Input can take one of two forms (i) external activation to unit *i* from the experimenter, and (ii) internal activation from other active units (unit *j*, where the index *j* ranges over all units with connections to *i*). The net input to a unit *i* is calculated according to the following function.

$$net_i = \sum_j w_{ij} output_j + extinput_i.$$

That is, the net input to unit *i* is the sum of all inputs to *i* from other units in the network (*j*), plus any external input. The influence of another unit *j*, is given by the product of *j*'s output ($output_j$) times the strength or weight of the connection from unit *j* to unit *i*, (w_{ij}).

Having calculated the net input to a unit, the change in its activation is defined as the following:

If ($net_i > 0$)

$$\Delta a_i = (max - a_i)\, net_i - decay(a_i - rest).$$

Otherwise

$$\Delta a_i = (a_i - min)\, net_i - decay(a_i - rest).$$

Max, min and decay are all parameters. The settings of the parameters used in the Burton *et al.* (1990) simulation are shown in Table 2.1.

Maximum activation	1.0
Minimum activation	-0.2
Resting activation	-0.1
Decay rate	0.09*
e_{str} (strength of external input)	0.4
Alpha (strength of excitatory activation)	0.1
Gamma (strength of inhibitory activation)	0.1

Table 2.1: The global parameters used by Burton, Bruce and Johnston (1990) in their model of face recognition. Note that these parameters were used to model priming on the basic architecture that excluded the name identity units (NIUs).

*In the later version, the model that includes the NIUs, the decay parameter was set at 0.1 to combat the bolstering effect of the NIUs (Burton *et al.*, 1991). Simulations modelling NIU function shown in this thesis are modelled on a network including the NIUs and subsequently with a decay parameter set at 0.1.

The activation levels of the units are intended to vary over time, and this is modelled on the computer by updating of activation levels across cycles; a cycle being a unit of time. All units have the same rate of decay, and the decay rate acts on the unit to return it to its minimum activation level. Units generally reach a stable level of activation (equilibrium), because their input is balanced by the decay function. This is shown by the equation

$$a_i = \frac{net_i}{net_i + decay}$$

Although the above equations show the computation of the activation level of a $unit_i$, they fail to take into account the fact that the activations of other units are also changing as a result of the changes in $unit_i$ itself. Hence, because units both influence and are influenced by other units, the overall picture is slightly more complex. McClelland and Rumelhart (1988) illustrate the *actual* net input to a unit in terms of the following example.

There are two units *a* and *b* and both are receiving excitatory activation from outside (the experimenter). However, the input to unit *a* (e_a) exceeds that to unit *b*. If γ is the inhibition that each unit exerts on the other unit then the *actual* net input to *a* is given by

$$net_a = e_a - \gamma(output_b)$$

Likewise, the net input to *b* is

$$net_b = e_b - \gamma(output_a)$$

In McClelland and Rumelhart's (1988) IAC network, $output_j = [a_j]^+$ where a_j is the activation of unit *j* and $[a_j]^+ = a_j$ for all $a_j > 0$. Hence, the equations become

$$net_a = e_a - \gamma a_b$$

and

$$net_b = e_b - \gamma a_a$$

The equations show that for the case described above, the greater initial external activation to unit *a* puts it at an advantage. The higher activation of *a*, means that the inhibitory output from *a* to *b* will exceed that from *b* to *a*. Hence, *a* will win over and have the higher activation level. Grossberg (1976) has described this phenomenon as "the rich get richer effect".

2.3.3 The Burton, Bruce and Johnston architecture

Figure 2.2 shows a schematic representation of the Burton *et al.* architecture.

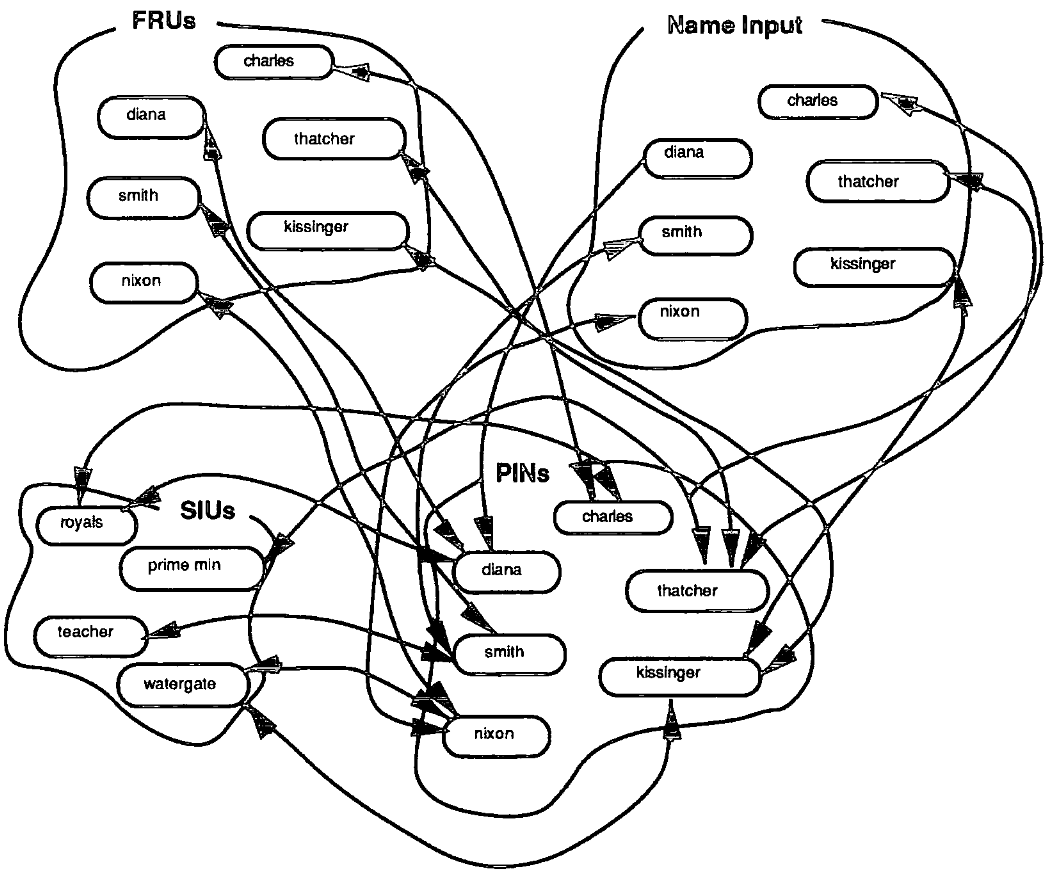


Figure 2.2: Burton, Bruce and Johnston's (1990) interactive activation and competition model of face recognition.

The model comprises of four interconnected pools of units; the face recognition units (FRUs), name identity units (NIUs), person identity nodes (PINs) and semantic identity units (SIUs). Burton *et al.*'s IAC model is a computer implementation of the recognition route of Bruce and Young's (1986) model and consequently they have a number of features in common. Both models claim that for each face with which we are familiar there exists a corresponding FRU and PIN. As regards the storage of semantic information however, the models differ. Bruce and Young (1986) suggested that semantic information relating to a person is either accessed by, or stored within the PINs. However, Burton *et al.* (1990) favour separate semantic structures, the SIUs, within their architecture and provide a convincing argument in support of their mode of thought. In addition to these new semantic structures, Burton *et al.* (1990) have added name input units (NIUs) to their model as a means of accounting for effects found with name stimuli.

Units within the same pool are linked by bidirectional inhibitory connections set at -0.1, while the connections between units in different pools, are bidirectional, excitatory and are set at 1.0. It is also important to note that no direct connections exist among the FRU, SIU or NIU pools. As such, changes in the level of activation of units within any one of these three pools can only affect units in the other two pools indirectly, via the PINs with which they are all connected.

The Burton *et al.* (1990) and Bruce and Young (1986) models contain common components, but, they disagree about the locality at which the process of recognising a face's familiarity takes place. Bruce and Young (1986) suggest that it occurs within the FRUs, while Burton *et al.* (1990) propose that it occurs within the PINs. By drawing on established experimental data discussed in Chapter 1, and simulating them at a computational level, Burton *et al.* (1990) provide support for their hypothesis. In particular they concentrate on face priming, both the repetition and semantic forms.

2.4 Modelling repetition and semantic priming in an IAC model

Chapter 1 discussed that the primary distinctions between repetition and semantic priming lie in terms of their time course and domain specificity. Repetition priming is long lasting (Bruce, 1986; Bruce and Valentine, 1985; Flude *et al.*, 1991), while in contrast, the effects of semantic priming dissipate within a few seconds (Bruce, 1986; Dannenbring and Briand, 1982). Further, repetition priming does not cross stimulus presentation domains (Bruce and Valentine, 1985; Ellis *et al.*, 1987), while semantic priming does (Young *et al.*, 1988). Burton *et al.* (1990) recognize these distinctions and offer plausible explanations to account for them.

2.4.1 Repetition priming

Repetition priming is explained in Burton *et al.'s* (1990) model in terms of the strengthening of connections between units; a concept that has also been suggested in the lexical literature to account for repetition priming (Allport and Funnell, 1981). In the case of face priming, it is the strengthening of the connection between a particular FRU and PIN that produces the effect. When a face is presented, it activates its corresponding FRU which in turn leads to the activation of its PIN, and as a result of this process the connection between the FRU and PIN becomes strengthened. Once strengthened, the connection can remain in this state for a long period of time, consequently leading to the facilitation of a response when the same face is repeated some time after its initial presentation. Similarly, repetition priming with names (name input units or NIUs) is accounted for by the strengthening of NIU-PIN connections. Note that because repetition priming is accounted for in terms of a domain-specific connection, i.e. FRU-PIN for face priming, NIU-PIN for name priming, the model can account for the fact that repetition priming does not cross stimulus domains (Bruce and Valentine, 1985; Ellis *et al.*, 1987).

Figure 2.3 shows the activation curves for Charles' PIN under two conditions (i) when Charles' FRU-PIN connection is set at 1.0 and (ii) when the connection strength has been increased by an arbitrary 50% to 1.5. From Figure 2.3 it is clear that strengthening the connection between an FRU and PIN produces faster and higher activation of the PIN. This simulation corresponds to the observation that a familiarity decision to a face is made faster to the second, or subsequent presentation of the face.

2.4.2 Semantic priming

While the IAC model locates repetition priming at the level of the input-PIN connections, its account of semantic priming is located at the level of PIN-SIU activation.

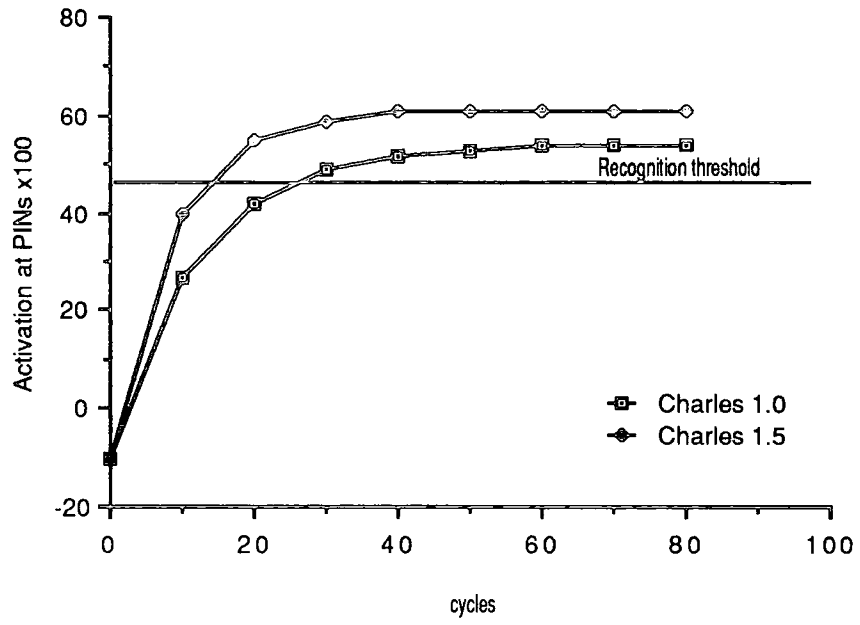


Figure 2.3: The activation curves of Charles PIN following an input to his FRU under two conditions (i) when his FRU-PIN connection is set at 1.0 and (ii) when the FRU-PIN connection is set at 1.5. The latter of these two conditions simulates the effect of repetition priming.

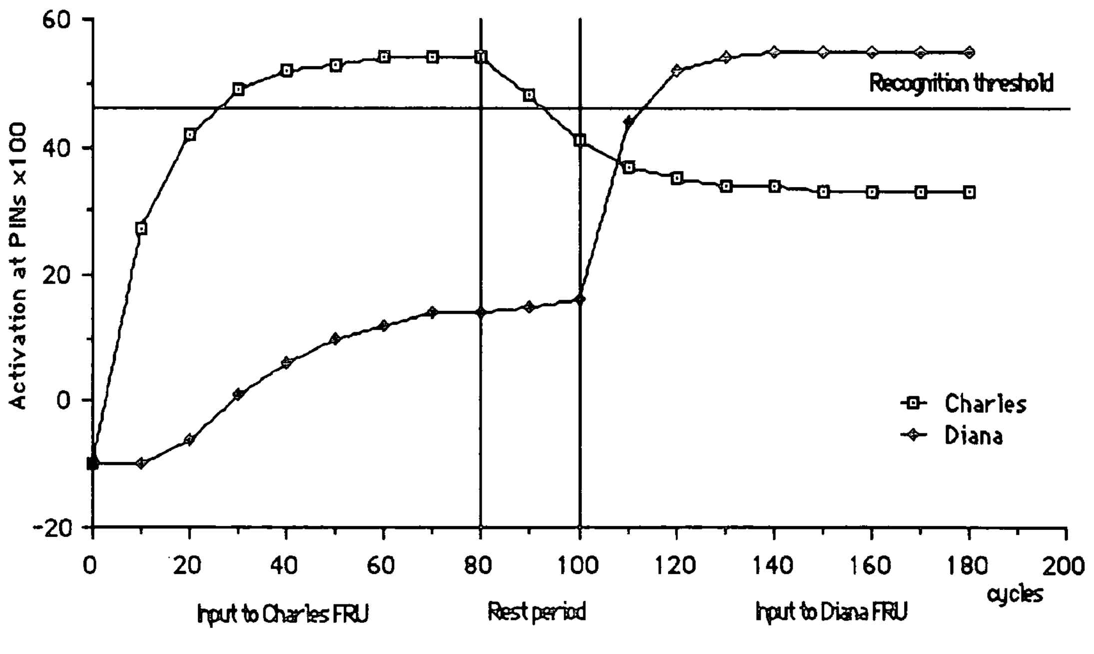
This is perhaps best illustrated in an example. Activation of Prince Charles' PIN produces activation of SIUs with which he is associated (e.g. Royalty, son called Prince William etc.). These SIUs in turn activate other PINs which share the same semantic information, principally, Princess Diana. Hence, when Diana's face is presented shortly after her (former) husband's, she is recognised faster than had she been preceded by an unrelated or unfamiliar face (Bruce, 1983; Bruce, 1986; Bruce *et al.*, 1992; Bruce and Valentine, 1986; Young *et al.*, 1988). Figure 2.4a shows the activation curves for Charles' and Diana's PINs following the input to Charles FRU, followed by a rest period in which there are no external inputs, and finally an input to Diana's FRU. Figure 2.4b shows the graph of the activation curves for the cross-domain semantic priming equivalent, i.e. Charles face priming Diana's name. Both curves show the same pattern of activation, an effect that mirrors Young *et al.*'s (1988) observation that cross and within-domain semantic priming designs show the same pattern of effects.

Note that the fact that Charles does not prime other members of the Royal family (Brennen and Bruce, 1991) can be accommodated within the model if we recognize the fact that Charles and Diana will share more SIUs than say, Charles and Princess Margaret.

In reality we may associate a person with one particular semantic trait, despite the fact that he/she is also associated with a number of other traits. e.g. Roy Hattersley is more frequently thought of as a politician than a novelist, despite being both. This may be reflected in terms of the different connection strengths between Hattersley's PIN and the SIUs for politician and novelist. However, Burton *et al.* make a point of defending their choice to set all excitatory and inhibitory weights at the same level, in order to achieve some constraint on a system capable of producing such multifarious outcomes.

Chapter 1 discussed attempts to accommodate semantic priming within the Bruce and Young (1986) model in terms of the FRUs (Bruce and Valentine, 1986) and as a post-access effect (Bruce, 1986).

2.4a



2.4b

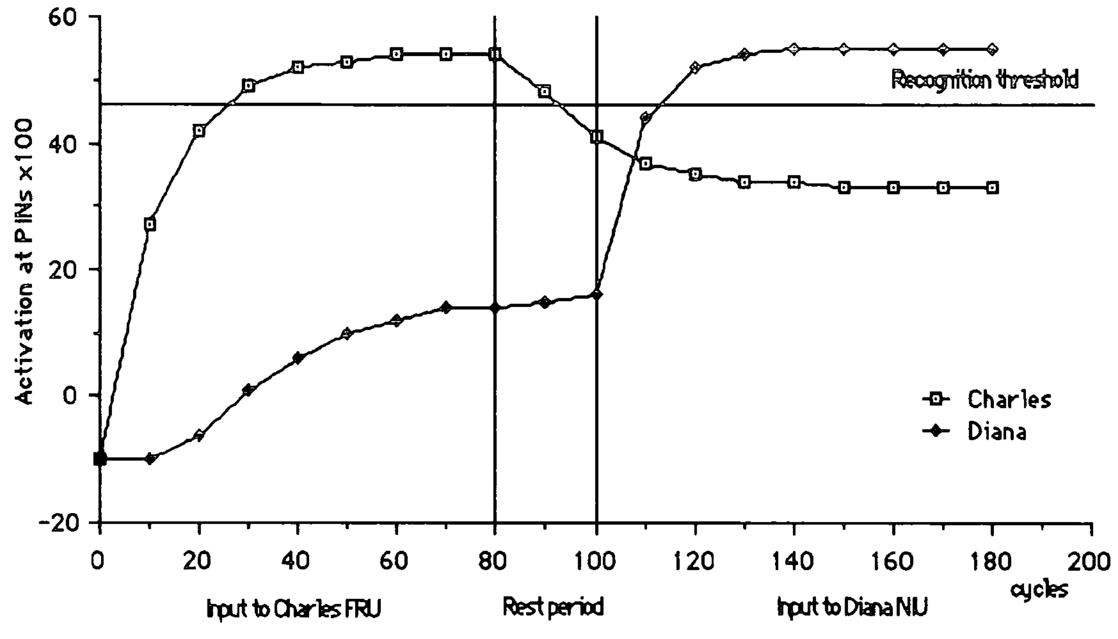


Figure 2.4: a The activation curves for Charles' and Diana's PINs are shown following an input to Charles' FRU, followed by a rest period of 20 cycles (corresponding to a prime-target ISI) and finally an input to Diana's FRU. b The activation curves for the same PINs are shown when an input to Diana's FRU is replaced with an input to her NIU. Note that both graphs show identical PIN activation.

Both of these explanations were shown to be unsatisfactory. The former explanation was confounded with the suggestion that repetition priming was also located at the FRUs and the latter, post-access explanation was inconsistent with the observation that a prosopagnosic can demonstrate semantic priming (Young *et al.*, 1988). The Burton *et al.* model presents a functional account of semantic priming in terms of PIN-SIU activation. In addition, the model offers a new perspective on the results of previous studies in this area.

2.4.2.1 An explanation of the time course of semantic priming

Chapter 1 discussed Bruce's (1986) study of repetition and semantic priming with faces, in which semantic associates were separated by 0, 1, 3 and 11 unrelated intervening stimuli. Bruce found that semantic priming effects were evident only at 0 lag, while repetition priming persisted across 11 intervening stimuli. The Burton *et al.* (1990) model suggests that it is not the time lag between semantic associates that determines priming, but the presence or absence of unrelated intervening stimuli. Burton *et al.* (1990) present computer simulations that demonstrate that the activity of a PIN is inhibited following the activation of a second, unrelated PIN. Hence, when the sequence Prince Charles, Eric Morecambe, Princess Diana is presented, Eric Morecambe's PIN inhibits the small amount of activation Princess Diana's PIN had received indirectly from the SIUs that she shares with Prince Charles. The net effect is that no semantic priming from Charles to Diana is found. Figure 2.5 illustrates this effect in terms of the activation levels of the PINs resulting from an input to Prince Charles' FRU followed by an input to Eric Morecambe's FRU. Note that as a consequence of the inhibitory within-pool connections, the input to Morecambe's FRU has the effect of forcing down the activation in both Charles' and Diana's PINs.

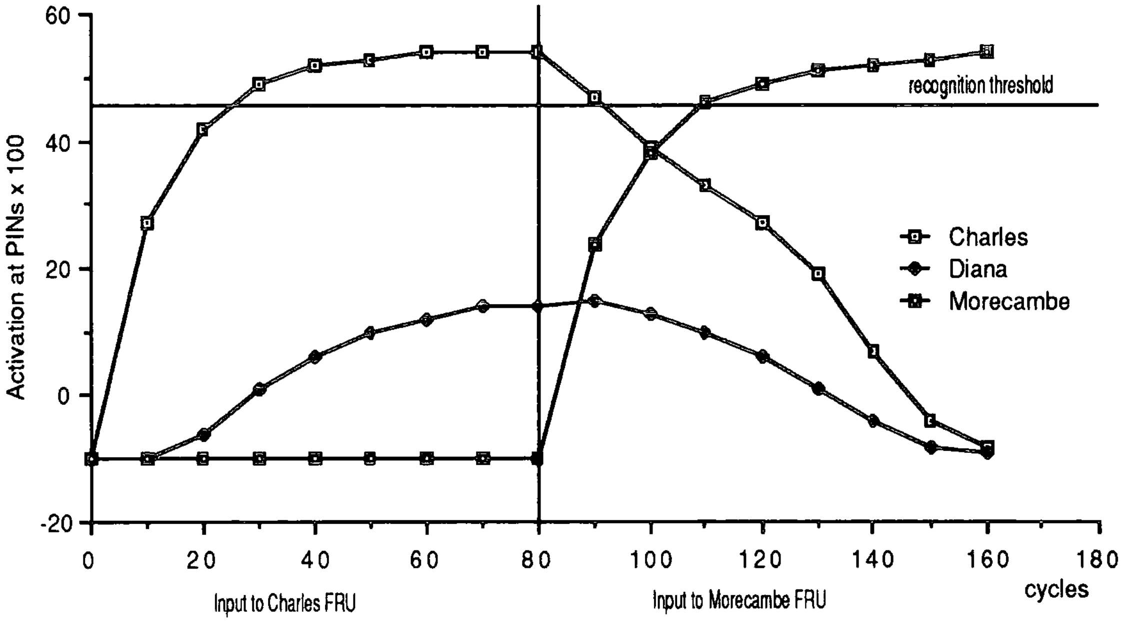


Figure 2.5: The PIN activation curves are shown for Charles, Diana and Morecambe, following an input to Charles' FRU, followed by an input to the FRU of an unrelated person, Eric Morecambe.

This observation leads to the prediction that a design with four variable prime-target ISIs, equivalent to Bruce's (1986) intervening stimulus presentation times (5, 10, 20 and 60 seconds), should produce semantic priming across all four of the conditions. However, a prediction of this sort may be confounded with the decay function that acts on all units to suppress their activity.

2.5 Additional observations from Burton et al.'s model

In the same paper Burton *et al.* (1990) present an account of distinctiveness effects and familiarity effects. The former of these two accounts is considered in Chapter 6, which introduces the work on distinctiveness.

Burton *et al.* present an account of familiarity effects in their IAC implementation. The effect of familiarity is based on the observation that the more SIUs to which a PIN is connected, the faster and higher its activation. Figure 2.6 shows a schematic representation of part of the network used to demonstrate this effect. Figure 2.7 shows the activation curves of Kissinger, Reagan and Thatcher's PINs, which for the purposes of the simulation, are connected to one, two or three semantic units respectively.

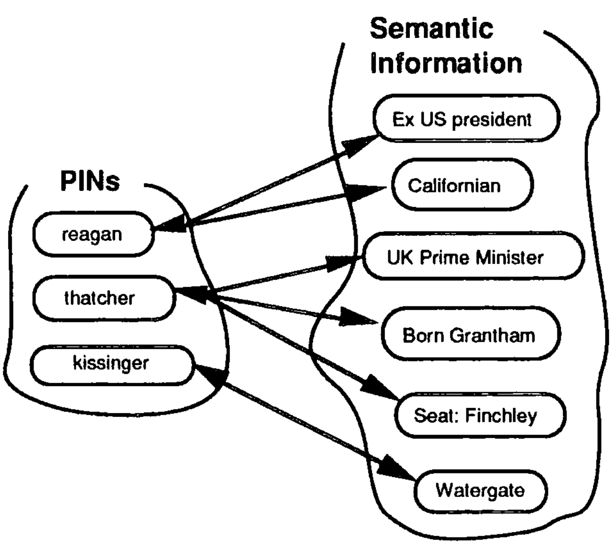


Figure 2.6: A schematic representation of part of Burton, Bruce and Johnston's (1990) network used to demonstrate frequency effects.

From Figure 2.7 it is clear that the PIN connected to the greatest number of SIUs (Thatcher) enjoys the highest activation level. This effect arises because of the interactive property of the network. Activity in a PIN activates the SIUs with which it is connected. This SIU activity then feeds back (via the bidirectional connections) to bolster the activity of the same PIN.

Earlier, the equation showing the change in activation of a unit receiving an input > 0 was defined as

$$\Delta a_i = (max - a_i)\, net_i - decay(a_i - rest).$$

where the net input to the unit was defined as

$$net_i = \sum_j w_{ij} output_j + extinput_i.$$

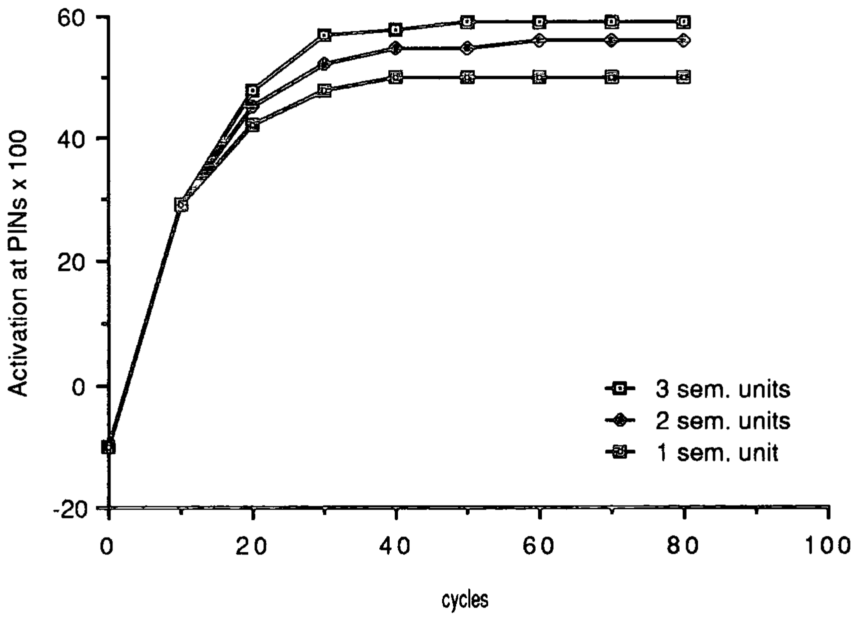


Figure 2.7: The activation curves of the three PINs in Figure 2.6, connected to three (Thatcher), two (Reagan) and one (Kissinger) semantic unit(s).

For a condition in which there is no external input (*extinput*$_i$ = 0) it is evident from the second of the above two equations that the net input to unit$_i$ is the sum of the product of all inputs from other units connected to unit$_i$ (*output*$_j$) times the connection strength between unit$_i$ and unit$_j$ (where the index *j* ranges over all units with connections to *i*). Hence, for all positive values of *output*$_j$, the more SIUs to which a node in the PIN pool is connected, the greater the change in activation (Δa_i) of that PIN.

Burton *et al.* (1990) suggest that this observation may offer a more appropriate explanation of frequency effects. In the past, frequency effects have been attributed to the same mechanisms that underlie repetition priming (Morton, 1979). However, in the word literature, Jacoby (1983a) has argued that this is implausible, as one brief encounter with a low frequency word in a priming paradigm is unlikely to overturn the long-term disadvantage it has acquired relative to high frequency words.

Burton *et al.* also present the activation curves of the SIUs shown in the network in Figure 2.6 (Figure 2.8).

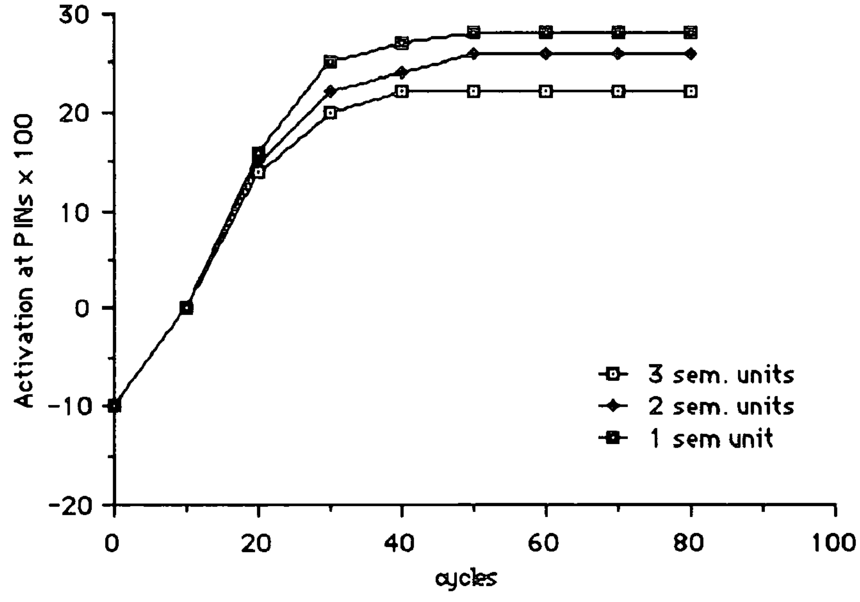


Figure 2.8: The activation curves of three semantic units that share a PIN with two other SIUs (3 sem. units), one other SIU (2 sem. units) and no other SIUs (1 sem. unit).

The activation curves of the SIUs are rather surprising in that a SIU that shares a PIN with two other SIUs has the slowest and lowest activation, while a SIU that is connected to only one PIN has the most rapid and highest activation. This result would suggest that a decision response to a question such as, 'is Joe Bloggs a painter', will be be faster the less you know about Joe Bloggs. Burton *et al.* cite a study by Lewis and Anderson (1976) who found that subjects who had been taught fantasy facts about familiar people and then asked to recognize real facts, took longer to recognize the real facts, the more fantasy facts they had learned.

2.6 I recognize your face but I can't remember your name: Burton and Bruce's (1992) explanation

In a separate paper, Burton and Bruce (1992) present a further development of the model that attempts to account for the observation that it is easier to recall semantic information about a person than it is to recall their name (Cohen and Faulkner, 1986; McWeeny, Young, Hay and Ellis, 1987; Young *et al.*, 1985). The common difficulty in recalling names is perhaps best typified in the tip-of-the-toungue phenomenon (Brennen, Baguley, Bright and Bruce, 1990). Here, subjects are able to recognize a face as familiar and are able to give semantic information about the person, but are unable to recall their name.

Burton and Bruce (1992) offer an account of the dichotomy between the recall of semantic information and the recall of names. They propose that in addition to semantic information, the SIU pool also includes name representation units. Names, unlike semantic information, are generally unique to one person, i.e. most of us know of only one Margaret Thatcher, whereas we are familiar with a number of politicians. Hence, in the SIU pool the node for the name 'Margaret Thatcher' will be connected to one PIN, while the node for 'politician' will be shared by a number of different PINs. Hence, activation of Margaret Thatcher's PIN will activate the 'politician' SIU and the name SIU 'Margaret Thatcher'. By virtue of the bidirectional connections, between the PIN and SIU pools, activation of the 'politician' SIU will in turn activate other PINs that share this semantic description. Subsequently, activation in these PINs feeds back to further activate the 'politician' SIU. However, if we know only one Margaret Thatcher then her name SIU is connected to only one PIN, and consequently her name SIU will not be bolstered by the activation in other PINs. Hence, the activation level of the 'politician' SIU will exceed that of the name SIU. This effect works on the same principle as the explanation of the frequency effect modelled on the network shown in Figure 2.6. Because, nodes corresponding to names are generally connected to only one PIN, their activation level will be lower than SIUs corresponding to semantic information, such as politician.

Burton and Bruce point out that their hypothesis is dependent on the assumption that the name Margaret Thatcher, is represented by one single node rather than two separate nodes, i.e. 'Margaret' and 'Thatcher'. Representation of names in terms of two separate nodes would render their argument untenable as we are familiar with a number of people that share the same forenames or surnames.

2.7 Modelling the neuropsychological data

2.7.1 Prosopagnosia with covert recognition

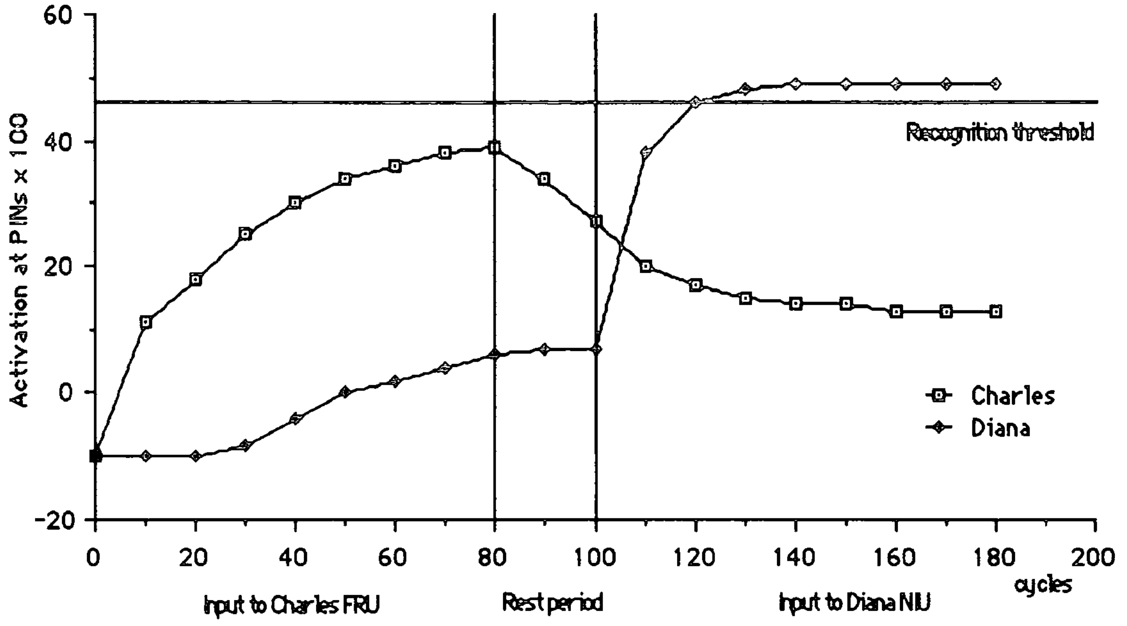
Research into face recognition has benefited from the study of prosopagnosics; patients whom have lost the ability to recognize familiar faces. Despite the failure of these patients to recognize faces overtly, a number of them, although not all (Bauer, 1986; Newcombe, Young and de Haan, 1989; Sergent and Villemure, 1989; Young and Ellis, 1989), have been found to show some residual recognition capacity in the form of covert recognition (Bauer, 1984; Bruyer, Laterre, Seron, Feyereisen, Strypstein, Pierrard and Rectem, 1983; de Haan, Young and Newcombe, 1987a; Sergent and Poncet, 1990). It is therefore essential that any credible model of face recognition should be able to account for these effects in addition to those from the study of normal subjects. Burton, Young, Bruce, Johnston and Ellis (1991) offer an account of the performance of the prosopagnosic patient, PH, (de Haan *et al.*, 1987a; de Haan, Young and Newcombe, 1987b; Young *et al.*, 1988), in terms of Burton *et al.*'s interactive activation model of face recognition.

Young, Hellawell and de Haan (1988) have shown that PH demonstrates semantic priming from a face prime to a name target. Moreover, the pattern of this cross-domain priming effect is the same as the pattern of priming he shows with a within-domain design from a name prime to a name target. They conclude that PH is demonstrating covert recognition of the face, and that the FRU representations are intact. Burton *et al.* (1991) suggest that this observation can be modelled in terms of the attenuation of the connection strengths between the FRUs and PINs in Burton, Bruce and Johnston's (1990) IAC model. They demonstrate that when the FRU-PIN connection strengths are reduced by an arbitrary 50%, an input to an FRU produces an insufficient level of activation in its corresponding PIN for it to cross the recognition threshold. Nevertheless, there is sufficient activation in the PIN to activate its semantic associate (via the SIUs) to the extent that the recognition of the associate will be primed. Figure 2.9 shows the activation curves presented by Burton *et al.* (1991) to demonstrate this effect.

It is interesting to note that the model also predicts that a prosopagnosic who demonstrates covert recognition of faces should also demonstrate cross-domain self priming from a person's face to their name (e.g. Prince Charles' face to the name Prince Charles) for short SOAs. This effect has been shown recently by de Haan, Bauer and Greve (1992) with another prosopagnosic patient, LF.

Young *et al.* (1988) have noted the similarities between the covert nature of the semantic priming shown by PH and studies showing sub-threshold semantic priming from masked stimuli (Carr, McCauley, Sperber and Parmelee, 1982; McCauley, Parmelee, Sperber and Carr, 1980). On this basis, Burton *et al.* (1991) suggest that the same account may suffice as an explanation of sub-threshold priming effects and predict the existence of sub-threshold priming with face stimuli.

2.9a



2.9b

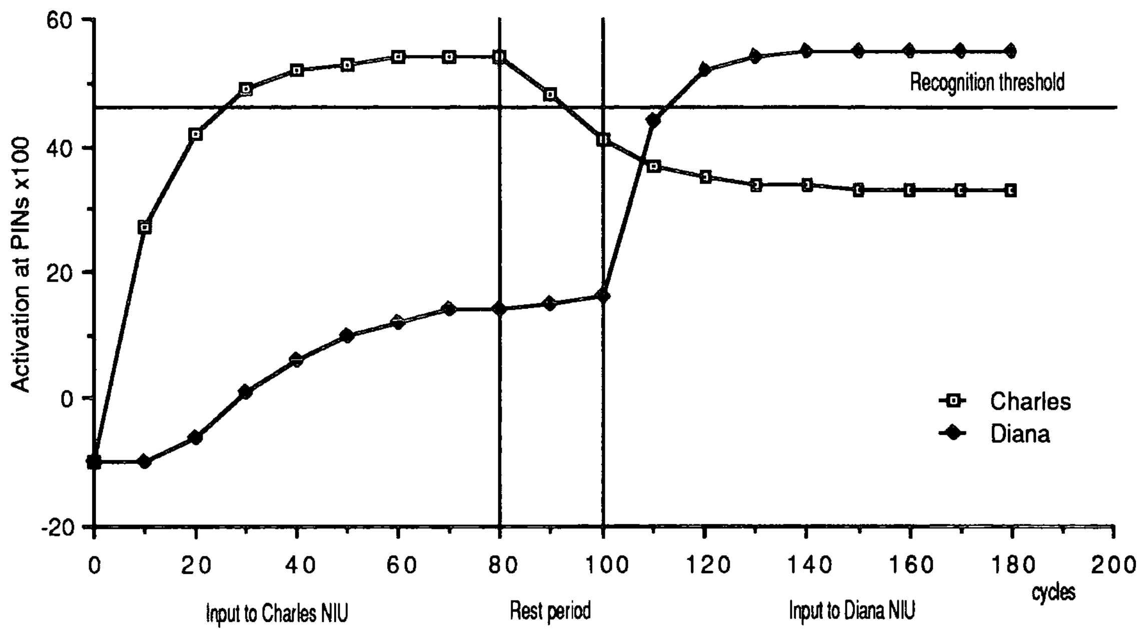


Figure 2.9: **a** The activation curves of Charles' and Diana's PINs are shown following an input to Charles FRU, followed by a rest period of 20 cycles, (corresponding to an prime-target ISI) and finally the presentation of the name Princess Diana. The network used was identical to that used to demonstrate semantic priming in Figure 2.4, but with exception that the bidirectional connections from the FRUs to PINs were reduced by 50% to 0.5. **b** The corresponding within-domain effect is shown following an input to Charles' NIU, a rest period of 20 cycles and an input to Diana's NIU.

2.7.2 Prosopagnosia without covert recognition

Not all prosopagnosics demonstrate covert recognition. Classically, prosopagnosics who do demonstrate the effect are better able to perform perceptual tests of face processing, such as matching different views of faces (Benton, Hamsher, Varney and Spreen, 1983), identifying expression, sex and age etc.. Prosopagnosics who are unable to perform these perceptual tasks do not demonstrate covert recognition (Bruyer, 1991). Burton *et al.* (1991) describe the performance of a patient MS (Newcombe *et al.*, 1989) who falls into the latter of these two categories. On tests of face recognition MS's performance is severely impaired (0/20) and on a test of object recognition he performs poorly also (8/36). Further, he is poor at matching different views of unfamiliar faces. Newcombe *et al.* (1989) presented MS with a number of tests of covert recognition such as face/name semantic priming and learning true face-name pairings. In the face-name pairing task the patient is required to learn to associate a face and a name. On some of the trials the face-name pair is true (e.g. Margaret Thatcher's face and her name) and on the rest of the trials they are false (Ronald Reagan's face and Prince Charles' name). On the semantic priming task MS showed no priming, although on a similar name/name semantic priming task, his performance was normal. On the second task MS showed no advantage for learning true name-face pairings compared to false name-face parings. Given that MS's performance is poor on object recognition as well as face recognition, Newcombe *et al.* suggest that his impairment lies at a higher-order perceptual level, i.e. a disruption of the input to the FRUs. In terms of the Burton et al (1990) model, this would mean that very little or no activation would be found at the level of the PINs following the presentation of a familiar face, an explanation that is wholly consistent with the observation that MS shows name/name semantic priming without face/name semantic priming.

2.7.3 Impairments of accessing semantic information and names

Burton *et al.* (1991) point out that a functional model of face recognition should also serve as a predictive tool, highlighting neuropsychological deficits that are yet to be observed. Burton, Bruce and Johnston (1990) suggest that the process of face recognition takes place at the level of the PINs. Hence any damage to systems beyond the PINs should not affect a patient's performance in a face familiarity task. Recently, de Haan, Young and Newcombe (1991) have reported a patient ME, who is very poor at accessing identity-specific semantic information, but shows no deficit on face familiarity tests. Burton *et al.* (1991) suggest that ME's deficit can be accounted for by the IAC model in terms of the attenuation of the bidirectional connections between the PINs and SIUs. Consistent with this interpretation is the observation that ME could match faces with their names. The Burton *et al.* model can also account for this observation (a finding that has also been demonstrated in prosopagnosics who show covert recognition (Sergent and Signoret, 1992). The format of the test is such that the patient is presented with a familiar face and two familiar names and asked which of the names matches the face. In terms of the model, any activation from the face will be small, and alone it is not enough for its PIN to reach activation threshold. However, the combined activation from the matching face and name together will produce the highest level of activation in their corresponding PIN. Consequently, the correct name will be selected as the match, i.e. the name corresponding to the highest PIN level.

It is interesting to note the comparisons between the patient reported by Flude, Ellis and Kay (1989) and ME. Flude *et al.*'s patient, EST, is impaired at accessing a person's name from their face, while his ability to access semantic information about the person is relatively unimpaired. Flude *et al.* attribute EST's deficit to the loss of links between the semantic store and name output. Burton and Bruce (1992) however, suggest that EST's deficit may be explained in terms of a similar explanation to that attributed to ME, i.e. the attenuation of links from the PINs to the SIUs. However, in the case of EST the attenuation is less severe. Earlier, Burton and Bruce's account of name recall was discussed, principally the finding that the activation in name SIUs is typically less than that found in other SIUs. Once the connections are weakened this effect is exaggerated to the point that the activation of the name SIUs never reach 'retrieval threshold', while the majority of other SIUs do. On this basis Burton and Bruce suggest that EST has a mild reduction in the strengths of the PIN-SIU bidirectional links. Note that this account predicts that EST should also be deficient at accessing other idiosyncratic identity-specific semantic information such as telephone numbers and addresses etc.. However, Flude *et al.* did not investigate this issue.

2.8 Summary of review

To summarise, Burton, Bruce and Johnston (1990) have presented an interactive activation and competition model of face recognition that can account for both repetition and semantic priming effects. Whereas the Bruce and Young (1986) functional model of face recognition found difficulty in accounting for the effects of semantic priming, the IAC model offers a plausible explanation of the effect. This has been achieved principally by redefining the function of the PINs. Bruce and Young posited that face recognition occurred at the level of the FRUs and were unclear about the precise function of the PINs, i.e. whether they were gateways to semantic information or actually held semantic information. Burton *et al.* (1990) suggest that semantic information is incorporated within separate structures, the SIUs, and that recognition of faces, names and other identity-specific cues occurs at the level of the PINs. By making use of an existing, but less obvious dimension of the Bruce and Young model, the connections between modules, they have provided a satisfactory account of repetition priming that explains its long time course and domain specificity. Nevertheless, they fail to address the observation that amount of repetition priming is dependent on the degree of similarity between the picture of the face used in the presentation and test phases (Ellis *et al.*, 1987). At present, their model is unable to accommodate this effect and this issue is discussed in more detail in Chapter 8. They suggest that semantic priming can be accounted for at the level of the PINs and SIUs, an account that satisfies the short time course of semantic priming and the observation that it crosses domains.

Within the same architecture, an account of covert face recognition in prosopagnosics has been modelled. Further, the model predicts that covert recognition of faces in normals, in the form of sub-threshold priming, should exist, and that a similar account to that offered for covert recognition in prosopagnosics should apply. The model has been extended also to account for the data on naming in normals and brain injured patients experiencing particular deficits in the retrieval of names or identity specific semantic information.

In short, the IAC model presents a good first account of much of the face priming literature in both normals and brain injured subjects. Any functional model however, should be capable of predicting new effects not yet documented. By virtue of the fact that the Burton *et al.* (1990) model is a dynamic computer simulation of face recognition, the model presents a number of predictions that were not evident from the Bruce and Young architecture. This thesis sets out to examine a number of these predictions. One such prediction is highlighted by Burton *et al.* themselves; the phenomenon of cross-domain self priming.

2.9 Cross-domain self priming

Most studies investigating repetition face priming use periods of approximately 20 minutes between the pre-training phase and test phase (Bruce and Valentine, 1985; Ellis *et al.*, 1990; Ellis *et al.*, 1987). As discussed above, Burton *et al.* (1990) account for this classic long-term effect of repetition priming in terms of the strengthening of connections. Closer examination of Burton *et al.*'s model, however, would suggest that for short prime-target inter-stimulus intervals (ISIs) (with no inter-stimulus presentation between prime and target) face repetition priming should be considered also in terms of increased PIN activation. Bruce (1985) has shown that when prime materials are presented in one block (the pre-training phase), and target stimuli in another block (the test phase), repetition priming does not cross stimulus domains. However, the IAC model predicts that priming should occur from a persons' face to their name (and *vice versa*) for short prime-target ISIs; e.g. the presentation of Prince Charles' face should prime his name. Further, these cross-domain priming effects should be quantitatively equivalent to that found for a within-domain presentation design. Figure 2.10 shows the activation curves for Charles and Diana following an input to Charles' FRU, a rest period, and then an input to Charles' NIU.

From Figure 2.10 it is clear that for short SOAs priming should extend from Charles' face to his name. The rest period here is 20 cycles. However, explorations with the model show that priming extends across longer rest periods. Note that this predicted effect is not accounted for in terms of the strengthening of connections, but purely at the level of PIN activation. To that extent it is fundamentally different in nature to the classic within-domain repetition priming effects to be found in the literature (Bruce and Valentine, 1985; Ellis *et al.*, 1990; Ellis *et al.*, 1987) and is more akin to semantic priming effects. Consequently, as with semantic priming, the effect should not survive intervening stimuli between prime and target presentations. Finally, because the effect results from the direct activation of a PIN and not via the SIUs, the facilitation should be stronger than that observed for semantic priming. In acknowledgement of these observations, Burton *et al.* (1990) refer to this predicted cross-domain priming effect as 'self-priming'.

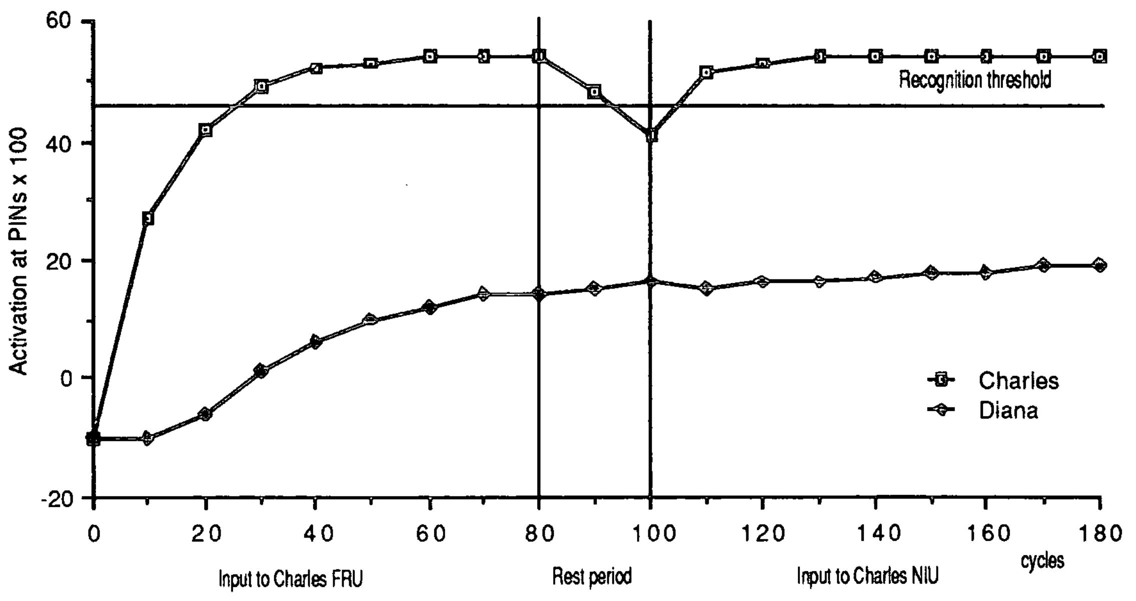


Figure 2.10: The activation curves for Charles' and Diana's PINs are shown following an input to Charles' FRU, followed by a rest period of 20 cycles (corresponding to a prime-target ISI) and an input to Charles' NIU.

This thesis identified the existence of self priming in normal subjects (Chapter 3), and then went on to use both self and semantic priming effects to test further predictions of the model (Chapter 4 and 5). Finally, Burton *et al.*'s account of distinctiveness effects was investigated. The self priming paradigm was used with a set of faces that varied in facial distinctiveness and a set of faces whose facial distinctiveness had been varied via computer manipulation (Benson and Perrett, 1991d) (Chapter 7).

3 Priming across stimulus domains

3.1 Introduction

3.1.1 Cross-domain self priming

Chapter 2 discussed Burton *et al.*'s (1990) prediction that for short SOA designs cross-domain self priming from a person's face to their name should be found. Self priming is explained in terms of the activation of PINs. The presentation of Prince Charles' face activates his PIN, if shortly after this his name is presented, the PIN, still being active, reaches its recognition threshold faster than had the name not been preceded by the face. In other words the face facilitates the recognition of the same person's name. A simulation of this effect is shown in Chapter 2, Figure 2.10.

The model indicates that an $input_i$ to Prince Charles' NIU would have the same effect on PIN activation as an $input_i$ to his FRU. Ignoring for the present, any effect resulting from the strengthening of connections, this observation would imply that cross and within-domain designs should produce the same degrees of self priming over short SOAs. Further, the model indicates a similar prime domain equivalence for semantic priming, an effect that has previously been demonstrated with a face prime/name target and name prime/name target design (Young *et al.*, 1988).

3.1.2 Semantic priming

Semantic priming results from the indirect activation of a PIN from another associated PIN via SIUs common to the two PINs, e.g. activation of Prince Charles' PIN activates Princess Diana's PIN by activating shared SIUs such as Royalty, son called Prince William, and separated! etc. Hence, because the semantic priming effect is located at the level of the PINs, the source of input to the PINs is irrelevant as both FRU and NIU inputs can be shown to have the same net effect.

The Burton *et al.* (1990) model predicts that at short SOAs self priming should produce a more marked degree of priming than semantic priming. This phenomenon is explained in terms of the different mechanisms underlying self and semantic priming. Self priming results from the repeated, direct activation of a single PIN i.e. the prime and target activate the same PIN. However, in semantic priming, an active PIN (corresponding to the prime) produces the indirect activation of a second PIN (corresponding to the target) via semantic identity units (SIUs) shared by the two PINs. Hence, the prime Prince Charles produces less activation of Princess Diana's PIN than of his own PIN for two reasons (i) for the former the activation is indirect, and (ii) Charles' PIN is initially the more active of the two, and therefore it inhibits Diana's PIN. Consequently, less facilitation should be found for semantic priming. In order that a comparison might be made between self and semantic priming, it was decided to investigate cross and within-domain self and semantic priming in the context of a single experiment.

The experiment was designed to investigate three predictions of the interactive activation model, (i) that self and semantic priming are found for both cross and within-domain prime-target designs, (ii) cross and within-domain designs produce equivalent degrees of self and semantic priming and, (ii) self priming produces a more marked priming effect than semantic priming.

3.1.3 Selecting an appropriate design

Bruce and Valentine (1986) chose a design with no stimulus repeats to demonstrate within-domain (face or name) semantic priming over short SOAs. Young *et al.* (1988) chose a similar design to demonstrate that cross and within-domain semantic priming produce equivalent effects. In the same paper, however, they used a design in which items were repeated across prime type conditions and found results consistent with the non-repeats design.

There are obvious methodological advantages in using a design with stimulus repeats. By using a few, highly familiar stimuli, problems relating to subjects' lack of familiarity with the stimuli are unlikely to arise. For these reasons, a design in which the stimuli were repeated was used.

One problem that is likely to arise with a repeated items design is interference from repetition priming effects. Because target names are repeated across prime-target conditions, the second and subsequent presentations of a particular name may be facilitated, because its initial presentation has primed them. In order to flush out any such effect, the subjects were presented with target names prior to viewing the experimental trials. Thus, the subjects were highly practised at recognising the target names prior to viewing the experimental trials, minimising any benefit of further repetition.

3.2 Experiment 1

3.2.1 Method

Subjects: 12 students from the post-graduate and undergraduate populations of the Department of Psychology, University of Durham participated as subjects. All had normal or corrected to normal vision. The subjects were paid for participating.

Stimuli: Black and white slides of the faces and names of 16 familiar individuals were employed as stimuli (see Appendix 1). The targets were printed names (upper case Helvetica script e.g. PRINCE CHARLES). Two types of priming agent were employed, (i) printed names in lower case Helvetica script with the exception of the first letters of the forenames and surnames which were upper case; e.g. Prince Charles and

(ii) black and white photographs of faces. The faces were photographed in such a way that the face filled the 36 mm x 24 mm slide.

Apparatus: A three-field projection tachistoscope and two Kodak AV 2050 projectors were used to present the stimuli. The slides were back projected onto a white screen, subtending a horizontal visual angle of approximately 8°. Reaction times were recorded on a electronic counter and were measured from the onset of the target name. They were terminated by a manual response made by the subject pressing one of two horizontally located buttons labelled 'Yes' and 'No'. Subjects were instructed to press the 'Yes' button if they thought that the target name was familiar and the 'No' button if they thought it was unfamiliar.

Design: The stimuli were presented within two blocks, one containing target names primed by faces (face prime block) and the other target names primed by names (name prime block). Four prime type conditions were used.

Same: The target name and prime were of the same person; e.g. Ronald Reagan's face (or name) followed by the printed target name, RONALD REAGAN.

Associated: The prime and target were closely associated; e.g. Nancy Reagan's face (or name) followed by the target name, RONALD REAGAN.

Neutral: The prime was an unfamiliar face (or unfamiliar name); e.g. unfamiliar face (or an unfamiliar name; e.g. Peter Sanders) followed by the target name, RONALD REAGAN .

Unrelated: The prime and target were both familiar persons who were not semantically related; e.g. Princess Diana's face (or name) followed by the target name, RONALD REAGAN.

Each of the 16 familiar names appeared as targets in each of the four prime type conditions. In addition, a further 64 prime-target pairs were added as 'No' response trials. The 'No' response trials were created by replacing the 16 familiar target names in the prime-target pairs with 16 unfamiliar names matched for length and titles e.g. Prince Andrew -> Prince Robert. Hence, in total there were 128 prime-target pairs in each of the face and name blocks. Within each of these two blocks presentation of the stimulus pairs was pseudo-random with respect to prime type condition and familiarity of the target names.

Procedure: On each trial, following a 'ready' signal from the experimenter, the prime was presented for 250 milliseconds, followed by an inter-stimulus interval (ISI) of 250 milliseconds, after which the target was displayed for 2.5 seconds. Hence, the stimulus onset asynchrony (SOA) was 500 milliseconds. Each of these prime-target trials was separated from the next by approximately 3 second intervals. Subjects were instructed to look at the prime but respond only to the target name by making a manual button-press response to indicate whether the name was familiar or unfamiliar. Half of the subjects made a positive familiarity response with their right hands and the other half with their left hands.

Prior to starting the experimental trials, the subjects were presented with the 16 familiar and 16 unfamiliar target names. Each name was presented for 2.5 seconds and the subjects were required to make a familiarity decision to it. The 32 target names were presented twice to ensure that the subjects were familiar with the target stimuli and practised in pressing the response keys. Presentation was pseudo-random with respect to familiarity.

Immediately prior to the experimental trials, a set of ten practice trials was run containing some of the stimulus pairs described above. All of the subjects completed blocks of both face prime and name prime trials. Half were assigned to the face prime block trials first and half to the name prime block.

3.2.2 Results

The mean correct reaction times and percentage error rates for correct familiarity decisions to the familiar and unfamiliar target names are shown in Table 3.1. For clarity correct response times to familiar target names are plotted in Figure 3.1. Error rates were low and will not be considered further.

	Familiar Targets				Unfamiliar Targets
	Same	Associated	Neutral	Unrelated	
RTs					
Face primes	557	595	608	633	651
Name primes	515	558	573	587	632
Errors					
Face primes	2.6	2.1	1.6	1.6	3.5
Name primes	1.5	1.6	0.8	1.4	2.8

Table 3.1: Mean correct reaction times in milliseconds and percentage error rates to target names preceded by face or name primes in the four prime type conditions; same, associated neutral and unrelated.

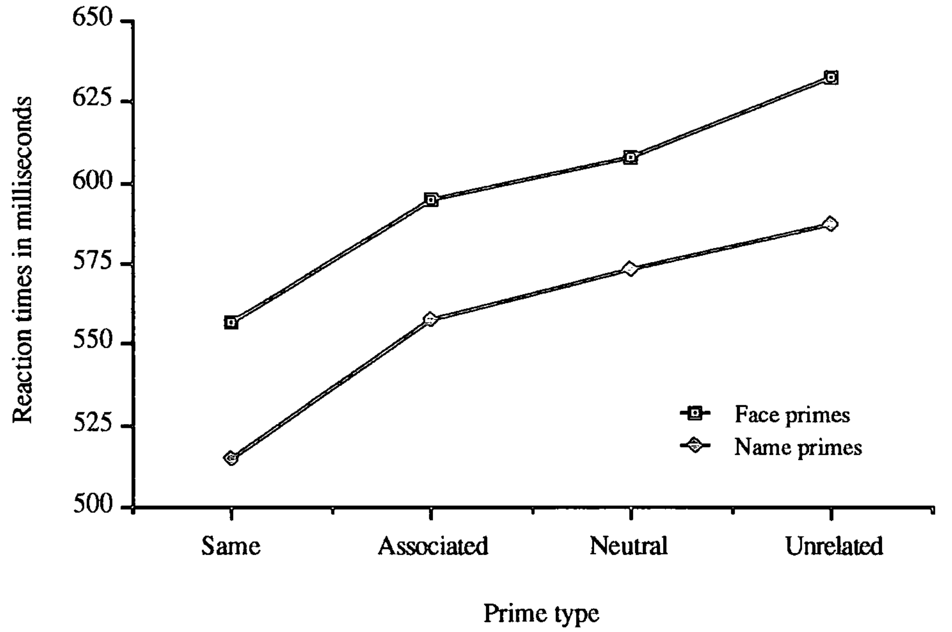


Figure 3.1: Mean correct reaction times in milliseconds to familiar target names preceded by face and printed name primes in the four prime type conditions same, associated, neutral and unrelated.

3.2.2.1 Analysis by subjects

A two-factor Analysis of Variance by subjects was carried out on the reaction time data to examine the effects of prime domain (faces or names; repeated measure) and prime type (same, associated, neutral or unrelated; repeated measure). A significant effect of prime domain (face or name primes), $F(1,11) = 26.851$, $p < 0.001$, indicated that target names preceded by name primes were responded to significantly faster than target names preceded by face primes. There was also a significant effect of prime type (same, associated, neutral & unrelated), $F(3,33) = 19.690$, $p < 0.001$. Planned comparisons[1] showed that responses to familiar target names preceded by the same primes were significantly faster than those preceded by the other three primes (associated, neutral and unrelated) (all p's < 0.01). There was no significant difference between the responses to familiar target names preceded by associated and neutral primes, or between the responses to target names preceded by neutral and unrelated conditions. There was no interaction between prime domain and prime type $F(3,33) = 0.211$, $p > 0.8$ indicating that the degree of priming from name primes and face primes was equivalent, relative to the neutral prime type conditions. The overall priming effect in comparison to the neutral condition, was therefore facilitation from same primes, no facilitation from associated primes and no inhibition from unrelated primes.

3.2.2.2 Analysis by items

An items analysis was also carried out on the same data. Prime domain and prime type were both within-items factors. There were highly significant effects of prime domain, $F(1,15) = 40.633$, $p < 0.001$ and prime type, $F(3,45) = 15.12$, $p < 0.001$ and no significant interaction effect between prime domain and prime type $F(3,45) = 0.135$, $p > 0.9$. Planned comparisons showed that responses to target names preceded by the same primes were significantly faster than those preceded by associated, neutral or unrelated primes (all p's < 0.01). Similarly, targets preceded by an associated prime were responded to faster than those preceded by both the neutral and unrelated primes ($p < 0.01$), which did not differ from one another. The overall priming effect was one of

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[1]For all planned comparisons the error term was based on all contrasts for the effect (see Winer (1971) pp 269-270)

facilitation from the same and associated conditions without inhibition from the unrelated condition.

3.2.3 Discussion

The above results show some differences between the subjects and items analyses. In particular, facilitation from the associated condition was only found in the items analysis. Given that the stimuli were repeated across the four prime-target experimental conditions, one might argue that the results of the items analysis are more informative. The items analysis gave an overall result of facilitation without inhibition for both same and associated prime-target conditions. This result is consistent with Posner and Snyder's (Posner and Snyder, 1975b) criterion of automatic priming i.e. facilitation from the related conditions (same and associated) without inhibition from the unrelated category (unrelated).

The most important point, however, is that no interaction effect was found between prime-target condition (same, associated, neutral and unrelated) and the domain of prime presentation (face or name) in either of the two analyses. The lack of any interaction effect between these two factors can be taken as consistent with the hypotheses that, (i) cross and within-domain designs produce equivalent degrees of self and semantic priming and, (ii) the domain of the prime does not affect the degree of priming. Secondly, in both analyses, the same condition produced a significantly greater degree of priming than the associated condition. This effect was also predicted from the Burton *et al.* (1990) model. Self priming (cross or within-domain) over short intervals is accounted for in terms of the repeated activation of a single PIN, while semantic priming is explained in terms of indirect activation of one PIN from another PIN via SIUs which they hold in common. The computer simulations (Figure 2.4 and Figure 2.10, Chapter 2) show that the former of these two effects produces a greater level of PIN activation than the latter.

One aspect of the results which cannot be explained in terms of the Burton *et al.* (1990) model is the significant effect of domain (face or name primes) found in both the subjects and items analyses. Therefore it is worth considering other ways which could account for this effect of domain.

One possible explanation is that printed lower-case names (primes) are more visually similar to printed upper-case names (targets) than are faces. Therefore, the effect of domain might be explained in terms of an additive effect of visual priming. This seems unlikely, however, as we would then expect to find an interaction between prime type and prime domain, as the prime and target in the within-domain same prime condition are more visually similar than those in the cross-domain same prime condition. Alternatively, it may be distracting for a subject if the domain of presentation changes between prime and target. A third possible explanation may lie in terms of the different visual complexities of the prime stimuli (faces and printed names). Faces are more visually complex and therefore may require more 'processing effort' than printed names. In other words, the amount of 'effort' required to process the prime may have a direct effect on the time taken to respond to the target name, but no effect on the amount of priming (as measured relative to the neutral prime type condition).

Experiment 2 set out to distinguish between the second and third explanations. It was reasoned that the name primes would require more 'processing effort' if they were degraded. One way to achieve a degradation was to replace the printed name primes with less legible handwritten name primes. If the significant effect of domain resulted from the effort required to process the prime, then one would expect to diminish or abolish this effect when the name primes are degraded. On the other hand, should the 'distracting to change domains' explanation be the more accurate account, then one would expect to replicate the domain effect found in Experiment 1.

3.3 Experiment 2

3.3.1 Method

Subjects: 12 students from the post-graduate and undergraduate populations of the Department of Psychology, University of Durham participated as subjects. All had normal or corrected to normal vision. None of the subjects had taken part in Experiment 1. The subjects were paid for participating.

Stimuli: The stimuli were identical to those used in Experiment 1, with the exception that the printed name primes in the name block were replaced with handwritten names. These names were written in lower-case script, with the exception of the first letter of both the forenames and surnames, which were upper-case.

Apparatus, Design and **Procedure** were identical to those used in Experiment 1.

3.3.2 Results

The mean correct reaction times and percentage error rates for correct familiarity decisions to the familiar and unfamiliar target names are shown in Table 3.2. Reaction times are plotted in Figure 3.2 Error rates were low and will not be considered further.

	Familiar Targets				Unfamiliar Targets
	Same	Associated	Neutral	Unrelated	
RTs					
Face primes	509	568	595	615	646
Name primes	518	564	581	610	666
Errors					
Face primes	1.2	1.6	2.6	3.6	3.1
Name primes	2.6	0.8	2.7	4.4	4.8

Table 3.2: Mean correct reaction times in milliseconds and percentage error rates for familiar and unfamiliar target names preceded by face or handwritten name primes from the four prime type conditions, same, associated, neutral and unrelated.

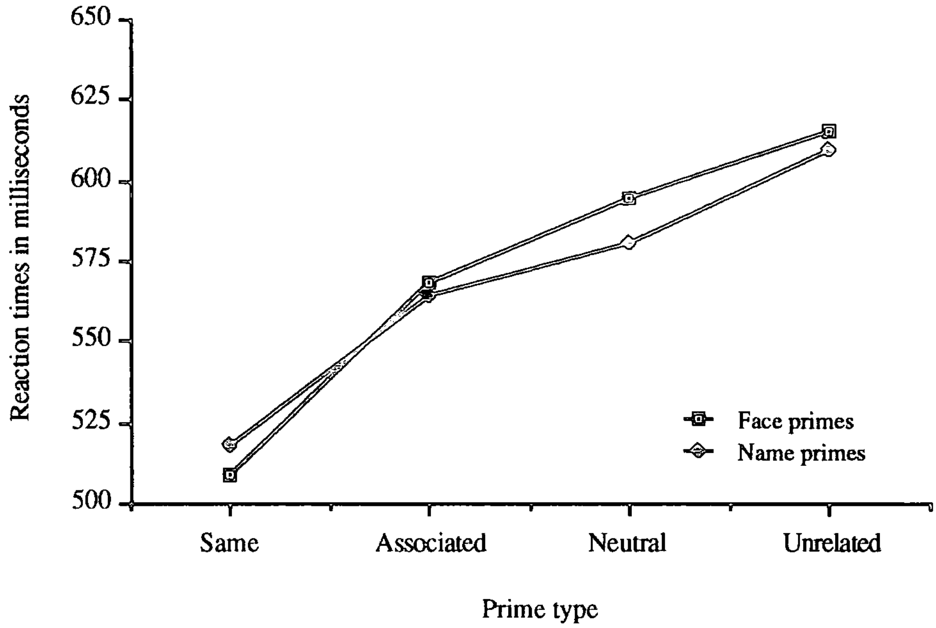

Figure 3.2: Mean correct reaction times in milliseconds to familiar name targets preceded by face and handwritten name primes in the four prime type condition; same, associated, neutral and unrelated.

3.3.2.1 Analysis by subjects

A two-factor Analysis of Variance by subjects was carried out on the reaction times. The within-subject factors were prime domain (face or handwritten name; repeated measures) and prime type (same, associated, neutral and unrelated; repeated measures). There was no significant effect of prime domain, $F(1,11) = 0.047$, $p > 0.8$, indicating that the domain of the prime did not affect the overall speed to make a familiarity decision to the target. There was, however, a highly significant effect of prime type, $F(3,33) = 48.812$, $p < 0.001$. Planned comparisons showed that familiar target names preceded by the same primes were responded to significantly faster than those preceded by the other three primes (associated, neutral and unrelated) (all p's < 0.01). Further, responses to familiar target names preceded by an associated prime were faster than responses to those preceded by neutral and unrelated primes (p's < 0.05). Response times to targets preceded by unrelated primes were significantly slower than those to the targets preceded by neutral primes ($p < 0.01$). Finally, there was no significant prime type x prime domain interaction, $F(3,33) = 0.791$, $p > 0.5$, indicating that face and handwritten name primes produce equivalent degrees of priming. The overall priming effect was one of facilitation from the same and associated conditions, with inhibition from the unrelated condition.

3.3.2.2 Analysis by items

An items analysis was also carried out on the data. Prime domain and prime type were both within subject factors. The only significant effect was that of prime type, $F(3,45) = 29.492$, $p < 0.001$. Planned comparisons showed the same pattern as that found in the subjects analysis, i.e. significant facilitation from both the same and associated conditions, with significant inhibition for the unrelated condition (all p's < 0.05). As with the subjects analysis both the effect of prime domain, $F(1,15) = 0.049$, $p > 0.8$, and the prime domain x prime type interaction, $F(3,45) = 0.771$, $p > 0.5$, did not reach significance.

3.3.3 Discussion

Both the subjects and items analyses produced the same overall result i.e. no significant effect of prime domain and no prime domain x prime type interaction, but a significant effect of prime type. It was suggested that handwritten names require more processing effort than printed names, and to that extent they are more similar to face primes than printed name primes. This hypothesis would seem to be supported by the results of Experiment 2.

As for Experiment 1, the lack of an interaction effect between domain and prime type is taken as support for the hypothesis that cross and within-domain priming produce equivalent degrees of self and semantic priming and to that extent Experiment 2 replicates the results of Experiment 1.

The nature of the priming found is consistent with the theory that both intentional strategies and automatic priming processes contributed to the priming effects found in Experiment 2 (Posner and Snyder, 1975b). Although facilitation was found for both same and associated conditions, inhibition was also found in the unrelated condition. The reason for this effect is not clear and may reflect the fact that the name primes were handwritten or different subject groups. Further, it is noted that other studies investigating semantic priming with face and name stimuli have found inhibition (Bruce and Valentine, 1986; Young *et al.*, 1988). The important findings to emphasise, however, are that cross and within-domain priming produce equivalent degrees of priming, and that the use of handwritten name primes abolishes the main effect of prime domain.

3.4 General Discussion

3.4.1 Cross and within-domain equivalence

Both Experiments 1 and 2 demonstrate the existence of cross-domain priming over short intervals. Further, neither of the two experiments produced an interaction effect between prime domain and prime type. This is taken as support for the hypothesis that cross and within-domain designs produce equivalent degrees of self and semantic priming. To that extent Experiments 1 and 2 replicate the results of Young *et al.* (1988), who found equivalent priming across domains for semantic priming, and extend their findings to encompass self priming as well.

3.4.2 Identity priming produces more facilitation than semantic priming

In both experiments, planned comparisons showed that targets preceded by the same face or name were responded to faster than targets in any of the other conditions. This effect is clouded to some extent by the absence of semantic priming (associative condition) in the subjects analysis of Experiment 1. However, it has been suggested that as a consequence of stimulus items being repeated across conditions, the results of the items analysis are more informative. Therefore, Experiments 1 and 2 provide support for the prediction that self priming produces more facilitation than semantic priming, regardless of prime domain.

3.4.3 Posner and Snyder's (1975) criterion of automatic priming

The items analysis in Experiment 1 produced an effect of facilitation from the same and associated prime type conditions without inhibition from the unrelated condition. This result is consistent with Posner and Snyder's theory of automatic priming. The results of the subject and items analyses of Experiment 2 are inconsistent with Posner and Snyder's criterion for automatic priming, due to the presence of inhibition from the unrelated condition. The reason for this effect is not quite clear. However, it is noted that there is evidence in the literature of comparable effects in name/name pair priming (Bruce and Valentine, 1986) and face (or name)/name priming (Young *et al.*, 1988) studies employing similar SOAs. Nevertheless, these present studies did not set out to make any predictions about the nature of the priming found across domains of presentation, but principally about the equality of these effects.

3.4.4 Inhibition and the use of strategies

It is worth noting that the Burton *et al.* (1990) model can account for inhibition without invoking the concept of subject strategies. Activation of Prince Charles' FRU leads automatically to the activation of his PIN. The architecture of the model is such that connections between different units in the PIN pool are inhibitory, as they are in the FRU pool. Hence, the activation of Charles' FRU produces the inhibition of all other FRUs and PINs other than the two units corresponding to Prince Charles (his FRU and PIN). The Burton *et al.* model would seem to suggest that a response to a target preceded by an unrelated prime may be slowed, because the prime inhibits the activation of the target. However, there are numerous examples of priming without inhibition in the literature, including Experiment 1 reported here. Therefore, a significant inhibitory effect may be subject to a number of factors such as familiarity, frequency, stimulus quality, relation between prime and target etc. Nevertheless, it would be conceivable that automatic priming can occur within the context of inhibition from the unrelated prime type condition. In other words, inhibition need not imply the use of strategies as Posner and

Snyder (1975) suggest. This is an important point and it is discussed in more detail in Chapter 8.

3.4.5 Main effect of domain

Experiment 1 found that target names preceded by name primes were responded to significantly faster than target names preceded by face primes. At first sight, the significant main effect of domain appeared problematic for the model. The effect is not apparent from the model's architecture. A 'pre-access' explanation has been offered in terms of processing effort. It is suggested that faces require more processing effort than printed names. Note that processing effort need not be equated with time, but instead may be thought of as the amount of attentional capacity required to encode a stimulus. Therefore, if a face requires a lot of attentional capacity, there is little left to process the target. In contrast, if a name requires little attentional capacity, there is ample residual capacity for the target. To test this hypothesis it was argued that if names were made harder to encode by reducing their legibility, then the effect of domain would be lost. This explanation would seem to be plausible, as Experiment 2 demonstrated that when the printed name primes were degraded (handwritten names), no effect of domain was found, the argument being that handwritten names require more processing effort than printed names.

This explanation is based on one of two assumptions (i) that it requires more effort to switch from processing a complex prime (a face) to processing the target or (ii) that the processing of the target takes place before the processing of the prime is complete. There is no logical reason why the latter explanation should not be the case, as the Burton *et al.* model does not, in theory, require that one input cycle should cease before another begins. Further, Ratcliff and McKoon (1988) have proposed a theory of semantic priming in which the prime and target are processed as a compound cue.

4 A closer look at self priming

4.1 Introduction

Experiments 1 and 2 demonstrated that cross and within-domain designs produce equivalent degrees of self priming and of semantic priming. It is important to note however, that prior to starting the main body of experimental trials the subjects had been presented with the target names. This was done in order to reduce any effects of repetition priming that would result from repeating stimulus items across the four prime type conditions (same, associated, neutral & unrelated).

In the Burton *et al.* model, activation of a NIU produces activation in its corresponding PIN. An algorithm operating on the system then determines which units are active and alters the connection strengths between active units in a positive direction; in this way the model accounts for repetition priming (Burton *et al.*, 1990). Given that this algorithm operates, the initial presentation of the target names in Experiments 1 and 2 would have produced a strengthening of the NIU-PIN connections. Further, any effect derived from the strengthening of these connections would have been reflected in the results. Closer examination of the model suggests that had the target names not been presented prior to viewing the prime-target trials, and had there been no stimulus repeats, a different outcome would have resulted. The explanation is perhaps best illustrated in an example.

If Ronald Reagan's face is presented his corresponding PIN will become activated. If shortly after his face, his name is presented, then his PIN, not having had sufficient time to return to its resting activation level, will reach recognition threshold faster than had the name not been preceded by the face. In other words the face facilitates the recognition of the name by activating the PIN. If, however, the name Ronald Reagan is preceded by the same name, not only does the first presentation activate his PIN, but it also causes the connection between his NIU and PIN to become strengthened. Hence, when Reagan's name is seen for the second time, the strengthened connection causes his PIN to increase in activation more rapidly. Thus, within-domain self priming over short intervals is accounted for by effects arising at two levels, increased PIN activation and the strengthening of the connections between NIUs and PINs.

This 'dual facilitation' account (PIN activation and strengthened connections) would suggest that a greater effect of self priming would be observed when the prime and target are from the same domain. Cross-domain priming, by its very nature does not involve the repetition of the same item. Thus, strengthening of connections plays no part. Likewise, semantic priming, regardless of domain of prime and target presentation, does not involve the repetition of the same stimulus. Therefore, the model predicts that within-domain design should produce more self priming than cross-domain design, but no more semantic priming than a cross-domain design. Note that in Experiments 1 and 2 the subjects were presented with the target names prior to viewing the experimental trials. In addition, stimulus items were repeated across prime type conditions. Both of these factors would have contributed to the strengthening of all NIU-PIN connections associated with the target name stimuli, and thus there was no scope for a greater within-domain self priming effect.

The experiments reported in this chapter tested two predictions of the Burton *et al.* model for a design in which there are no stimulus repeats; (i) within-domain self priming should produce more facilitation than cross-domain self priming, (ii) that no such domain inequality should exist for semantic priming. Ideally, one would want to examine these effects in the context of a single experiment, where same and associated prime type conditions are investigated together. Originally, such an experiment was carried out, but the results were extremely unclear. This was attributed to the limited number of possible stimuli caused by the lack of appropriate associated pairs. The results of this experiment are not reported here. Some of the 40 associated pairs that were used were replaced by more familiar people and it was decided to investigate self and semantic priming in separate experiments, but using the same 40 associated pairs in each experiment. Experiments 3 and 4 investigated the hypothesis that within-domain self priming produces a greater effect than cross-domain self priming. Experiment 5 used a reduced stimulus set to investigate semantic priming, as subject ratings indicated that only 20 of the stimulus pairs used in Experiments 3 and 4 were very closely related. Experiment 6 confirmed that the interaction effect found in Experiments 3 and 4 was not an artifact of the stimulus set by showing that the same interaction effect was found with this reduced stimulus set.

In Experiments 3, 4, 5 and 6 items were rotated across subjects and subjects saw each item only once. Items analysis were not carried out on the data, because the counterbalancing of the items across subjects meant that only two means contributed to a prime type cell for each item. Further, misses produced a number of missing data cells and therefore, it was thought that the results of item ANOVAS would be misleading.

4.2 Experiment 3

4.2.1 Method

Subjects: 20 subjects from the post-graduate and undergraduate populations of the University of Durham participated as subjects. All subjects were over the age of 25 years and had normal or corrected to normal vision. The subjects were paid for participating. None of the subjects had taken part in Experiments 1 or 2.

Stimuli: The names and faces of 40 pairs of closely associated famous persons (Appendix 2) were used to create the experimental trials to which a positive familiarity response was required. Target stimuli were names printed in upper case Helvetica font (e.g. RONALD REAGAN). Prime stimuli were both names and faces. Where a prime was a name it was printed in lower case Helvetica font, with the exception of the first letter of its forename and surname which were capitals (e.g. Ronald Reagan). Face primes were photographed in such a way that the face filled the 36 mm x 24 mm frame. All stimuli were black and white slides.

Apparatus: A three-field projection tachistoscope and two Kodak AV 2050 projectors were used to present the stimuli. The slides were back-projected onto a white screen subtending a horizontal visual angle of approximately 8°. Reaction times were recorded on an electronic counter and were measured from the onset of the target name and terminated by a manual response made by the subject pressing one of two horizontally located buttons. The buttons were labelled 'Yes' and 'No'. Subjects were instructed to press the 'Yes' button if they thought that the target name was familiar and the 'No' button if they thought it was unfamiliar.

Design: The stimuli were presented in two blocks; one containing target names primed by faces (face prime block) and the other target names primed by names (name prime block). The design of these two blocks was identical, exluding the fact that domain of the primes differed. Therefore, the design section explains the format of the wihtin-domain set (name prime/name target) only.

Three prime type conditions were used in this experiment.

Same: The prime and target were of the same person; e.g. prime name, Ronald Reagan followed by the target name RONALD REAGAN.

Neutral: The target name was preceded by an unfamous face (or name); e.g. unfamiliar name (e.g. Peter Sanders), followed by the target name RONALD REAGAN. The neutral prime was a face in the cross-domain, face prime block.

Unrelated: Both the prime and target were familiar persons who were not semantically related; e.g. prime name, Prince Charles followed by the target name

RONALD REAGAN. The unrelated pairs were produced by mixing the related pairs together.

Items were counterbalanced across subjects according to the following design. The names were divided into two sets, each containing four subsets (A - D set 1 and E -H set2) of 10 names; set 1: A, B, C & D and set 2: E, F, G & H (Appendix 2). The semantic pairs were divided between the sets such that all names paired with the stimuli in set 1 were in set 2.

For each of the two sets, four permutations of experimental trial blocks were prepared such that each of the names appeared only once as a target in each of the three prime type conditions. The names in sets 1 and 2 also acted as primes (with the exception of the neutral prime which was the same unfamiliar name throughout). The four prime-target permutations of stimulus set 1 are shown in Figure 4.1. The four prime-target permutations of set 2 followed an identical format. Similiarly, the face prime blocks were identical to the format of the name prime blocks described above, but with the name primes replaced with their corresponding faces.

1.	SAME	NEU	UNRE	2.	SAME	NEU	UNRE
Prime	A	N	D	Prime	B	N	C
Target	A	B	C	Target	B	A	D

3.	SAME	NEU	UNRE	4.	SAME	NEU	UNRE
Prime	C	N	A	Prime	D	N	B
Target	C	D	B	Target	D	C	A

Figure 4.1: The experimental trial blocks 1-4 containing four permutations of stimuli drawn from stimulus set 1. Experimental trial blocks 5-8, containing stimuli from set 2 were of the same format. Two further experimental trial blocks 9-12 and 13-16 were identical to experimental trial sets 1-4 and 5-8 with the exception that the name primes were replaced with face primes of the same individuals. N refers to the neutral prime, an unfamiliar face or name.

In summary, the names in sets 1 and 2 were arranged to give 4 permutations of name prime/name target pairs and four permutations of face prime/name target pairs for each of the two sets. Hence, in all there were 16 experimental trial sets, each of which contained 30 prime-target pairs to which a positive familiarity response was required. In addition to these familair prime-target pairs, two different sets of 30 prime-target 'No' response trials were added (one for set 1 (A-D) and one for set 2 (E-H)). The 'No' response trials, were composed of invented unfamilir target names, matched to the familiar target names in sets 1 and 2 for number of letters and titles, etc.; e.g. Princess Diana -> Princess Tracy. These unfamiliar target names were primed by the names or faces of 40 familiar persons (20 for the name prime block 20 for the face prime block), different to those included in the 40 pairs used in the positive response trials. In addition, the 'No' response trials inlcuded the same number of neutral prime/target trials as were used in the familair prime-target pairs. In order to reduce the possibility of the subjects using strategies, the majority of the 'No' response primes were members of a semantic pair. This prevented the subjects calculating a response on the basis of the prime being a member of/not being a member of a semantic pair.

Each subject saw all 40 associated pairs either as primes or targets, but never as both, and no stimulus face or name was presented more than once either as a prime or a target. Experimental trial sets and order of viewing the within and cross-domain trials were counter-balanced across subjects and the prime target pairs were pseudo-random with respect to prime-target condition, familiarity response and group to which the target belonged (i.e. A-D, E-H).

At the end of the experiment the subjects were asked to name all 80 familiar faces used in the positive response trials. If they had difficulty in recalling a name they were asked to give the person's occupation. Any familiar face that they did not recognize was noted. Once they had completed the naming task they were read the names of the faces they did not recognize and asked to state if they were familiar.

To summarise, prime type (same, neutral & unrelated), and prime domain (face & name primes) were both within-subject factors.

Procedure: On each trial, following a 'ready' signal from the experimenter, the prime was presented for 250 milliseconds followed by an inter-stimulus interval (ISI) of 250 milliseconds, after which the target was displayed for 2.5 seconds. Hence, the stimulus onset asynchrony (SOA) was 500 milliseconds. Each of these prime-target trials was separated from the next by approximately 3 second intervals. Subjects were instructed to look at the prime but respond only to the target name by making a manual button-press response to indicate whether the name was familiar or unfamiliar.

Immediately prior to the experimental trials a set of ten practice trials was run containing some of the stimulus pairs of the type described above. None of the items included in the practice trials were repeated in the experimental trials. All of the subjects completed both face prime and name prime block trials. Half were assigned to the face block trials first and half to the name block. Note that the subjects were not presented with the target names prior to viewing the experimental trials.

4.2.2 Results

Subjects were rejected from the analysis if they (i) recognized less than seven target names from any one prime type condition of the experiment, or (ii) indicated that they were familiar with less than seven names or faces at the post-hoc naming phase. The data from four subjects were rejected on this basis. The mean correct reaction times and percentage error rates for correct familiarity decisions to familiar and unfamiliar target names from the remaining 16 subjects are shown in Table 4.1. For clarity the mean correct reaction times are also plotted in Figure 4.2.

	Familiar Targets			Unfamiliar targets
	Same	Neutral	Unrelated	
RTs				
Face primes	747	809	824	938
Name primes	638	787	789	947
Errors				
Face primes	7	9	4	9
Name primes	10	4	6	16

Table 4.1: Mean correct reaction times in milliseconds and percentage error rates to familiar and unfamiliar target names preceded by face or name primes for the three prime type conditions; same, neutral and unrelated.

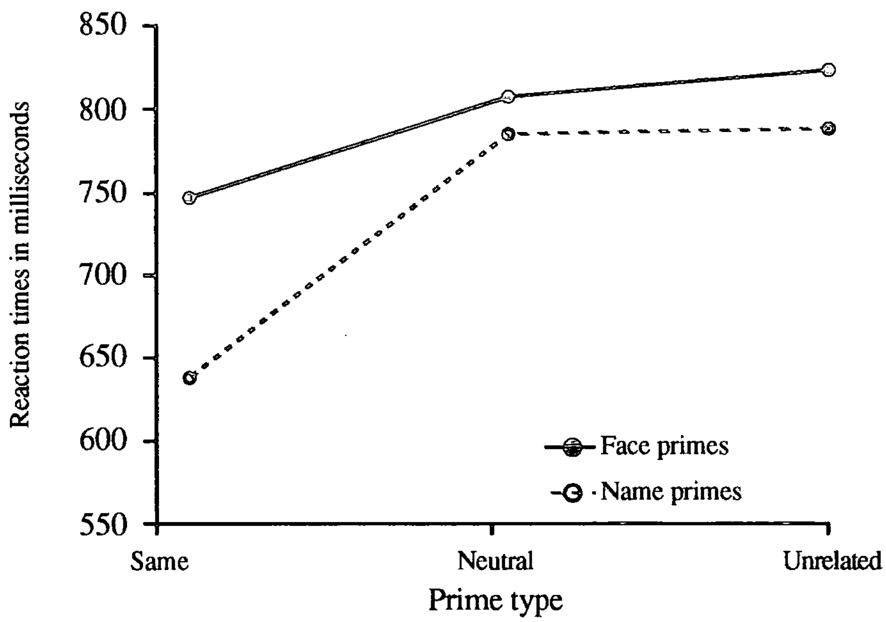

Figure 4.2: Mean correct reaction times in milliseconds to familiar target names preceded by face and printed name primes in three prime type conditions: same, neutral and unrelated.

Error rates were not analysed, as Bruce and Valentine (1986) have pointed out that it is inappropriate to examine errors in an experiment where a negative response may merely reflect a genuine lack of familiarity with the target. A two-factor ANOVA was carried out on the reaction time data to familiar target names. Prime domain (face and name) and prime type (same, neutral and unrelated) were both within-subject factors. There was a significant effect of prime type, $F(2,30) = 24.746$, $p < 0.001$. Planned comparisons showed that target names preceded by the same primes were responded to significantly faster than those preceded by neutral or unrelated primes (p's < 0.01), which did not differ. The overall priming effect was therefore one of facilitation without inhibition, a result consistent with Posner and Snyder's (1975) criterion of automatic priming. In addition, there was a significant prime domain x prime type interaction effect $F(2,30) = 6.114$, $p < 0.01$. Simple effects analyses showed that an effect of domain was restricted to the same prime type condition, $F(1,15) = 8.312$, $p < 0.05$, ($F < 1.1$ for the other two prime type conditions). To confirm further that the source of the interaction effect was from the effect of domain for the same prime type condition, separate comparisons of the prime domain x prime type interaction were carried out on the same/neutral reaction times and the neutral/unrelated reaction times (Keppel, 1973); pp 448-453). The same/neutral analysis of the interaction produced a significant effect, $F(1,30) = 10.56$, $p < 0.01$, which indicated that there was interaction between prime domain and prime type for these two levels of prime type. The neutral/unrelated analysis was not significant ($F<1$). The results indicate that the significant interaction effect found in the overall ANOVA reflected the greater degree of within-domain self priming than cross-domain self priming. No significant main effect of prime domain was found.

4.2.3 Discussion

4.2.3.1 A within-domain priming effect

The presence of an interaction effect between prime domain (face or name) and prime type supports the hypothesis that within-domain self priming produces a more marked effect than cross-domain self priming. The Burton *et al.* (1990) model suggests that the presentation of a prime name would result in the strengthening of a NIU-PIN connection. In the within-domain, same prime type condition the prime and target are the same name. Hence, when the target is presented the strengthened NIU-PIN connection reduces the time taken for the PIN to reach recognition threshold. In the cross-domain same prime type condition, the face prime presentation causes a FRU-PIN connection to become strengthened, hence, the subsequent presentation of the target name is unaffected by this strengthened connection. In short, the results of this experiment would appear to support the prediction of the interactive activation model (Burton *et al.*, 1990); i.e for short SOA designs cross-domain self priming is accounted for in terms of PIN activation only, while within-domain self priming results from the additive effects of PIN activation and strengthened connections.

4.2.3.2 Alternative explanations

One might argue, however, that the significant interaction effect could be an artifact of factors other than a within-domain priming effect. For example, whereas a particular photograph may be a bad likeness of the person it depicts, the same cannot be said of a printed name. In addition, a subject may be familiar with a person's name, but not so familiar with their face. The fact that the subjects encountered each of the stimuli only once may also have enhanced these contaminating effects. In order to control for these factors, subjects were asked to indicate if they recognised the faces used in the experiment after completing the prime-target experimental trials. The data from any subject who failed to recognize three or more faces in any of the three prime type conditions, were excluded from the above analysis. This safeguard method could be criticised, however, as one might argue that the subjects need only refer back to the set of names used in the experiment to guess at the identities of the faces. During the experiment the subjects had no such clue to a face's identity, and for this reason the results may have been confounded with factors such as goodness of likeness, and inconsistent degrees of familiarity with face and name stimuli.

A second means of demonstrating that the priming effect was not an artifact of the subjects being more familiar with the names than with the faces, was to repeat the experiment with face targets primed by faces and names. If the result was indeed an effect of domain then one would expect to find the same within-domain advantage when the targets are faces. Experiment 4 set out to investigate this hypothesis.

4.3 Experiment 4

4.3.1 Method

Subjects: 19 students from the undergraduate and post-graduate populations of the University of Durham participated as subjects. All subjects were over the age of 25 years and had normal or corrected to normal vision. Subjects were paid for participating. None of the subjects had taken part in Experiments 1, 2 or 3.

Materials: The prime sets used in Experiment 3 were also used in this experiment. Target stimuli were faces; primes were names or faces. In Experiment 3 the name primes and name targets that made up the within-domain condition were not identical, in that the primes were printed in lower-case letters and the targets in upper-case letters. To ensure a degree of consistency between the designs of the two experiments, face primes and face targets were different views of the same face. Unfamiliar faces were used in place of the invented unfamiliar names used in Experiment 3 as 'No' response trials.

It was not possible to obtain a second photograph of 5 of the personalities used in Experiment 3. For this reason their target face was replaced by an unfamiliar face and the reaction time data from these trials was analysed along with the 'No' response trial data.

Apparatus, design and procedure were identical to that used in Experiment 3 with the exception that the targets were black and white faces, rather than names.

4.3.2 Results

Mean correct reaction times and percentage error rates for correct familiarity responses to familiar and unfamiliar target faces are shown in Table 4.2. For clarity the mean correct reaction times are also plotted in Figure 4.3.

	Familiar Targets			Unfamiliar targets
	Same	Neutral	Unrelated	
RTs				
Face primes	646	821	830	785
Name primes	688	760	840	856
Errors				
Face primes	12	15	17	12
Name primes	11	16	17	14

Table 4.2: Mean correct reaction times and percentage error rates for correct responses to target faces preceded by face or name primes for the three prime type conditions; same, neutral and unrelated.

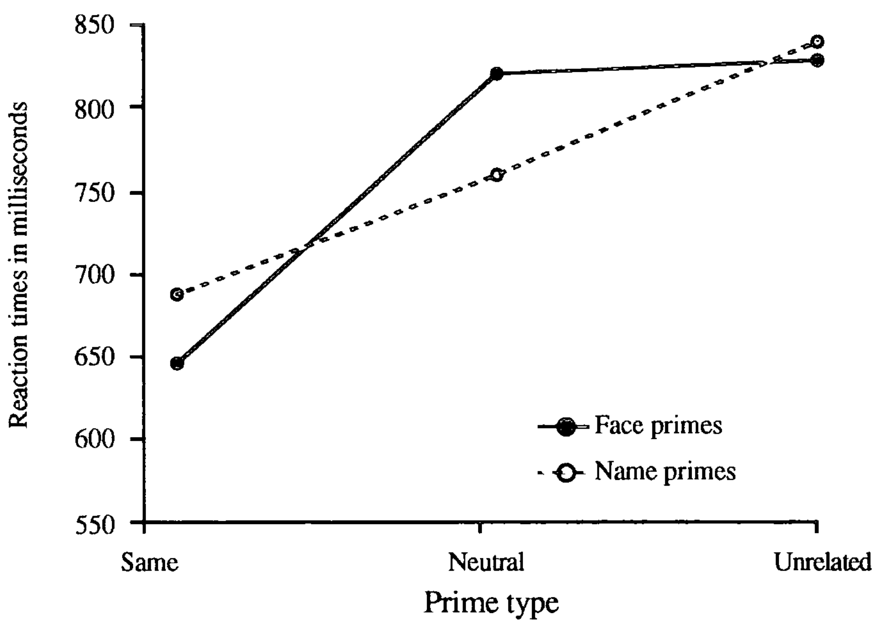

Figure 4.3: Mean correct reaction times in milliseconds to familiar target faces preceded by face and printed name primes in three prime type conditions; same, neutral and unrelated.

Error rates were not analysed in accordance with the reasons given by Bruce and Valentine (1986). A two-factor ANOVA was carried out on the reaction times to familiar face targets. Both prime domain (face and name) and prime type (same, neutral and unrelated) were within-subject factors. There was a significant effect of prime type, $F(2,30) = 34.641$, $p < 0.001$. Planned comparisons showed that target names preceded by the same primes were responded to significantly faster than targets preceded by the neutral or unrelated primes (p's < 0.01), which were also significantly different from each other ($p < 0.05$). The overall priming effect was therefore one of facilitation with inhibition. This result is inconsistent with Posner and Snyder's (1975) criterion for automatic priming. Of most interest, there was a significant prime domain x prime type interaction, $F(2,30) = 3.865$, $p < 0.05$. No significant effect of prime domain was found. Simple effects analyses showed a significant effect of domain for the neutral prime stimuli only, $F(1,15) = 4.680$, $p < 0.05$. In order to clarify the source of the interaction, the analysis was broken down further, and separate comparisons of the prime domain x prime type interaction were carried out on the same/neutral reaction times and neutral/unrelated reaction times (Keppel, 1973); pp 448-453). The same/neutral comparison showed a significant effect $F(1,30) = 7.393$, $p < 0.05$, indicating the presence of an interaction between prime domain and the same/neutral prime type. The result of the neutral/unrelated comparison was not significant ($F < 3.5$). The results indicate that the interaction found for the overall ANOVA can be attributed to the greater degree of facilitation from the same face primes, i.e. within-domain self priming produced more facilitation than cross-domain self priming.

4.3.3 Discussion

The above experiment demonstrated that a within-domain design produces a greater degree of self priming than a cross-domain design when targets are faces and primes are names and faces. Experiment 4 was designed to distinguish between two possible explanations of the priming effect found in Experiment 3: (i) that the effect was due to the strengthening of connections, and to that extent reflected the structure of the face recognition system, or (ii) a stimulus inequality explanation; that the face stimuli were in some way more difficult to recognize than the name stimuli. The results of Experiment 4 suggest that the former of the two explanations is the more accurate account of the results.

However, further confirmatory evidence of the effect would be found if the data from Experiments 3 and 4 were combined in one analysis to produce a three-way interaction between Experiment (3 and 4; between subjects), prime domain (face prime and name prime; repeated measure) and prime type (same, neutral and unrelated; repeated measure). The results from this analysis were as follows: the only significant main effect was prime type, $F(2,30) = 58.840$, $p < 0.001$. Planned comparisons indicated that responses to target names or faces preceded by same primes were faster than those to targets preceded by neutral and unrelated primes ($p < 0.01$), which did not differ. Thus the overall priming effect was one of facilitation from the same prime without inhibition from unrelated primes. The only other significant effect was the three-way interaction between experiment, prime domain and prime type, $F(2,60) = 8.413$ $p < 0.001$.

Experiment 4 was carried out in order to determine whether the significant interaction effect found in Experiment 3 reflected more fluent processing of name stimuli, or the structure of the recognition system. The results of Experiment 4 would suggest that it is the latter, because the same set of face primes that were used in Experiment 3 were found to produce more self priming than name primes, when targets were faces.

In Experiment 4 there was significant inhibition. Further planned comparisons carried out on the within and cross-domain set means showed that the overall effect of inhibition was confined to the cross-domain stimulus set. Other studies have found effects of inhibition with name prime stimuli (Bruce and Valentine, 1986; Young *et al.*, 1988) and it may be that name to face priming magnifies this effect.

4.4 Experiment 5

4.4.1 Introduction

Experiments 3 and 4 both demonstrated greater self priming from a within-domain design than a cross-domain design. This effect has been attributed to the structure of the recognition system, or more precisely the strengthening of connections between distinct units. Earlier it was noted that the strengthening of connections plays no part in an explanation of semantic priming. Semantic priming is an interaction between PIN and SIU activation (Burton *et al.*, 1990). In Chapter 2 it was noted that an input to a FRU produces the same level of activation in the corresponding PIN as an input to the corresponding NIU (Figure 2.4). Given this assumption one would not expect to find a within-domain advantage for semantic priming. Experiment 5 set out to investigate this hypothesis.

The stimulus set used in Experiments 3 and 4 consisted of 40 semantically associated pairs of personalities selected by the experimenter. A pilot experiment similar to Experiment 5, investigating semantic priming alone, was run using the 40 stimulus pairs used in Experiments 3 and 4. An analysis of the results showed no significant effect of semantic priming. This was surprising as semantic priming has been reported many times in the literature. However, on questioning the subjects it become clear that they did not think some of the people chosen were closely related. The results of this experiment are therefore not reported. In order to produce a stimulus set that potential subjects regarded as associated pairs, 20 subjects were asked to rate the 40 associated pairs for level of association.

4.4.2 Method

4.4.2.1 *Associated pair ratings*

Subjects: 20 subjects from the undergraduate population of the University of Durham participated as subjects. All subjects had normal or corrected to normal vision.

Materials: The names of the persons that made up the 40 associated pairs used in Experiments 3 and 4 were divided into two lists of 40 names. One member of each semantic pair appeared in each list.

Procedure: Each of the lists were presented to ten subjects. Next to each of the names they were instructed to write a second name with which they felt the given name was most associated. In addition, they were asked to rate the degree of the association on a scale from 1 to 7, where 1 indicated a weak association and 7 a strong association.

The names and faces of 20 pairs of famous individuals that received an association rating of 4.5 and above were used as stimuli in the following experiment (see Appendix 3).

4.4.2.2 Cross and within-domain semantic priming

Subjects: 24 subjects from the undergraduate and post-graduate populations of the University of Durham participated as subjects. Subjects were over the age of 25 years and had normal or corrected to normal vision. The subjects were paid for participating. None of the subjects had taken part in Experiments 1 - 4.

Materials: The names and faces of the 20 associated pairs, selected using the associative pair rating described above, were used as stimuli. Both faces and names were used as primes, targets were always names. Prime names were printed in lower case Helvetica font, with the exception of the first letter of the forenames and surnames which were capitals (e.g. Ronald Reagan), and target names were printed in upper case Helvetica font (e.g. RONALD REAGAN). Face primes were photographed in such a way that the face filled the 36 mm x 24 mm frame. All stimuli were black and white slides.

Apparatus: The apparatus used in this experiment was the same as that used in Experiments 1 - 4.

Design: Two experimental conditions were employed. Prime domain was a between-subjects condition and had two levels; face prime and name prime. Half the subjects saw the target names preceded by face primes; the other half of the subjects saw target names preceded by name primes. Prime type was a within-subjects condition and had three levels, associated, neutral and unrelated, defined as follows.

Associated: The target was preceded by a familiar prime commonly associated with the target; e.g. prime Nancy Reagan followed by target name RONALD REAGAN.

Neutral: The target name was preceded by an unfamiliar invented name or an unfamiliar face; e.g. prime name Peter Sanders followed by the target name RONALD REAGAN.

Unrelated: The prime and target were of unrelated famous individuals; e.g. prime Ernie Wise followed by the target name RONALD REAGAN.

The names of the twenty pairs of associated individuals were arranged into four groups of ten (Group A, B, C & D) such that the individuals paired with those in group A were in group B and those paired with group C were in group D. The groups were then arranged to give four permutations of prime-target stimuli as shown in Figure 4.4.

1.	**Ass**	**Neu**	**Unre**
Prime	B	N	U
Target	A	C	D

2.	**Ass**	**Neu**	**Unre**
Prime	A	N	U
Target	B	D	C

3.	**Ass**	**Neu**	**Unre**
Prime	C	N	U
Target	D	A	B

4.	**Ass**	**Neu**	**Unre**
Prime	D	N	U
Target	C	B	A

Figure 4.4: Four permutations of prime target pairs preceded by associated (Ass), neutral (Neu) and unrelated (Unre) prime types. N = Neutral prime, i.e. unfamiliar name or face, and U = Unrelated prime. The same set of ten unrelated name or face primes were used throughout the experiment.

Because there were only two sets of ten related pairs (AB & CD) it was necessary to create two separate sets of unrelated prime sets. One set contained the faces and the other the names of one member of the ten semantic pairs that received the next highest association ratings to those in sets A, B, C and D. The same unrelated prime sets were used in the unrelated conditions in each of the four experimental trial set permutations shown in Figure 4.4.

In all there were four experimental trial sets. Each contained 30 prime target pairs to which a positive familiarity response was to be made to the target name. In addition, a further 30 prime-target pairs were added as 'No' response trials. The 'No' response trials were made up of unfamiliar, invented target names matched in terms of number of letters and titles to the familiar target names, e.g. Prince Andrew -> Prince Robert. Two-thirds of the unfamiliar target names were preceded by the names (or faces) of twenty familiar persons, none of whom were included in the 20 semantic pairs. In order to prevent subjects developing response strategies, the majority of these familiar persons were members of semantic pairs.

No stimulus face or name was presented more than once either as a prime or a target to any one subject. Presentation of prime-target pairs was pseudo-random with respect to prime type condition, familiarity response and group to which the target belonged (i.e. A,B,C & D).

Procedure: On each trial, following a 'ready' signal from the experimenter, the prime stimulus was presented for 250 milliseconds followed by an inter-stimulus interval (ISI) of 250 milliseconds, after which the target name was displayed for 2.5 seconds. Hence, the stimulus onset asynchrony (SOA) was 500 milliseconds. Each prime-target trial was separated from the next by an interval of approximately 3 seconds. Subjects were instructed to look at the prime but respond only to the target name by making a manual response to indicate whether the name was familiar or unfamiliar. Prior to the main body of experimental trials a short practice trial was run containing stimulus pairs of the same type to those described above. The practice trials ran into the main experimental trials. All subjects saw the same 60 familiar and unfamiliar target names but for half of the subjects they were preceded by face primes and for the other half by name primes.

At the end of the experiment all subjects were presented with the 40 familiar faces used as stimuli and asked to name them. If they had difficulty in recalling a name they were asked to give the persons occupation. Any faces the subjects were unfamiliar with were noted and once they had completed the naming task the subjects were asked to indicate if they were familiar with the names of the person they did not recognize.

4.4.3 Results

The mean correct reaction times and percentage error rates for responses to familiar name targets preceded by associated, neutral and unrelated primes and to unfamiliar target names are summarized in Table 4.3. For clarity, the mean correct reaction times are also plotted in Figure 4.5.

	Familiar Targets			Unfamiliar targets
	Associated	Neutral	Unrelated	
RTs				
Face primes	704	763	780	906
Name primes	643	729	775	785
Errors				
Face primes	6	3	5	8
Name primes	6	3	3	8

Table 4.3: Mean correct reaction times and percentage error rates for correct responses to target faces preceded by face or name primes for the three prime type conditions; associated, neutral and unrelated.

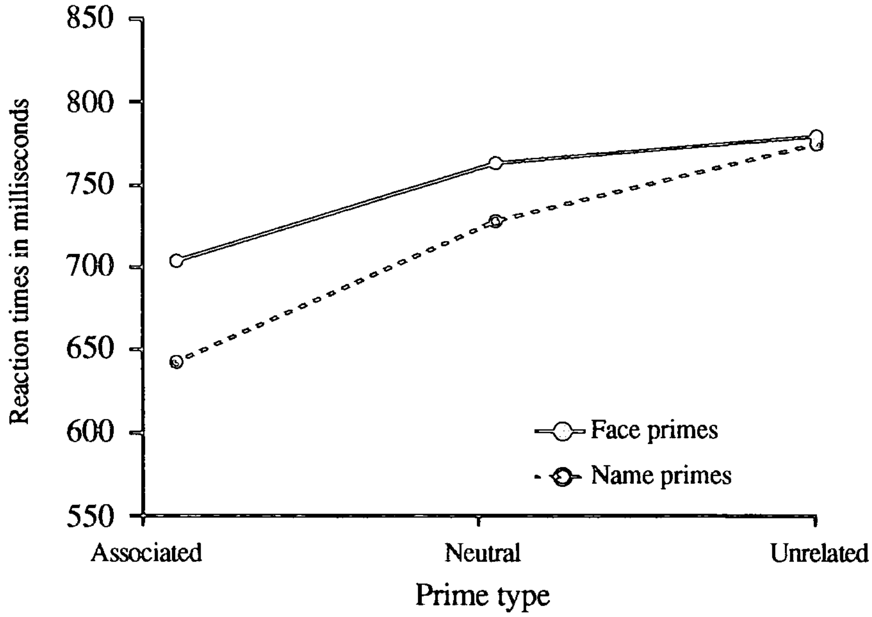

Figure 4.5: Mean correct reaction times in milliseconds to familiar target names preceded by face and printed name primes in three prime type conditions: associated, neutral and unrelated.

Error rates were not analysed in accordance with the reasons given by Bruce and Valentine (1986). The reaction time data to familiar targets were submitted to a two-factor ANOVA. Prime domain (face or name primes) and prime type (associated, neutral and unrelated) were between and within-subject factors respectively. The only significant effect was that of prime type, $F(2,22) = 28.07$, $p < 0.001$. Planned comparisons showed that target names preceded by associated primes were responded to faster than those preceded by the neutral or unrelated primes (p's < 0.01). Further, responses to target names preceded by an unrelated prime were slower than those preceded by a neutral prime ($p < 0.05$). Hence, the overall priming effect was one of facilitation from the associated primes and inhibition from the unrelated primes. There was no significant effect of prime domain, and most informative of all, no prime domain x prime type interaction, $F(2,44) = 1.95$, $p > 0.1$. Therefore, this result would seem to support the hypothesis that within and cross-domain semantic priming produce equivalent degrees of priming.

4.4.4 Discussion

The results of the above experiment confirm the prediction of the Burton *et al.* model (1990) that cross and within-domain designs produce equivalent degrees of semantic priming for a design without stimulus repeats. Further, they replicate the results of Young, Hellawell and De Haan (1988) who have shown the same effect with a smaller stimulus set (15 semantic pairs).

Although this same effect has been demonstrated previously in the literature (Young *et al.*, 1988), justification for this experiment is sought on the basis that it was motivated by different reasoning and it is important to show that these effects are robust.

An overall effect of facilitation from the associated primes and inhibition from the related primes was found. Young *et al.* (1988) found a comparable result in their subjects analysis, but facilitation without inhibition on the items analysis. As previously mentioned Bruce and Young (1986) found inhibition when primes and targets were names but not when they were faces. An explanation of these inconsistent effects is not immediately apparent, but some explanations are offered in the general discussion section of this chapter.

The stimulus set used in this experiment was not exactly the same as that used in Experiments 3 and 4. It is therefore possible that the effect may be an artifact of the different stimulus sets used. Further, whereas in Experiments 3 and 4 prime domain was a within-subjects factor, in Experiment 5 it was a between-subjects factor. These differences may not relate to the pattern of results found. Nevertheless, it is important to eliminate them as explanations, however improbable they may sound. For this reason Experiment 6 set out to replicate the results found in Experiment 3, but with the reduced stimulus set used in Experiment 5, and a between-subjects design.

4.5 Experiment 6

4.5.1 Method

Subjects: 24 subjects from the undergraduate and post-graduate populations of the University of Durham participated as subjects. All subjects had normal or corrected to normal vision and were over the age of 25 years. The subjects were paid for participating. None of the subjects had taken part in Experiments 1 - 5.

Materials: The reduced set of 20 associated pairs used in Experiment 5 was used as stimuli. All stimuli were black and white slides.

Apparatus: The apparatus used in this experiment was identical to that used in Experiments 1 - 5.

Design: There were two experimental conditions; prime domain and prime type. Prime domain was a between-subjects condition and had two levels; face primes and name primes. Prime type was a within-subjects condition and had three levels; same, neutral and unrelated, defined as follows.

Same: The prime face (or name) and target name were of the same person; e.g. Ronald Reagan's face (or name) followed by the target name RONALD REAGAN.

Neutral: The target name was preceded by an unfamiliar face (or unfamiliar name); e.g. prime name, Peter Sanders followed by the target name RONALD REAGAN.

Unrelated: The prime and target were unrelated famous individuals; e.g. Ernie Wise's face (or name) followed by the target name RONALD REAGAN.

A similar four group arrangement to that used in Experiment 5 was also used in this experiment. The four permutations of prime-target stimuli are shown in Figure 4.6.

1.	Same	Neu	Unre
Prime	A	N	U
Target	A	B	C

2.	Same	Neu	Unre
Prime	B	N	U
Target	B	C	D

3.	Same	Neu	Unre
Prime	C	N	U
Target	C	D	A

4.	Same	Neu	Unre
Prime	D	N	U
Target	D	A	B

Figure 4.6: Four permutations of prime target pairs used. N = Neutral prime; i.e. unfamiliar name or face, and U = Unrelated prime. The same set of ten unrelated name or face primes were used throughout the experiment.

As in Experiment 5 there were four experimental trial sets, each containing 30 prime target pairs to which a positive familiarity response was required. The same 30 'No' response trials and unrelated prime sets used in Experiment 5 were used in this experiment also. No stimulus face or name was presented more than once either as a prime or a target to any one subject. Prime target pairs were pseudo-random with respect to prime-target condition, familiarity response and group to which the target belonged (i.e. A,B,C & D).

Procedure: On each trial, following a 'ready' signal from the experimenter, the prime was presented for 250 milliseconds followed by an inter-stimulus interval of 250 milliseconds, after which the target was displayed for 2.5 seconds. Hence, the stimulus onset asynchrony (SOA) was 500 milliseconds. Each prime-target trial was separated from the next by an interval of approximately three seconds. Subjects were instructed to look at the prime but respond only to the target name by making a manual response to indicate whether the name was familiar or unfamiliar. Immediately prior to viewing the main body of experimental trials, 10 practice trials were presented consisting of stimulus pairs of the type described above. Each subject saw 60 familiar and unfamiliar target names. For half the subjects they were preceded by face primes and for the other half by name primes.

At the end of the experiment all subjects were presented with the 40 familiar faces of the individuals used as stimuli and asked to name them. If they had difficulty in recalling a name they were asked to give the person's occupation. Any faces the subjects were unfamiliar with were noted and once they had completed the naming task the subjects were asked to indicate if they were familiar with the names of these faces.

4.5.2 Results

The mean correct reaction times and percentage error rates for responses to familiar name targets preceded by same, neutral and unrelated primes and for responses to unfamiliar target names are summarized in Table 4.4. For clarity, the mean correct reaction times are also plotted in Figure 4.7.

	Familiar Targets			Unfamiliar targets
	Same	Neutral	Unrelated	
RTs				
Face primes	647	750	762	811
Name primes	569	729	760	829
Errors				
Face primes	6	8	6	9
Name primes	8	8	11	14

Table 4.4: Mean correct reaction times and percentage error rates to familiar and unfamiliar target names preceded by face and name primes in the three prime type conditions; same, neutral and unrelated.

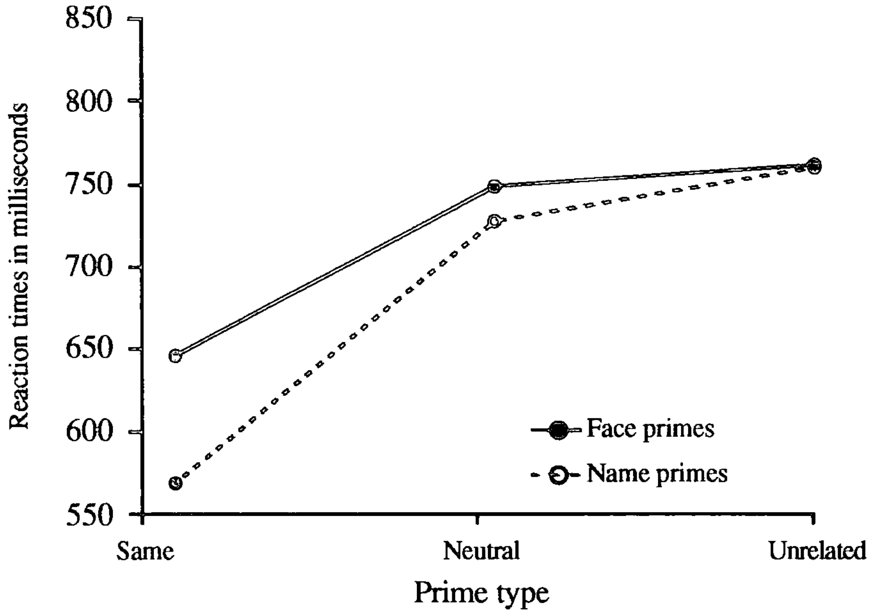

Figure 4.7: Mean correct reaction times in milliseconds to familiar target names preceded by face and printed name primes in three prime type conditions: same, neutral and unrelated.

Error rates were not analysed, in accordance with the reasons given by Bruce and Valentine (1986). The reaction time data to familiar targets were submitted to a two-factor ANOVA. Prime domain (face and name) and prime type (same, neutral and unrelated) were between and within-subject factors respectively.

There was no significant effect of prime domain, but a significant effect of prime type (same, neutral and unrelated), $F(2,22) = 122.063$, $p < 0.001$. Planned comparisons showed that responses to familiar target names preceded by the same primes were significantly faster than those preceded by a neutral or unrelated prime (p's < 0.01). Responses to familiar targets preceded by an unrelated prime were significantly slower than those preceded by a neutral prime ($p < 0.05$). Therefore, the overall priming effect was one of facilitation from targets preceded by the same prime and inhibition from targets preceded by an unrelated prime. Finally, there was a significant interaction between prime domain and prime type, $F(2,44) = 6.998$, $p < 0.005$. Simple effects analysis showed no significant effect of domain at any of the three levels of prime type. Therefore, the analysis was broken down further in order to confirm the source of the interaction effect (Keppel, 1973; pp 458-453). Two separate comparisons of the prime domain x prime type interaction were carried out on the same/neutral reaction times and neutral/unrelated reaction times. The same/neutral comparison showed a significant effect, $F(1,44) = 7.344$, $p < 0.01$ indicating the presence of an interaction between prime domain and same/neutral prime types. The neutral/unrelated comparison was not significant ($F < 1$), indicating no interaction effect was present between prime domain and neutral/unrelated prime types. The results of these two comparisons verified that the overall interaction effect resulted from the greater amount of facilitation from the same primes in the within-domain condition compared with the cross-domain condition.

4.5.3 Discussion

Experiment 6 showed that for the reduced stimulus set, a greater within-domain self priming effect was found. Experiment 5 showed that no within-domain effect is found in semantic priming. Taken with the results from Experiments 3 and 4, these studies would seem to suggest that the structure of the face recognition system is consistent with the architecture proposed by Burton *et al.* (1990). Nevertheless, a more convincing demonstration of the dichotomous results for self and semantic priming would be found if the data from Experiments 5 and 6 were combined in one analysis to produce a three-way interaction between experiment (5 & 6), prime domain (face & name) and prime type (same/associated, neutral and unrelated). The results from this analysis were as follows.

The only significant main effect was prime type, $F(2,44) = 117.810$, $p < 0.001$. Planned comparisons indicated that targets preceded by related primes (same/associated) were responded to faster than those preceded by neutral and unrelated primes (p's < 0.01). Further, responses to targets preceded by unrelated primes were slower than those to targets preceded by neutral primes ($p < 0.05$), giving an overall priming effect of facilitation from related primes (same/associated) and inhibition from unrelated primes. In addition, there was a significant interaction between experiment and prime type, $F(2,88) = 6.747$, $p < 0.005$, showing that self priming produces more priming than semantic priming. There was also a significant prime domain x prime type interaction,

$F(2,88) = 7.159$, $p < 0.005$, probably forced through from the large significant interaction in Experiment 5. Finally, the three-way interaction between experiment, prime domain and prime type did not reach significance ($F = 0.45$).

4.6 General Discussion

4.6.1 Priming without stimulus repeats

For the main part, the results of the six experiments in Chapters 3 and 4 have produced consistent results, and where the results have differed, a plausible theoretical explanation has been offered; the strengthening of connections. Therefore, priming designs with and without stimulus repeats would seem to produce consistent findings in that both designs produce, (i) cross and within-domain self and semantic priming, (ii) greater self than semantic priming and (iii) equivalent degrees of semantic priming across prime domain conditions. The principal inconsistent result is the more marked effect of within-domain self priming compared to cross-domain self priming. This finding was predicted by the Burton *et al.* (1990) model and its verification through experiment lends further support to the model's architecture.

One of the methodological problems in the study of face recognition, is the limited number of semantic pairs of very high familiarity. Even that once great bastion of reliable semantic pairs, the Royal family, is crumbling. The above demonstration that cross and within-domain designs produce very similar patterns of semantic priming, would suggest that investigations of semantic priming can overcome the problems of stimulus pair shortage by repeating stimuli across conditions.

4.6.2 An effect of domain and not of stimulus

Experiments 3 and 4 both demonstrated significantly greater within-domain self priming than cross-domain self priming. Experiment 4 showed that this effect was not an artifact of a possible lack of familiarity the subjects may have had with the face stimuli. This was further confirmed by the three-way interaction between Experiment (3 and 4), prime domain (face and name) and prime type (same, neutral and unrelated), found in the combined analysis of Experiments 3 and 4.

4.6.3 Nature of the priming effect

With the exception of Experiment 1 and 3, the experiments reported so far have produced significant amounts of inhibition, in addition to significant facilitation. It is not clear why this effect is found. However, separate analyses of the experiments showing interactions revealed that the inhibition was restricted to the name-prime condition. At first sight this might imply that inhibition is a within-domain phenomenon. However, Experiment 4 illustrates that it is not the case, as no inhibition was found from the unrelated face prime condition when targets were faces. Further, it is noted that Bruce and Valentine (1986) found inhibition in a name/name semantic task but not in a face/face task. It would appear that for a 500 millisecond SOA, inhibition would seem to be a phenomenon of name prime stimuli only.

4.6.4 Inhibition as a result of strategy

In Experiment 1 the main effect of domain was accounted for in terms of the explanation that names require less processing effort than faces. Similarly, one could argue that there is more room to devote attentional processing space to strategic processes in the case of name prime processing than face prime processing. Posner and Klein (1973) suggest that the mechanisms of conscious attention are limited, and that the employment of a conscious strategy might inhibit the processing of signals inconsistent with the strategy. Therefore, in the case of self priming the most obvious strategy, 'attend to the prime and get ready for the same target name', may be employed. When the 'expected' target is not presented, i.e. in the case of the unrelated condition, there is a slowing of response to the target. Further, because face processing requires more processing effort, there is little left to devote to conscious strategies at a 500 millisecond SOA presentation time. Hence, inhibition is not observed when primes are faces.

4.6.5 Repetition and semantic priming effects

Bruce (1986) has shown that repetition priming and semantic priming produce very different results. Semantic priming is short lived while repetition priming is long lasting. Further, semantic priming can cross stimulus domains, while repetition priming does not (Bruce and Valentine, 1985; Ellis *et al.*, 1987). The results of the above studies would seem to suggest that repetition priming persists across stimulus domains for a short SOA (500 milliseconds). However, in terms of the model, this cross-domain self priming effect has little in common with the classic long term repetition priming effects reported in the literature (Bruce and Valentine, 1985; Brunas *et al.*, 1990; Brunas-Wagstaff *et al.*, 1992; Ellis *et al.*, 1990; Ellis *et al.*, 1987; Ellis *et al.*, 1993; Young, McWeeny, Hay and Ellis, 1986a). The model suggests that the effect is more akin to semantic priming than to long term repetition priming. Burton *et al.* recognize this distinction by referring to short term cross-domain repetition priming as self priming. Given the IAC model's account of self priming it would seem theoretically correct to consider this effect as distinct from the classic within-domain repetition priming. Hence, there is no reason to extend the definition of repetition priming; repetition priming does *not* cross stimulus domains. That is not to say that priming from the same person over short SOAs is some sort of strategic pseudo-phenomenon. The architecture of the model dictates that the effect, in Posner and Snyder's (1975) terminology, is automatic, and stems from the recognition system of face memory.

4.6.6 Absence of an effect of domain

With the possible exception of the marginal effect of domain found in Experiment 3 ($p = 0.082$), none of the experiments in Chapter 4 replicated the effect of domain found in Experiment 1. As in Experiment 1, prime names were printed in lower case script. The lack of an effect is probably due to the fact that subjects were more familiar with the stimuli used in Experiment 1 as they were a small number of very famous personalities. Further, the fact that the stimuli used in Experiment 1 were repeated a number of times would also have reduced the time taken to process the primes.

5 Self and semantic priming across different SOAs

5.1 Introduction

Burton *et al.* (1990) present a simulation of self and semantic priming over short intervals. A similar simulation is shown in Figure 5.1.

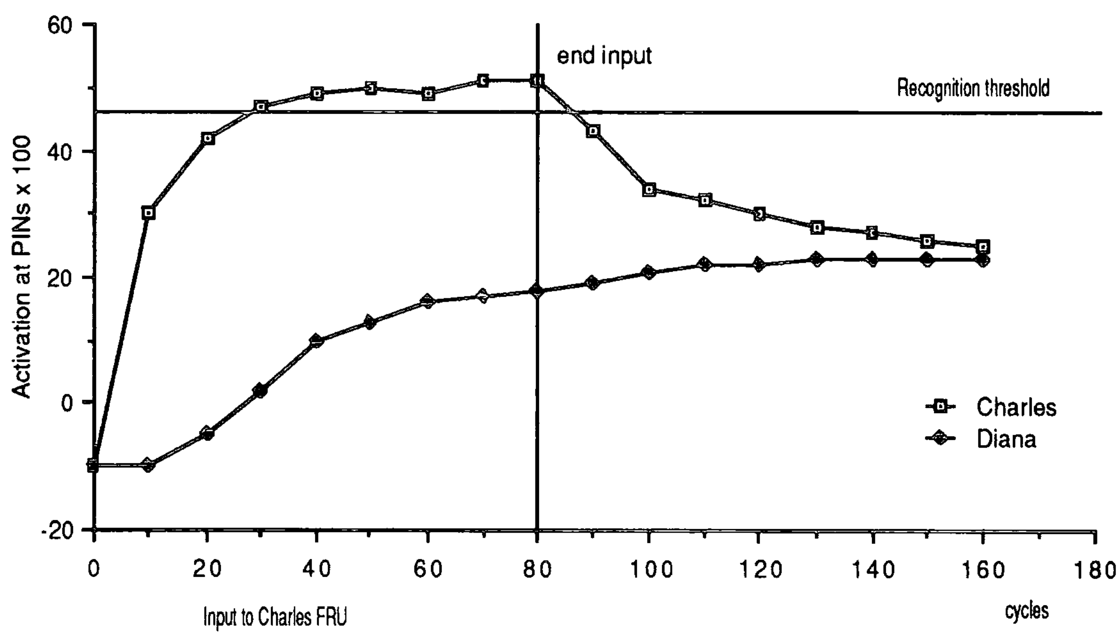

Figure 5.1: The levels of activation of the PINs for Prince Charles and Princess Diana are shown following the activation of Charles' face recognition unit (FRU). Because Charles and Diana have semantic information in common, Diana's PIN becomes active without any direct activation to her FRU or name identity unit (NIU). Note also that when the input to Charles' FRU ceases, the activation levels of the two PINs gradually converge. Because the classic 500 millisecond SOA type experiment described above yields a more marked self priming effect, this time course *probably* corresponds to the presentation of the target before the 140 cycle mark where the activation of Charles' and Diana's PIN have begun to converge.

The simulation represents the resultant PIN activation following the presentation of Prince Charles' face (or name). Activation of Prince Charles' PIN produces the indirect activation of Diana's PIN via SIUs that are connected to both PINs. The activity after the 'end input' line (see Figure 5.1) represents the activation in the two PINs when the presentation of Prince Charles' face (or name) has ceased. This region might be thought of as representing a prime-target ISI in the classic prime-target SOA experiment (Posner and Snyder, 1975b). PIN activation following the presentation of a target is not represented.

Note that the activation in Diana's PIN continues to increase after the 'end input' mark, while activation in Charles' PIN dies down to a point at which the two activation curves converge. If a second presentation of Charles or Diana's name was presented at each of four points corresponding to 90, 100, 120 and 140 cycles, the simulation would suggest that as the number of cycles increased, the response times to recognize Charles' name (self priming) and Diana's name (semantic priming) as familiar would progressively converge.

In other words, the simulation predicts that as the prime-target ISI increases, the difference between the same and associated condition reaction times, as found in Experiments 1 and 2, should progressively reduce.

In the light of this computer simulation Experiment 7 was carried out. In Experiment 7 cross-domain self and semantic priming are examined over four ISIs. For Experiment 8, a second prediction was derived from the area of the graph prior to the 'end input' point (see Figure 5.1). Experiment 8 therefore tested the hypothesis that as prime presentation increased, the amount of semantic priming should also increase. Further, the simulation predicts that semantic priming cannot exist in the absence of self priming, and that at all points prior to the 'end input' point the self priming effect should exceed the semantic priming effect.

5.2 Experiment 7[2]

5.2.1 Method:

Subjects: 12 subjects from the undergraduate and post-graduate population of the Department of Psychology, University of Nottingham participated as subjects. All had normal or corrected to normal vision. Subjects were paid for participating.

Materials: Black and white slides of the faces and names of eight pairs of familiar, semantically associated individuals were employed as stimuli (see Appendix 4). Targets were names, printed in upper case Helvetica script (e.g. RONALD REAGAN), and primes were faces. Face primes were photographed in such a way that the face filled the 36 mm x 24 mm frame.

Apparatus: The apparatus was identical to that used in Experiments 1 - 6.

Design: Two within-subjects factors were investigated (i) the prime-target inter-stimulus interval (ISI) which had four levels (20, 250, 750 and 1250 milliseconds; see Figure 5.2) and prime type, which also had four levels; same, associated, neutral and unrelated which were defined as follows.

Same: The target name and prime were of the same person; e.g. Ronald Reagan's face followed by the printed target name, RONALD REAGAN.

Associated: The prime was that of an individual closely associated with the target name; e.g. Nancy Reagan's face followed by the target name RONALD REAGAN.

Neutral: The prime was an unfamiliar face and the target a famous name; e.g. unfamiliar face, followed by the target name RONALD REAGAN.

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[2]Experiment 7 was carried out in the University of Nottingham. The visit to the University was funded by a study visit grant awarded by the Experimental Psychology Society.

Unrelated: The prime and target name were both famous persons who were not semantically related; e.g. Princess Diana's face followed by the target name RONALD REAGAN.

Prime Exposure (in milliseconds)	ISI (in milliseconds)	SOA (in milliseconds)
250	20	270
250	250	500
250	750	1000
250	1250	1500

Figure 5.2: Prime exposure, prime-target ISI and SOA for each of the four levels in the within-subjects factor, prime-target ISI. All times are shown in milliseconds.

Each of the target names appeared once in each of the four prime type conditions preceded by the appropriate prime, giving a total of 64 familiar target names to which the subjects were required to make a positive familiarity response. In addition to these, a further 64 'No' response prime-target pairs were added. These were produced by replacing the 16 familiar target names with 16 unfamiliar, invented names, matched to the familiar target names in terms of number of letters and titles etc. e.g. Prince Andrew -> Prince Robert. Hence, in total there were 128 prime-target pairs in the experimental trials block. Subjects were presented with the experimental trial block four times, each time at a different level of ISI (20, 250, 750 and 1250 milliseconds). Order of presentation of ISI blocks was counter-balanced across subjects. Presentation of all stimulus pairs within each of the four blocks was pseudo-random with respect to prime type condition and familiarity of the target names.

Procedure: On each trial, following a 'ready' signal from the experimenter, the prime was presented for 250 milliseconds followed by an inter-stimulus interval (which varied depending on the level of the prime-target ISI), after which the target was displayed for 2.5 seconds. Each prime-target trial was separated from the next by an interval of approximately three seconds. Subjects were instructed to look at the prime but respond only to the target name by making a manual button-press response to indicate whether the name was familiar or unfamiliar. Half of the subjects made a positive familiarity response with their right hands and the other half with their left hands. Prior to starting the experiment, the subjects were presented with all 16 familiar and 16 unfamiliar target names, written in upper case Helvetica script (i.e. exactly as they were to appear in the main task itself). The names were pseudo-randomly presented with respect to familiarity, and the subjects were required to make a familiarity decision to each. Each of the names was presented twice to ensure that the subjects were familiar with the target stimuli and practised in pressing the response keys. Following this, a short practice trial was run containing some of the stimulus pairs described above. Immediately after the practice trial the main experimental trials were run. ISI level was blocked such that the subjects saw all 16 target names in the four prime type levels at one ISI level in one session. Order of presentation of ISI blocks was counterbalanced across subjects. Subjects saw each four blocks in separate testing sessions. Testing sessions were separated by one day.

5.2.2 Results

The mean correct reaction times and percentage error rates to familiar and unfamiliar target names are shown in Table 5.1. Error rates were low and will not be considered further. For clarity, mean facilitation values are shown in Figure 5.3. Facilitation values were calculated relative to the neutral prime type condition reaction times. Hence, facilitation = neutral prime type condition - prime type condition.

5.2.2.1 Analysis by subjects

The reaction times to familiar target names were submitted to a two-factor repeated measures ANOVA. Two within-subjects factors were examined, prime-target ISI, which had four levels (20, 250 750 and 1250 milliseconds; repeated measure) and prime type which also had four levels (same, associated, neutral and unrelated; repeated measure). The results showed a significant effect of prime type, $F(3,33) = 76.251$, $p < 0.001$. Planned comparisons showed that responses to familiar name targets preceded by same primes were faster than responses to target names preceded by the other three primes (associated, neutral and unrelated) (all p's < 0.01). Responses to target names preceded by associated primes were faster than those to target names preceded by neutral and unrelated primes (p's < 0.01). Responses to target names preceded by unrelated primes were slower than those to target names preceded by neutral primes (p < 0.01), giving an overall priming effect of facilitation to target names preceded by same and associated primes and inhibition to target names preceded by an unrelated prime. No significant effect of ISI was found (F<1) indicating that the overall response times to target names are not affected by the length of the prime target ISI. Finally, there was no interaction between prime type and ISI (F<1), showing that self and semantic priming effects were not affected by the length of the prime-target ISI.

	Familiar Targets				Unfamiliar Targets
RTs	Same	Associated	Neutral	Unrelated	
ISI					
20	493	532	569	577	624
250	499	527	566	579	605
750	501	542	562	582	594
1250	490	542	555	598	615
Errors					
ISI					
20	0.0	1.6	3.1	4.7	3.3
250	0.0	3.1	2.6	1.6	3.4
750	0.5	0.0	2.6	4.2	2.1
1250	0.5	1.0	3.6	3.1	3.4

Table 5.1: Mean correct reaction times and percentage error rates for familiar target names preceded by same, associated, neutral and unrelated prime types at each of the four prime presentation times, 20, 250, 750 and 1250 milliseconds.

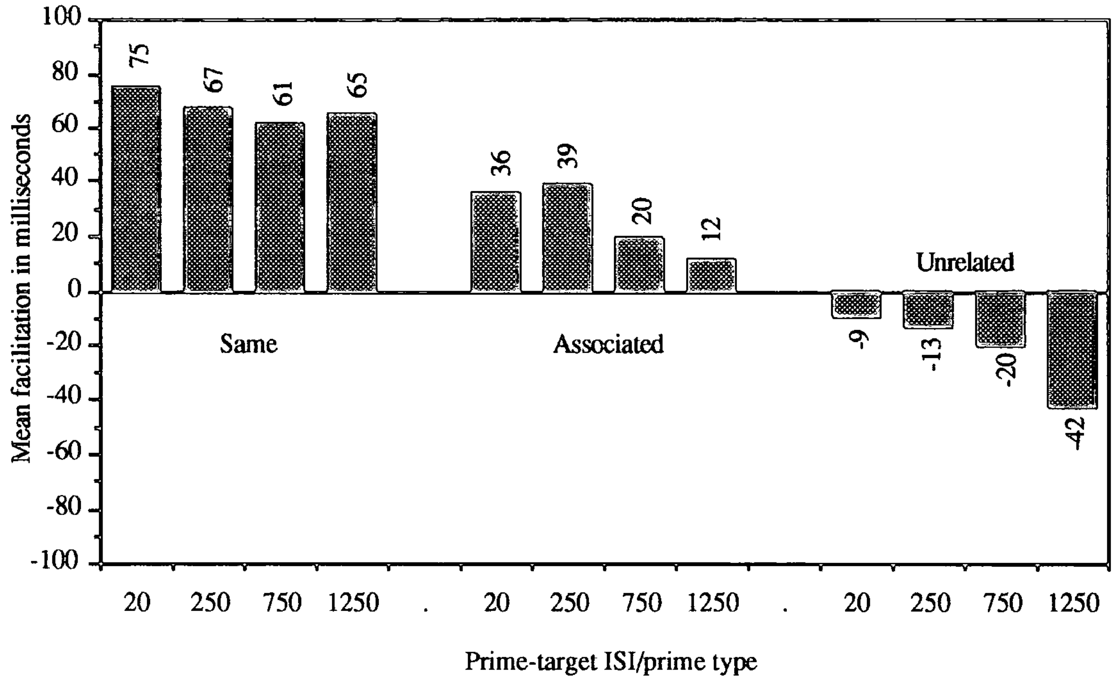

Figure 5.3: Mean facilitation or inhibition of reaction times measured relative to the neutral prime type condition for responses to familiar name targets preceded by same, associated and unrelated face primes across four different ISI durations with constant prime presentation duration of 250 milliseconds.

5.2.2.2 Analysis by items

A two-factor ANOVA by items was also carried out on the same reaction time data (within-subjects factor 1: ISI; repeated measure, within-subjects factor 2: prime type; repeated measure). The results showed a very similar pattern of effects. Prime presentation was the only significant effect found, $F(3,45) = 55.380$, $p < 0.001$). Planned comparisons showed that responses to target names preceded by same primes were significantly faster than those to target names preceded by the other three prime types (associated, neutral and unrelated) (all p's < 0.01). Responses to target names preceded by associated primes were significantly faster than those to target names preceded by neutral or unrelated primes (p's < 0.01). Responses to target names preceded by unrelated primes were significantly slower than those to target names preceded by neutral primes ($p < 0.05$). Hence, the overall priming effect was one of facilitation from same and associated prime types with inhibition from unrelated primes. No other significant effects were found ($F < 1$).

5.2.3 Discussion

The simulation of semantic priming shown in Figure 5.1 indicated that after the input to Charles' FRU had ceased, the activation of Charles and Diana's PINs should converge. Following this simulation, it was predicted that this difference between self priming and semantic priming found in Experiments 1 and 2 should reduce as the ISI between prime and target increased. The results of Experiment 7 did not support this hypothesis. Failure to find the predicted effect might be explained in terms of secondary factors such as a decay function acting on the PINs.

The hypothesis was based on the activity of the PINs in the far right region of the graph (Figure 5.1) i.e after the input to Charles' PIN had ceased. It could be argued, that the behaviour of the PINs at this point is vulnerable to a greater decay parameter than that, modelled in the simulation. This may account for the fact that both the self and semantic priming decreased slightly with increasing ISI. However, neither of these effects were significant. Alternatively, the results may have been affected by conscious strategies as significant inhibition was found.

This sort of design highlights the difficulties in matching the time parameter in the simulation, cycles, to real time. Figure 5.1 presents a simulation that predicts that as the prime-target ISI increases the difference between self and semantic priming should reduce. However, it is difficult to estimate at what ISI the activation of Charles' and Diana's PINs converge. The shortest SOA used was 270 milliseconds. However, this may translate to the simulation at 90 cycles, 160 cycles or even 500 cycles, in which case the results may reflect the decay of Charles' and Diana's PIN activation, conscious strategies, or a combination of both and the predicted effect.

5.3 Experiment 8

5.3.1 Introduction

A second experiment was designed to examine the effects of varying the prime presentation. From the previous graph (Figure 5.1) it would seem clear that for a zero ISI, self priming should be found with a shorter prime presentation than that required to produce semantic priming. In addition, as the duration of prime presentation increased so should the semantic priming effect. Finally, for all prime presentation times self priming should exceed semantic priming.

These three predictions are derived from a simulation where the effect results directly from stimulus presentation and not activation levels in the ISI. For this reason the second hypothesis is less vulnerable to secondary factors, such as decay functions. Further, it examines an intrinsic feature of the model, i.e. that the presence of self priming is a necessary concomitant of semantic priming.

Experiment 8 set out to examine the effects of varying prime presentation. A pilot experiment that is not reported in this thesis attempted to examine the effects of sub and supra-threshold priming. The experiment found that subjects were able to identify face primes at an average masked prime presentation exposure time of 30.5 milliseconds. Further, significant priming to target names was found at this prime exposure time. For this reason it was decided to investigate prime presentation times (unmasked) of 25, 50, 100 and 250 milliseconds with a prime-target ISI of zero. Further, it was thought that at shorter SOAs strategic processes were less likely to interfere.

Subjects: 12 subjects from the undergraduate and post-graduate population of the Department of Psychology, University of Durham participated as subjects. All had normal or corrected to normal vision. Subjects were paid for participating. None of the subjects had taken part in Experiments 1 - 7.

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Materials and apparatus: The materials and apparatus were identical to those used in Experiment 7.

Design: Two within-subject factors were investigated; prime type and prime presentation time. The same four levels of prime type used in Experiment 7 were also used in this experiment; same, associated, neutral and unrelated. Prime presentation had four levels as shown in Figure 5.4. Note that prime presentation and stimulus onset asynchrony were synonymous in this experiment.

Prime Exposure (in milliseconds)	ISI (in milliseconds)	SOA (in milliseconds)
25	0	25
50	0	50
100	0	100
250	0	250

Figure 5.4: The four levels of prime presentation times are shown with the corresponding ISI and SOA times in milliseconds. Prime presentation and SOA were synonymous.

Procedure: Following a 'ready' signal from the experimenter the prime was presented for one of 25, 50 100 or 250 milliseconds. Immediately after the prime, the target was presented for 2.5 seconds. The prime-target ISI was zero. Subjects were instructed to look at the prime but respond only to the target name by making a manual button-press response to indicate whether the name was familiar or unfamiliar. Half of the subjects made a positive familiarity response with their right hands and the other half with their left hands. Prior to starting the experiment, the subjects were presented with all 16 familiar and 16 unfamiliar names as targets written in upper case Helvetica script (i.e. exactly as they were to appear in the experimental trials). The presentation of the target names was pseudo-random with respect to familiarity, and the subjects were required to make a familiarity decision to each. Each of the names was presented twice to ensure that the subjects were familiar with the target stimuli and practised in pressing the response keys. Following this, a short practice trial was run containing some of the stimulus pairs described above. Immediately after the practice trial the main experimental trials were run. All subjects saw prime-target pairs at each of the four levels of prime-presentation. SOA was blocked such that subjects saw all 16 prime-target pairs at one of the four levels of prime type in one block. Order of presentation of SOA blocks was counterbalanced across subjects. Subjects saw each of the four blocks in separate testing sessions. Testing sessions were separated by a day.

5.3.2 Results

Mean correct reaction times and error rates to familiar and unfamiliar target names in each of the four prime type conditions are shown in Table 5.2. Error rates were low and will not be considered further.

	Familiar Targets				Unfamiliar Targets
RTs	Same	Associated	Neutral	Unrelated	
SOA					
25	534	538	579	574	595
50	526	552	575	606	597
100	531	570	591	636	610
250	499	563	574	650	592
Errors					
SOA					
25	0.5	1.6	2.1	2.1	3.1
50	2.0	1.6	3.6	3.6	3.6
100	0.0	1.0	1.6	1.6	2.7
250	0.5	0.0	3.0	3.6	2.7

Table 5.2: Mean correct reaction times and percentage error rates to familiar and unfamiliar target names preceded by face primes presented at each of the four levels of prime presentation time (25, 50, 100, 250) in each of four levels of prime type (same, associated, neutral & unrelated). Note prime presentation and SOA were synonymous.

For clarity, mean facilitation values are shown in Figure 5.5. Facilitation values were calculated relative to the neutral prime type condition reaction times. Hence, facilitation = neutral prime type condition - prime type condition.

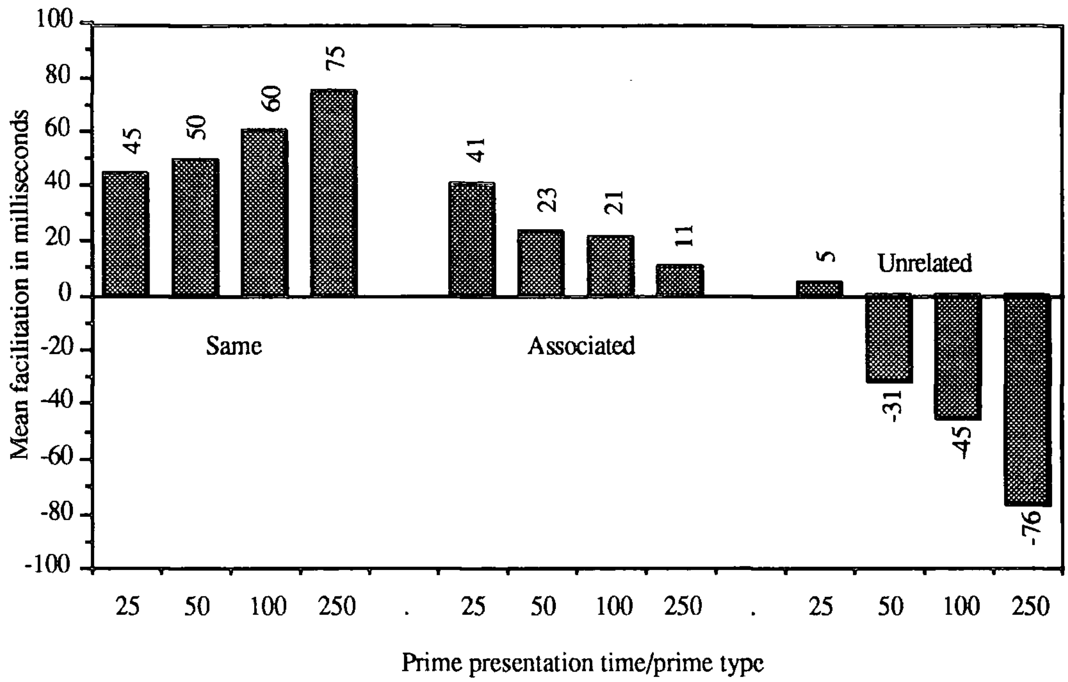

Figure 5.5: Mean facilitation to target names preceded by face primes at each of the four levels of prime type, presented at each of the four levels of prime presentation.

5.3.2.1 Analysis by subjects

A two-way within subjects factor ANOVA was carried out on the subjects' correct reaction times to familiar target names. Two factors were investigated, prime presentation, which had four levels (25, 50, 100 and 250 milliseconds; repeated measure) and prime type, which had four levels also (same, associated, neutral and unrelated; repeated measure). A significant effect of prime type was found, $F(3,33) = 47.4449$, $p < 0.001$. Planned comparisons showed that responses to targets preceded by the same face were significantly faster than those to targets preceded by any of the other three prime types (associated, neutral and unrelated) (all p's < 0.01). Responses to targets preceded by an associated prime were faster than those to targets preceded by neutral and unrelated primes (p's < 0.01). Responses to targets preceded by an unrelated prime were slower than those to targets preceded by a neutral prime ($p < 0.01$), giving an overall priming effect of facilitation from same and associated primes with inhibition from unrelated primes.

There was also a significant prime presentation (25, 50, 100 and 250 milliseconds) x prime type (same, associated, neutral and unrelated) interaction, $F(9,99) = 10.543$, $p < 0.001$, indicating that the size of the priming effects varied over the prime presentation times. Simple effects analyses showed that this effect was primarily attributable to the increase in inhibition at longer presentation times ($F = 4.709$, $p < 0.01$) as none of the other effects in the simple effects analysis reached significance ($p > 0.2$).

No effect of prime presentation (25, 50, 100 and 250 milliseconds) was found ($F = 0.738$), indicating that overall reaction times to target names did not vary significantly between the levels of prime presentation.

Simple effects analyses and were carried out to see if there was an effect of prime type for each of the four prime presentation conditions. The results are shown below.

<u>Simple effects for prime type at each of the four presentation times</u>

<u>25 milliseconds</u>

A significant effect of prime type was found, $F(3,33) = 14.963$, $p < 0.001$. Newman-Keuls tests ($\alpha = 0.05$) showed that responses to target names preceded by same or associated primes were faster than those to target names preceded by neutral and unrelated primes. Responses to target names preceded by the same or an associated prime did not differ, nor did responses to target names preceded by a neutral or an unrelated prime. The results indicate that at 25 milliseconds presentation, equivalent degrees of facilitation are produced by same and associated prime types, with no inhibition from unrelated primes.

50 milliseconds

A significant effect of prime type was found, $F(3,33) = 21.979$, $p < 0.001$. Newman-Keuls tests ($\alpha = 0.05$) showed that responses to target names preceded by the same face were faster than those to target names preceded by any of the other three prime types (associated, neutral and unrelated). Responses to target names preceded by an associated prime were faster than those to target names preceded by neutral or unrelated conditions. Targets preceded by an unrelated prime were responded to significantly slower than target names preceded by a neutral prime. The results indicate that at the 50 millisecond prime presentation time more facilitation is observed from the same prime than the associated prime, with significant inhibition from the unrelated prime.

100 milliseconds

A significant effect of prime type was found, $F(3,33) = 26.64$, $p < 0.001$. Newman-Keuls tests ($\alpha = 0.05$) showed that responses to target names preceded by the same prime were significantly faster than responses to target names preceded by any of the other three prime types (associated, neutral and unrelated). Responses to target names preceded by an associated prime did not differ from those to target names preceded by a neutral prime. Responses to target names preceded by an unrelated prime were significantly slower than those to target names preceded by a neutral prime. The results indicate that at the 100 millisecond prime presentation time, there is facilitation from the same, but not the associated primes and inhibition from the unrelated primes.

250 milliseconds

A significant effect of prime type was found, $F(3,33) = 47.549$, $p < 0.001$. Newman-Keuls tests ($\alpha = 0.05$) showed that responses to target names preceded by the same primes were faster than those to target names preceded by any of the other three prime types (associated, neutral & unrelated). Responses to target names preceded by an associated prime did not differ from the responses to target names preceded by a neutral prime. Responses to target names preceded by an unrelated prime were slower than responses to target names preceded by a neutral prime. The results indicate an overall priming effect of facilitation from the same prime, but not the associated prime, and inhibition from the unrelated face prime.

5.3.2.1 Analysis by items

An analysis by items was also carried out on the data. The two-factor within-subjects ANOVA (within factor 1: prime presentation; repeated measure; within factor 2: prime type; repeated measure) showed a significant effect of prime presentation, $F(3,16) = 5.561$, $p < 0.005$. Newman-Keuls tests indicated that overall reaction times to target names preceded by primes presented for 25 milliseconds were faster than those to target names preceded by primes presented for 100 and 250 milliseconds). There was also a significant effect of prime type, $F(3,48) = 37.499$, $p < 0.001$. Planned comparisons showed that responses to target names preceded by same primes were significantly faster than those to target names preceded by any of the other three prime types (associated, neutral and unrelated) (all p's < 0.01). Responses to target names preceded by associated primes were faster than those to target names preceded by neutral and unrelated prime types (p's < 0.01). Responses to target names preceded by unrelated primes were slower than those to target names preceded by neutral primes ($p < 0.01$). Hence, the overall priming effect was one of facilitation from same and associated primes, with inhibition from unrelated primes.

Finally, there was a significant prime presentation x prime type interaction, $F(9,144) = 6.320$, $p < 0.001$. Simple effects showed that this was due to the gradual decrease in semantic priming ($F = 3.556$, $p < 0.05$) and increase in inhibition ($F = 15.655$ $p < 0.001$) observed as prime presentation times increased (25 -> 250 milliseconds).

Simple effects for prime type at each of the four presentation times

A brief account of the simple effects analyses for each of the presentation times is given below.

25 milliseconds

There was a significant effect of prime type, $F(3,48) = 12.925$, $p < 0.001$. Newman-Keuls tests ($\alpha = 0.05$) showed that the overall priming effect was one of equivalent facilitation from both same and associated prime types, with no inhibition from the unrelated prime types.

50 milliseconds

There was a significant effect of prime type, $F(3,48) = 15.116$, $p < 0.001$. Newman-Keuls tests ($\alpha = 0.05$) showed that the overall priming effect was one of facilitation from both same and associated prime types (same facilitation > associated facilitation), with no inhibition from the unrelated prime types.

100 milliseconds

There was a significant effect of prime type, $F(3,48) = 15.086$, $p < 0.001$. Newman-Keuls tests ($\alpha = 0.05$) showed that the overall priming effect was one of facilitation from the same primes, with inhibition from the unrelated primes. There was no facilitation from the associated primes.

250 milliseconds

There was a significant effect of prime type, $F(3,15) = 34.859$, $p < 0.001$. Newman-Keuls tests ($\alpha = 0.05$) showed that the overall priming effect was one of facilitation from the same primes, with inhibition from the unrelated primes. There was no facilitation from the associated primes.

5.3.3 Discussion

From Figure 5.1 three predictions were derived; (i) that self priming is a necessary concomitant of semantic priming; e.g. priming from Prince Charles' face to Princess Diana's name will not be observed in the absence of priming from Prince Charles face to his own name; (ii) that as the prime presentation increases, the semantic priming effect should increase, in terms of the amount of facilitation measured relative to the neutral prime condition. Finally, (iii) at all levels of prime presentation times, the self priming effect should exceed the semantic priming effect.

The results of the analysis showed that all occurrences of semantic priming were accompanied with self priming. Therefore, the results do not contradict prediction (i). The experimental data did not uphold prediction (ii) as semantic priming decreased with increasing prime presentation to a point where it was no longer present in the 100 and 250 milliseconds prime presentation conditions. Self priming, however, increased across the four prime presentation conditions, but simple effects analyses (subjects and items) showed that this increase was not significant. The subjects simple effects analyses also showed that overall, the decrease in facilitation from semantic priming relative to the neutral condition was not significant. However, the items analysis showed that it was significant. Further, separate ANOVAs on each of the four prime presentation levels (subjects and items), showed the presence of semantic priming at only the 25 and 50 millisecond prime presentation times. To that extent it would seem that a decrease, and eventual loss of semantic priming was evident, an effect that cannot be accounted for by the model alone. An explanation might be found however, in terms of a combination of the predictions of the model <u>and</u> subjects' use of conscious strategies.

5.3.3.1 Self priming, a necessary concomitant of semantic priming?

At the shortest prime presentation time (25 milliseconds) self and semantic priming were found to be equivalent in both items and subjects analyses. This is clearly inconsistent with the simulation shown in Figure 5.1. This predicts that self priming should exceed semantic priming for all SOAs with no prime-target ISI. To that extent, the results violate prediction (iii). Indeed, one might argue that the model predicts that self priming is a necessary prerequisite of semantic priming because Charles' PIN is active while Diana's is still at resting activation (-10). Nevertheless, it is not possible to determine unequivocally whether self priming is a necessary prerequisite of semantic priming, as no data are available for prime presentation times below 25 milliseconds. To that extent, the results are not inconsistent with the view that self priming is a necessary concomitant of semantic priming, but they are inconsistent with the view that self priming should exceed semantic priming for all SOAs with no prime-target ISI.

5.3.3.2 An explanation in terms of strategies

It was suggested that the results of Experiment 7 might be accounted for in terms of conscious strategies on behalf of the subjects. The results of Experiment 8 may also be accounted for in terms of the adoption of strategies at the longer prime presentation times (50, 100, 250 milliseconds) as significant inhibition was found here.

The subjects were presented with prime-target pairs in which two related conditions were included. The face prime could be followed by (i) its own name (same condition) or (ii) the name of its semantic associate (associated condition). If subjects were to adopt one of two strategies such that they consciously attended to the identity of the face prime, and got ready to view either (i) the name corresponding to that face prime or (ii) the name corresponding to the semantic associate of the prime face, they might improve their performance. It seems reasonable to assume that the generation of a face's corresponding name is a less cognitively demanding task than the generation of its semantic associate's name. Given this assumption, it would be more sensible for the subjects to adopt the former, less demanding strategy (notwithstanding the fact that both would yield the same benefit). Given this argument, in some situations the outcome of strategic processing and automatic effects will have been congruous, i.e. same prime type condition, and in others they will not, associated and unrelated prime type conditions. The results of Experiment 8 may therefore be explained if one assumes that where the outcomes of conscious strategic processing and automatic processing (Burton *et al.* model) are congruous there is no benefit to be gained from the congruity, while there is significant loss when they are incongruous.

The results showed a non-significant increase between self priming and prime presentation. Here, strategy and automatic effect are congruous, and there is no significant increase in priming. The decrease in semantic priming can be accounted for because the automatic effect and the strategy are incongruous. On the presentation of Charles' face, subjects are getting ready to expect the name Prince Charles and not Princess Diana i.e. the execution of the strategy is inhibiting the automatic processing of a signal. In support of this explanation Posner and Klein (1973) have demonstrated that if a subject consciously attends to the word DOG, he/she will facilitate his/her processing of the word "DOG", but inhibit his/her ability to attend to the semantic associate "CAT". Further, the increasing effect of inhibition can also be explained in the same way i.e. the subjects are attending to the identity of the prime and hence, attention to target names that do not share the same identity as the prime is inhibited (see also Doll, 1969).

Thus, to some extent the results can be explained in terms of the Burton *et al.* model and conscious strategies. Further, it is suggested that automatic and strategic effects stem from different regions of the cognitive system, but feed into the same response buffer, and it is in the response buffer, and not at the level of the PINs that the above effects arise.

Note that at the shortest prime presentation condition (25 milliseconds) one might argue that strategies are not in use as (i) self and semantic priming produce the same degrees of priming, (ii) there is no inhibition (while at the other three prime presentation levels there is), and (iii) 25 milliseconds is too short a period to evoke a strategy. If this is the case then it would follow that the 25 millisecond prime presentation condition demonstrates pure automatic priming, while the other three prime presentation conditions (50, 100 and 250 milliseconds) include strategic effects in addition to automatic priming.

If the 25 milliseconds condition generates a purely automatic priming effect, then this effect is not easily reconciled with the model's simulation of semantic priming shown in Figure 5.1. The results of Experiment 8 indicated that for a prime presentation (SOA) of 25 milliseconds, self and semantic priming effects are equivalent. However, Figure 5.1 would suggest that semantic priming effect should be significantly smaller than the self priming effect. It is difficult to offer an explanation of this effect in terms of the Burton *et al.* model, and this result clearly presents a problem for the model.

Finally, the items but not the subjects analysis found an overall increase in speed of response to target names preceded by primes presented at 25 milliseconds. This may merely reflect an urgency to respond when the prime is presented for such a short period. Further, the large increase in inhibition with increased prime presentation will also have contributed to this effect.

5.4 General discussion

5.4.1 Conscious strategies

The effects found in Experiment 8 have been attributed to the subjects' use of conscious strategies in addition to automatic processes. A similar pattern of results was found in Experiment 7, although the effects were not significant. Nevertheless, a similar explanation may account for the observed trend in the data.

It is argued that faced with the choice of two strategies; (i) attend to the identity of the prime, (ii) attend to the identity of the semantic associate of the prime, the subjects adopted the former, less cognitively strategy. In a situation where only semantic priming is being investigated the subject should therefore adopt strategy (ii), as this is the only one available. Further, as the SOA increased and the strategy component came into play more, the amount of semantic priming should not decrease as there would be no inconsistency between the automatic priming and strategic priming input into the response buffer.

Bruce and Valentine (1986) have carried out such an investigation of face/face semantic priming at three levels of ISI (0, 250, 750 milliseconds) and name/name semantic priming at two levels of ISI (0, 750 milliseconds), both with a constant prime presentation of 250 milliseconds. They found that as the SOA increased, the amount of semantic priming also increased. However, in an analysis of variance of the data, the interactions between prime type and SOA just failed to reach significance in both experiments (face/face; $p = 0.085$; name/name; $p = 0.055$). In the lexical literature however, Neely (1976) has found a significant increase in semantic priming with increasing SOA. One inconsistency between Bruce and Valentine's results and those found in Experiment 8 regards the amounts of increasing facilitation and inhibition across increasing SOAs. Increasing facilitation was accompanied with increasing inhibition across SOAs in Experiment 8, but Bruce and Valentine found no significant increase in facilitation or inhibition with name/name priming or face/face priming across SOAs. Bruce and Valentine note that their results depart from the predictions of Posner and Snyder's (1975b) theory, and note that lexical studies have also produced similar inconsistent effects (Becker, 1980; Neely, 1976). It is noted, however, that Bruce and Valentine's (1986) design is similar to the design of Experiment 7 which also failed to find a significant increase in inhibition. Further, in Bruce and Valentine's study items were not repeated. Thus, the connections between FRUs and PINs would not be strengthened. This would explain the near-significant increase in facilitation with increasing ISI, as the 'automatic' activation curves for PINs (as shown in Figure 5.1) would be more gradual than those that would be expected for Experiments 7 and 8. Hence, the increase in priming found by Bruce and Valentine might reflect an automatic, rather than a strategic effect.

5.4.2 Effects of altering prime presentation, SOA and ISI

The results of Experiments 7 and 8 show that two very similar SOAs 270 (Experiment 7) and 250 milliseconds (Experiment 8) produce different patterns of effects. Where the prime presentation and SOA are synonymous (Experiment 8) significant facilitation is observed from the same prime (75 milliseconds), but not from the associated prime (11 milliseconds). Further, there is significant inhibition from the unrelated prime (-76 milliseconds). Where a short prime-target interval of 20 milliseconds is added to a 250 millisecond prime presentation time (Experiment 7) the pattern of results changes drastically. Facilitation is observed from both the same (75 milliseconds) and associated (36 milliseconds) conditions and no significant inhibition from the unrelated condition (-9 milliseconds). An explanation of these results is not at all clear, and may merely reflect different subject groups. Alternatively, the additional 20 millisecond prime-target ISI in Experiment 7 may be sufficient to produce a major alteration of the results that the Burton *et al.* model is unable to accommodate.

5.4.3 Repetition of stimuli

In view of the results of Experiment 8 it is worth reflecting on the experiments that have gone before. During the courses of Experiments 7 and 8 the subjects were presented with each face prime 48 times. Nevertheless, the pattern of results found is similar to that found in Experiments 1 - 6. The results would suggest that the three types of design employed in this thesis so far, (i) priming without stimulus repeats, (ii) priming with small numbers of stimulus repeats and (iii) priming with large numbers of stimulus repeats, all produce comparable cross-domain self and semantic priming effects. Repetition of stimuli *per se* does not appear to have major effects on the pattern of priming observed. Nevertheless, alterations in the prime presentation within a reasonably short range (25 - 250 milliseconds) would appear to have an effect on the pattern of priming.

5.4.4 Experiments 1 - 6

One of the hypotheses tested in Experiments 1 and 2 was the model's prediction that self priming should be greater than semantic priming; this prediction was confirmed. However, the results of Experiment 8 might suggest that the greater self priming effect was due to subjects' use of strategies. This seems unlikely however, as no inhibition was observed in Experiment 1. Given that inhibition is an indicator of the use of strategies (Posner and Snyder, 1975b) it would appear that this effect was not influenced by strategies.

The joint analyses of Experiment 5 (semantic priming) and Experiment 6 (self priming) indicated that more self priming than semantic priming was observed. Given that these were separate experiments, the smaller semantic priming effect cannot be attributed to subjects using an identity-based (self priming) strategy. Thus the results of Experiments 1 - 6 would still appear to confirm the predictions of the Burton *et al.* model.

5.5 Conclusions

Priming is undoubtedly a multidimensional phenomenon, of which the Burton *et al.* model attempts to simulate only one facet; the automatic component. An explanation of the results of Experiments 7 and 8 has been offered in terms of a combination of the Burton *et al.* model and conscious response strategies, although undoubtedly this is not the only possible explanation. Note however, that this explanation cannot account for the observation that at the shortest SOA (25 milliseconds prime-presentation; Experiment 8) self and semantic priming effects are equivalent, as this effect violates a fundamental aspect of Burton *et al.*'s account of semantic priming, i.e. that for a design where there is no prime-target ISI, self priming should exceed semantic priming for all prime presentation times. Nevertheless, given that the other experiments reported in this thesis have supported the model's predictions, it would be hasty to reject the model on the basis of Experiment 8 alone.

Other hypotheses might be developed from the results of this chapter. However, the aim of this thesis was to test predictions derived from the structure, and computer simulations, of the Burton *et al.* model. To test further hypotheses based on the results of Experiments 7 and 8 would involve departing from this aim. Further, it would seem that an investigation of the effects of increasing SOA on self and semantic priming is fraught with methodological problems, not least the contaminating effects of conscious strategies.

To that extent it was decided that this method was inappropriate as an investigative tool of a model designed to account for automatic processing of faces. As such, it was decided that the line of investigation suggested by Experiments 7 and 8 was likely to prove less fruitful than other lines of research included in the thesis.

In summary, although some of the results of Experiment 8 do not support the Burton *et al.* model, in themselves, they do not provide a sufficient basis on which to reject it.

6 A review of distinctiveness effects in the face literature

6.1 Norm-based coding model

It is a well documented observation that previously unfamiliar faces that are distinctive in appearance are better remembered than previously unfamiliar faces that are typical in appearance (Bartlett, Hurry and Thorley, 1984; Cohen and Carr, 1975; Going and Read, 1974; Light, Kayra-Stuart and Hollander, 1979; Shepherd, Gibling and Davies, 1991; Winograd, 1981). More recently, Valentine and Bruce (1986a; 1986b) have shown that this effect also extends to the recognition of familiar faces; i.e. distinctive familiar faces are recognized faster than typical familiar faces. To account for the effects of distinctiveness, Valentine and Bruce (1986a; 1986b) have presented a hypothesis that suggests that faces are encoded relative to a single prototype or norm face; the 'prototype hypothesis'. The hypothesis states that a prototype, or norm face, is abstracted from all faces with which we are familiar, and is updated with each encounter with a new face. Each face is encoded as a number of vector transformations required to transform the encoded face into the prototype. More recently, Valentine and Endo (1992) have rejected a norm-based coding model in favour of an exemplar-based coding model. However, both models have a number of features in common. As such, the norm-based coding model will be discussed briefly before going on to consider the exemplar-based coding model.

Figure 6.1 presents a schematic representation of Valentine's conception of the representation of faces in norm-based multidimensional space. The diagram is drawn in two dimensions, however, Valentine points out that this is merely for representational purposes.

The norm-based coding model suggests that faces are encoded as vectors relative to a norm or prototype and are normally distributed around the norm. Faces that are typical in appearance will resemble the norm more closely, while faces that are distinctive in appearance, by their very nature, will not resemble the norm face. Hence, in terms of multidimensional space faces that are typical in appearance are stored in close proximity to the face prototype or norm, while faces that are distinctive in appearance are stored at a distance from the norm. Thus, the density of face representations decreases with increasing distance from the norm. This aspect of face space is also illustrated in Figure 6.1.

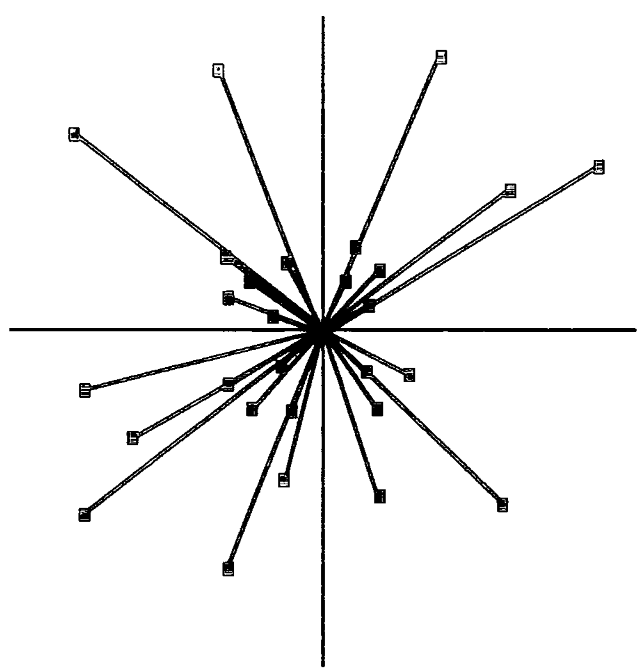

Figure 6.1 A two-dimensional schematic representation of Valentine's (1991) multidimensional space. Typical faces are stored within close proximity of the norm and have a number of neighbours, while distinctive faces are stored at a distance from the norm and have few neighbours.

The process of face recognition is envisaged in two stages, (i) a presented face is encoded as an *n*-dimensional vector, (ii) a decisional process mechanism searches for a match with a vector in face space. It is assumed that confidence signalled by the decisional process mechanism is governed by a number of factors, (a) any error resulting from the encoding of the presented face, (b) the degree of similarity between the presented face vector and the closest match in face space (the target vector), and (c) the degree of similarity of the presented face vector and the target vector's neighbour(s). The observation that distinctive faces are recognized faster than typical faces is accounted for by the fact that distinctive faces have few neighbours. Hence, whereas for typical faces, process (c) will be hindered by detailed discrimination between close matching neighbours, a match with a distinctive target vector can be made with relative ease. Further, there is more room for inaccuracy in processes (a) and (b) for distinctive faces, as small amounts of discrepancy between the encoded presented image and the target representation will have a less detrimental impact on the recognition of distinctive faces.

The concept of a category prototype is not a new one and there is a wealth of data on the abstraction of prototypes from real and invented categories (Goldman and Homa, 1977; Homa, Cross, Cornell and Goldman, 1973; Homa and Vosburgh, 1976; Posner and Keele, 1970; Strange, Keeney, Kessel and Jenkins, 1970). These experiments have demonstrated that the greater the degree of resemblance between a category exemplar and its category prototype, the faster the exemplar is correctly classified as a member of its category. Light *et al.* (1979) note that a classification task is different from a recognition task and suggest that this explains the initially paradoxical findings that distinctive or unusual category exemplars, are *classified* slower than typical exemplars, while distinctive faces are *recognised* faster than typical faces. Given Light *et al.*'s distinction, Valentine and Bruce (1986a) reasoned that in a categorisation task in which subjects are presented with intact and jumbled faces, intact distinctive faces should take longer to classify as faces than intact typical faces. The results confirmed their hypothesis.

Valentine and Bruce (1986a) point out that their conception of a prototype is distinct from that of studies investigating prototype abstraction from artificial data sets. Whereas in the artificial set studies the creation of a prototype is a consequence of the experimental design, Valentine and Bruce's conception of a face prototype is one that the subject brings with them to the experiment. This is not to say, however, that a number of exemplars of a particular face are not subject to collective encoding in the form of a prototype. Bruce, Doyle, Dench and Burton (1991) have found evidence to suggest that subjects may abstract prototypes from face-like stimuli (shaded drawings created using the Mac-a-Mug software) that vary in terms of the configuration of their internal features. In a training phase subjects were asked to rate faces for perceived age or sex. In a later unexpected test phase the subjects were required to select from two faces (a prototype face and a further unseen manipulation) a face they had rated earlier. Subjects frequently chose the prototype face (i.e. average of the manipulations) even when the prototype had not been included in the training phase.

6.2 Exemplar-based coding models

Recently, Valentine (1991a; 1991b; Valentine and Endo, 1992) has pointed out that the norm-based coding model is not the only possible account of distinctiveness effects in the face literature. He suggests that exemplar-based coding models that have been applied to the storage of concept representations (Medin and Shaffer, 1978; Nosofsky, 1986) may provide an equally adequate, if not more parsimonious account of the data. He proposes an exemplar-based coding model that is similar to the norm-based model, in that the concept of multidimensional space is common to both. However, whereas in the norm-based coding model, exemplars are stored relative to a central average norm, in the exemplar-based model exemplars are stored relative to each other. An exemplar's similarity to other members of the same category is a monotonic function of the distance between itself and all other members of the category. In terms of their location in multidimensional space, typical exemplars are located in areas of high density, while distinctive exemplars are located in area of low density. Further, although no average or norm is abstracted from the faces, the typical faces will be densely clustered around a 'central tendency'. Thus, Valentine and Bruce's (1986a) finding that typical faces are classified as faces faster than distinctive faces can be accommodated.

6.2.1 The face familiarity decision; recognition or identification?

In the concept literature, a number of authors have suggested that recognition of a category exemplar is based on the 'summed-similarity rule' (Hintzman, 1986; Medin, 1986; Nosofsky, 1988). The rule states that the familiarity of a stimulus is calculated by summing the similarity between the stimulus and all exemplars of all categories stored in memory. A consequence of the rule is that typical exemplars (those that are similar to a large number of other exemplars) should be recognised faster than distinctive exemplars. In the case of face recognition, this prediction is clearly inconsistent with the large number of studies that have demonstrated the opposite effect (Bartlett *et al.*, 1984; Cohen and Carr, 1975; Going and Read, 1974; Light *et al.*, 1979; Valentine, 1991b; Valentine and Bruce, 1986a; Valentine and Bruce, 1986b; Valentine and Endo, 1992; Winograd, 1981). In addition, Valentine notes that this predicted effect also contradicts the results of studies investigating memory for rare and common words (Glanzer and Adams, 1985; Hintzman, 1988).

Nosofsky (1986) has suggested that the identification of a stimulus constitutes the retrieval of a label that is unique to the stimulus. He proposes that the probability that a label will be retrieved from a probe is given by the similarity between the probe and its memory representation associated with the label, divided by the summed similarity between the probe and all exemplars in memory. When this rule is applied to the exemplar-based coding model it predicts that distinctive faces will be *identified* faster than typical faces. Studies investigating recognition of distinctive and typical faces have used a familiarity decision. Valentine argues that if the exemplar-based coding model is to be applied to the storage of faces, then one must assume that a familiarity decision constitutes the retrieval of an identity-specific label. Valentine, Bredart, Lawson and Ward (1991) have found evidence to suggest that familiarity decisions to people's names are based on the output from name recognition units, i.e. the decision is being made at the PIN level. Following Bruce and Young (1986), Valentine *et al.* suggest that the PINs store identity-specific semantic information. It then follows that subjects may be accessing the identity-specific semantic information associated with a name when making a familiarity decision to it. On this basis Valentine *et al.* argue that a familiarity decision to a name constitutes identification, rather than recognition of the name. Similarly, Valentine (1991a) argues that a familiarity decision to a face also constitutes identification rather than retrieval. In addition, he suggests that identification of a face is contingent on being able to access semantic infirmation relating to the face Valentine (1991a). It is interesting to note, however, that in the Burton, Bruce and Johnston model semantic information is stored in separate structures, the SIUs. The PINs have no semantic or episodic content. They function as mediators between different domains (face, name and semantic information), signalling the recognition of signals from the different inputs. Whether the activation of a PIN constitutes identification or recognition is open to debate. The important point is that the identity-specific label on which the explanation of distinctiveness effects in the exemplar-based coding model hinges, need not contain any information about a person. Further, whereas Nosfosky argues that identification involves the recovery of a label that is unique to the stimulus, this does not necessitate the recovery of identity-specific semantic or episodic information.

6.3 Distinguishing between exemplar-based and norm-based coding models of face recognition

Recently, Valentine and Endo (1992) have attempted to determine whether a norm-based or an exemplar-based coding multidimensional model of face recognition produces a better account of face recognition. Valentine (1991a) had earlier suggested that one method of distinguishing between the two models was to investigate the effects of distinctiveness and race. Figure 6.2 shows Valentine's conception of the point location of other-race faces in a norm-based coding model (left) and an exemplar-based coding model (right).

Note that in both models other-race faces are clustered in a particular region of face space (upper right quadrant in the diagram). In the norm-based coding model all faces, same-race or otherwise, are encoded relative to a norm that is abstracted principally from same-race faces. This has the effect of maximising the differences between same-race faces and minimising the differences between other-race faces, as the norm is an inappropriate coding point for other-race faces. Thus, other-race faces are more difficult to discriminate between.

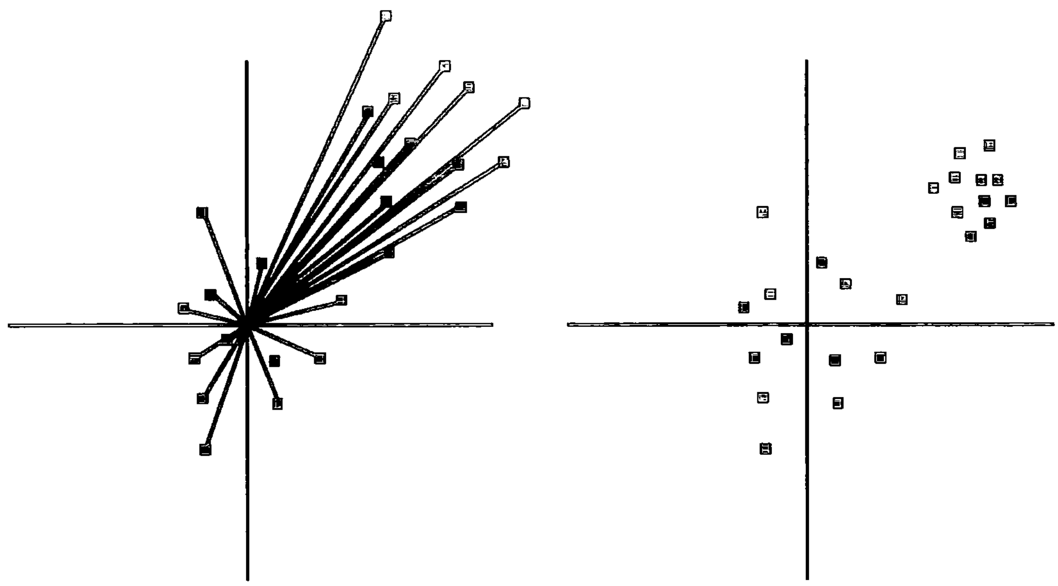

Figure 6.2: Schematic representations of the storage of other-race faces relative to same-race faces in a norm-based coding model (left) and an exemplar-based coding model (right).

The exemplar-based coding model makes a slightly different assumption regarding the arrangement of other-race faces in multidimensional space. In the exemplar model similarity between exemplars is governed by the distance between exemplars as there is no norm. In order to account for the observation that same-race faces are recognized better than other-race faces, the other-race faces are envisaged as being more densely grouped than the same-race faces. However, Valentine and Endo argue that there is no reason to assume that the relative densities of distinctive and typical same-race and other-race faces are different. Given this assumption, the two models make different predictions regarding the effect of distinctiveness on the recognition of same-race and other-race faces. In the norm-based coding model the difference between the vectors (encoded relative to the norm) of typical and distinctive same-race faces is greater than the difference between the vectors of typical and distinctive other-race faces. In the exemplar-based coding model there is no difference in density of typical and distinctive same and other-race faces. Therefore, the norm-based coding model predicts an interaction between race and distinctiveness, (i.e. own race faces will produce a larger distinctiveness effect), while the exemplar-based model predicts that the effects of distinctiveness and race should be additive. Valentine and Endo report the results of cross-cultural study that examines the recognition of distinctive and typical same-race and other-race faces. The result of these experiments suggest that the exemplar-based coding model provides a more satisfactory account of the effect of distinctiveness. Valentine and Endo suggest that there other reasons for favouring a exemplar-based coding model, (i) it is more parsimonious in the sense that if perceptual encoding effects such as race and distinctiveness can be accounted for without reference to a norm then there is no reason to complicate the model by including one and, (ii) it avoids the conceptual problem of how the norm is abstracted.

6.4 Simulating distinctiveness effects

Valentine and Ferrara (1991) have presented three connectionist models of distinctiveness using McClelland and Rumelhart's (1988) auto-associator and back propagation network implementations. A property of both of these implementations, that makes them suited to simulating distinctiveness effects, is their ability to extract a prototype from a set of distorted exemplars. One of the simulations on the auto-associator implementation is discussed here.

6.4.1 An auto-associator model of distinctiveness

Valentine and Ferrara's auto-associator simulation consists of a single set of 24 units where every unit is connected to every other unit, excluding itself. Sixteen units are assigned to represent visual patterns and eight units are assigned to represent labels of the visual patterns. Unlike other PDP models the units are not split up into input and output units, but instead each unit has both an input and an output unit status. The network was trained with 12 exemplars of each of two categories, Category 1 and Category 2. The 12 exemplars were created by distorting a prototype corresponding to its category by varying degrees. The network was not presented with the prototypes.

Following the training phase two simulations were carried out on the network, a categorisation task and an identification task. In the former, all of the visual patterns in a category were given the same label. The network was presented with a typical exemplar that differed from one of the category prototypes by 1 component, and a distinctive exemplar that differed from the prototype by four components. Figure 6.3 shows the mean activation levels for distinctive and typical category exemplars from the two categories over ten simulations. Statistical analysis of the simulations showed that distinctive exemplars were categorised more slowly than typical exemplars; an effect that mirrors Valentine and Bruce's (1986a) experimental study (see also Valentine, 1991b; Valentine and Endo, 1992).

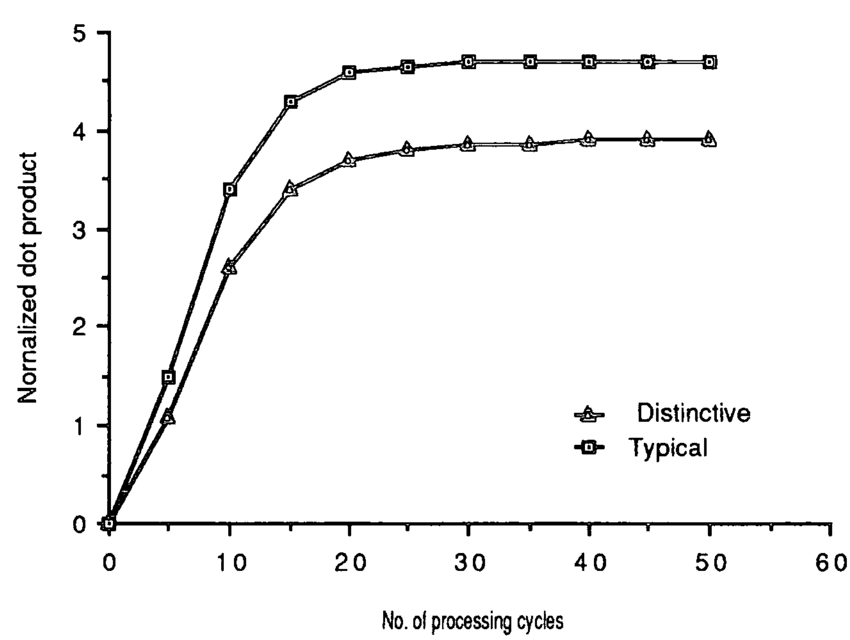

Figure 6.3: Simulation of a categorisation task: The normalized dot product between activity of the label units and the category label plotted as a function of the number of processing cycles at test. From Valentine and Ferrara (1991).

In a second simulation identification was modelled. First each visual pattern was assigned a different label. Again ten simulations were run with distinctive and typical pattern exemplars from both categories. The result of the simulations are shown in Figure 6.4.

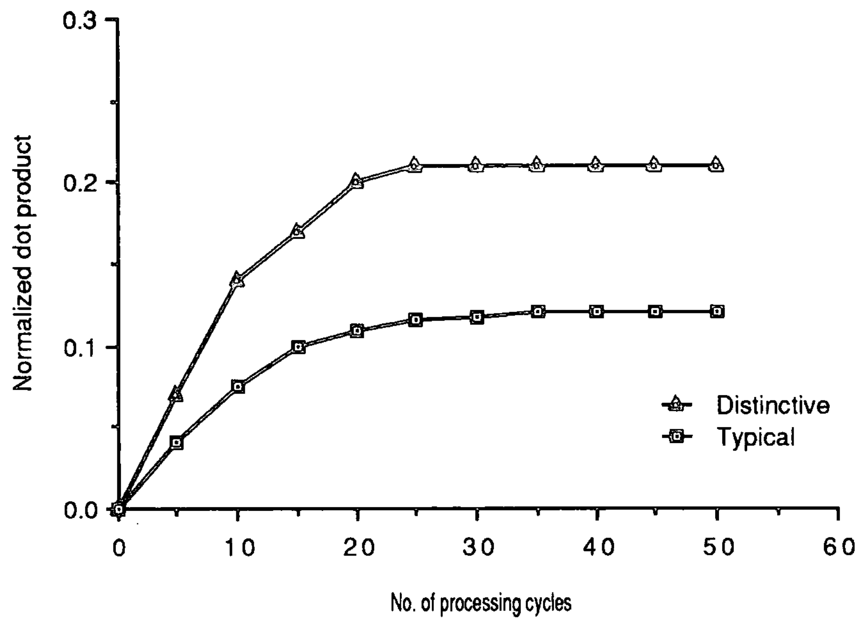

Figure 6.4: Simulation of an identification task: The normalized dot product between activity on the label and the identification label plotted as a function of the number of processing cycles at test. From Valentine and Ferrara (1991).

Statistical analysis of the activation levels showed that distinctive visual patterns were identified more accurately that typical visual patterns. Valentine and Ferrara identify the criticism that the categorisation and identification simulations are testing models in which there are different degrees of association between visual patterns and labels (individual or category). They present consistent simulations with a larger network in which there are separate units for category labels and identity labels.

Note that Valentine and Ferrara's model is based on the assumption that face familiarity decisions involve the identification of a face rather than the recognition of the face. Valentine has argued that accessing any identity-specific information about a face is tantamount to identification. In the case of recognition of faces that were unfamiliar prior to the start of the experiment, Valentine (1991a) has suggested that identity may constitute access to a specific episode (e.g. "that's the one I saw earlier with the spiky hair"). However, as was discussed earlier, retrieval of an abstract label, the PIN may be sufficient to account for the effect with familiar faces.

6.4.2 Burton, Bruce and Johnston's (1990) IAC model of distinctiveness

Burton, Bruce and Johnston (1990) present a simulation of distinctiveness in their IAC model of face recognition. Figure 6.5 shows a schematic representation of the model with the added face character units. The connections from the visual character units (VCUs) (nose, eyes, hair in Figure 6.5) to the FRUs are excitatory and unidirectional. With the exception of the within-pool FRU inhibitory connections, that are set at -1.0, all other excitatory and inhibitory connections are as for the original implementation of the model described in Chapter 2.

Faces are composed of a number of visual components. For simplicity Burton *et al.* give them an individual feature, photofit status in the model, e.g. nose, eyes, hair etc.; although they may equally, and more probably, represent configural aspects of a face. In the actual simulation there are six pools of visual characteristic units (VCUs), each containing six units. Each FRU is connected to one unit in each of the six pools. A measure of distinctiveness is calculated by counting the number of overlaps between an FRU and the entire population of FRUs. Hence, a 'distinctive FRU' might have an overlap count of 0, as it shares its six VCUs with no other FRUs, while a 'typical FRU' might have an overlap count of 35. Figure 6.6 shows the activation levels of two PINs, one connected to a distinctive FRU and the other connected to a typical FRU, following an input to each of their six corresponding VCUs.

From the Figure 6.6 it is clear that the PIN associated with the distinctive FRU has the more rapid and higher level of activation. As PIN activation is a measure of

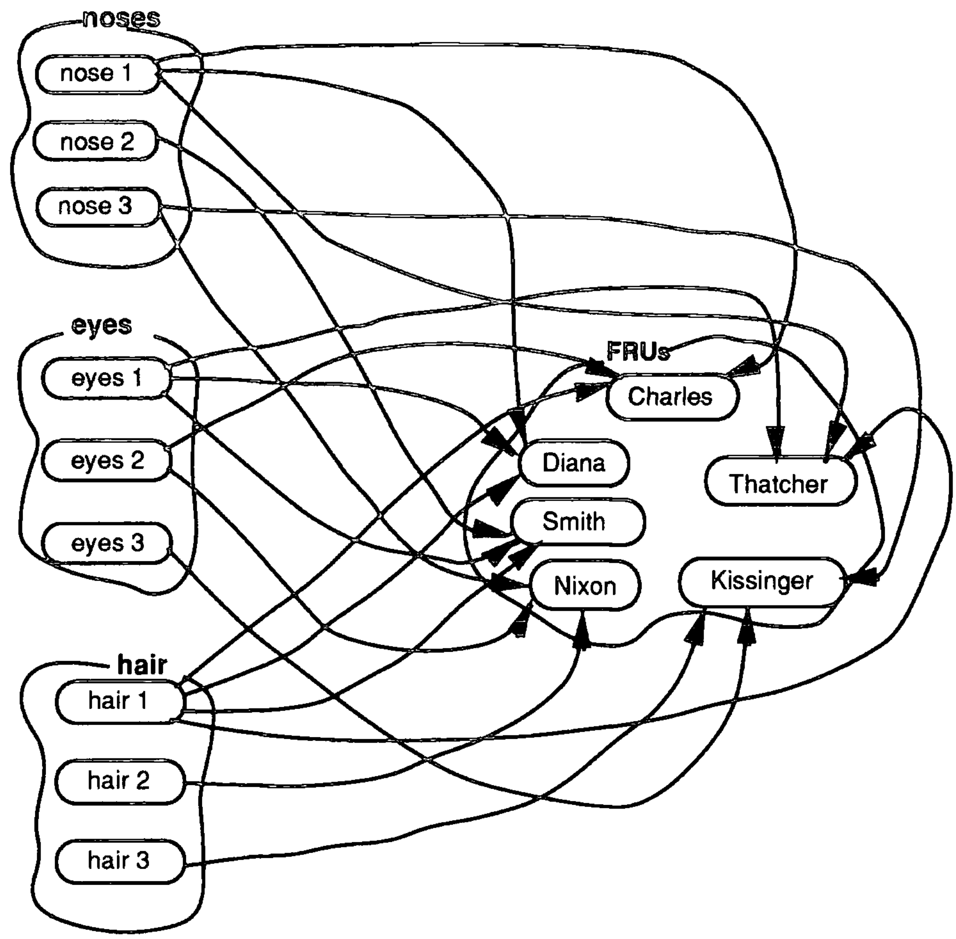

Figure 6.5: A schematic representation of the IAC architecture used by Burton, Bruce and Johnston (1990) to simulate the distinctiveness effect. Connections from the VCUs to FRUs are excitatory and unidirectional.

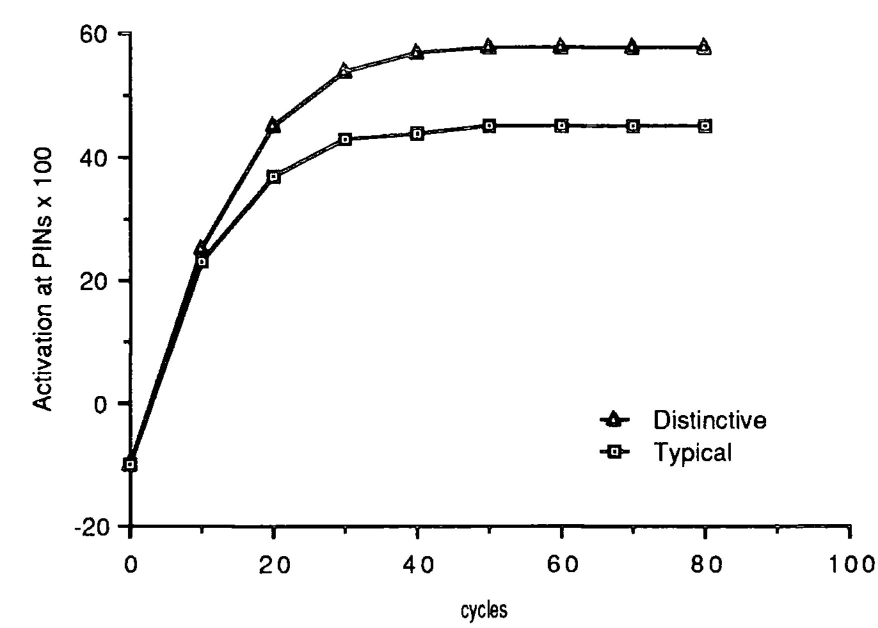

Figure 6.6: Activation curves of two PINs one connected to a distinctive FRU and the other connected to a typical FRU, following inputs to their corresponding VCUs.

recognition, the simulation models the finding that distinctive faces are recognised faster than typical faces. It is also worth emphasising that whereas Valentine and Ferrara's models require that faces must be identified to show a distinctiveness effect, the Burton *et al.* architecture can simulate the effect for recognition.

The Burton *et al.* model of distinctiveness is very different from Valentine and Ferrara's models. In the latter, the representations are distributed while in the former the representations are discrete representations, analogous to logogens. One shortcoming of the IAC model that is highlighted when modelling distinctiveness effects is the observation that the IAC model has no capacity to learn. In contrast, the auto-associator and back propagation implementations used by Valentine and Ferrara are designed to learn. Hence, whereas Valentine and Ferrara's models can accommodate the observation that distinctiveness effects are found with previously unfamiliar faces, the Burton *et al.* model cannot.

6.5 Within-face distinctiveness: The caricature

Over the past 30 years, a number of studies have investigated the nature and efficiency of face caricatures as a representational form of facial information. Haig (1984; 1986a; 1986b) has shown that subjects are highly sensitive to slight changes in the configural make-up of a face. Despite the gross, overall configural changes encountered in line drawing caricatures, people are surprisingly good at recognising the persons they depict. A number authors have offered explanations of the efficacy of caricatures as face-like representations. Goodman (1968) and Gombrich (1969) attributed the success of the caricature to its ability to depict an individual in terms of the culturally prevalent system of pictorial schemata. For example, a politician might be depicted standing in front of the Houses of Parliament wearing a suit. Perkins (1975), challenged this hypothesis. He suggested that caricatures act as 'superfaithful' carriers of information, and noted that in a caricature, an individual's most salient features are not only preserved, but exaggerated, while in addition, characteristics irrelevant to identification are deleted. In other words, it is the exaggeration of distinctive facial features that leads to the efficient recognition of the face. Perkin's termed this, the 'The Distinctive-Features Theory'.

Perkin's distinctive-features theory gained further support from the work of Goldman and Hagen (1978). In two separate studies Perkin's (1975) and Goldman & Hagen examined a number of caricatures of the ex-president of the USA, Richard Nixon. Their results were consistent and indicated a high degree of concordance across artists with respect to the features caricatured, but not with respect to degree of exaggeration (which varied from +12% -> +86% in Goldman and Hagen's study). Both studies concluded that the choice of features to be caricatured was dictated by the salient or distinctive features of the face.

Hagen and Perkins (1983) investigated whether caricatured faces are better representations than undistorted photographs of faces. They noted that Ryan and Schwartz (1956) had found a cartoon drawing to be more efficient communication device of an inanimate objects' structure than a line drawing, shaded drawing or a photograph of the object. Hagen and Perkins attempted to discover whether the same effect might apply to faces; they termed their hypothesis the 'superfidelity hypothesis'. Their study compared identification of line drawing caricatures and veridical photographs of unfamiliar faces. In contrast to the superfidelity hypothesis, their results showed that for a face identity task line drawing caricatures were worse representations of faces than photographs. Their finding was supported by a similar study by Tversky and Baratz (1985), which used famous faces as stimuli. Tversky and Baratz found that compared to photographs, line drawn caricatures produced poorer performance on name recall, face recognition and name/face match reaction time tasks.

In both Hagen and Perkins' and Tversky and Baratz's studies, a comparison was being made between line drawing caricatures and photographic images. This cross-medium design could be construed as undesirable. Davies, Ellis and Shepherd (1978) have shown that simple and detailed veridical line drawings are judged poorer representations of individuals than photographs, and also produce poorer recognition.

Recently, Rhodes, Brennan and Carey (1987) have eliminated this cross-medium problem by employing a design that tested for a caricature advantage across one representational medium, line drawings. Line drawings of faces were distorted to produce caricatures using a computer-implemented caricature generator developed by Brennan (1985) (see also Dewdney, 1986).

Essentially Brennan's program alters line drawing representations of faces by comparing the position of facial feature points in a face target to the corresponding feature points in an average face. The average face is a computer implemented average of the feature positions of faces of the same sex, age and race etc.. Figure 6.7 shows examples of male and female average faces.

Average male face

Average female face

Figure 6.7: Examples of an average male and an average female face. Each average face was abstracted from 30 faces of the same sex and an approximate age of 20 years (+/- 2 years).

Any deviations between the point locations on the target face and the corresponding point locations on the average face can be altered by a specified degree. Exaggerating and decreasing these differences produce caricature and anticaricature images respectively. An anticaricature is an image in which the distinctive features have been reduced relative to the average face. Figure 6.8 shows an example of the type of stimuli used by Rhodes *et al.*; an anticaricature, veridical (undistorted) and caricature line drawing of the ex-British Prime Minister, Harold MacMillan.

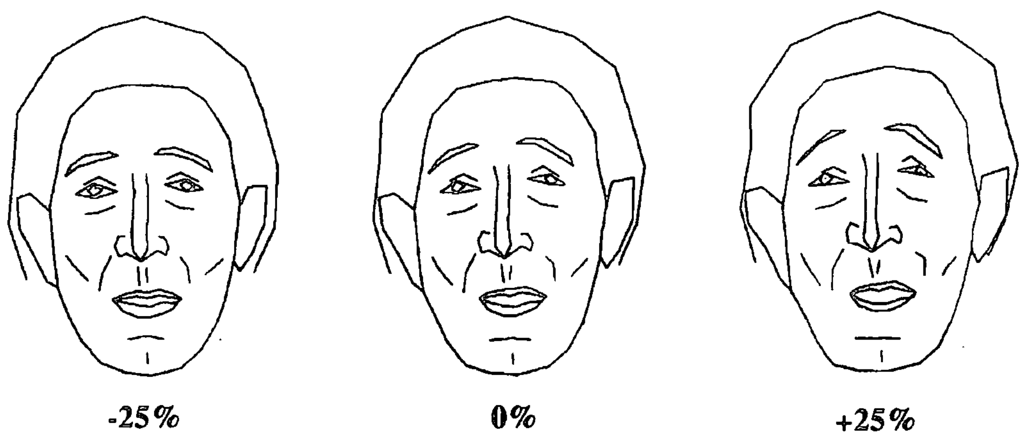

Figure 6.8: Three caricatured line drawing images of Harold MacMillan. From left to right; a -25% caricature where the distinctive features are reduced by 25% to look more like an average face; the 0% undistorted, veridical image, and a +25% caricature where the distinctive features have been exaggerated by 25%. Note the terms 25% anticaricature and -25% caricature are synonymous.

Rhodes *et al.* presented subjects with a number of line drawings of familiar faces caricatured at seven levels (-75%, -50%, -25%, 0%, +25%, +50%, +75%). In a goodness of likeness task, subjects were asked to rate each of the faces on a scale from 1 - 7 for goodness of likeness. The results showed that subjects regarded the +25% caricature to be as good a likeness of a face as the 0% veridical image. Further, the mean exaggeration level selected as best likeness was +16% (significantly different from the veridical 0% image). It is important to note, however, that this was an interpolated value and the subjects were never actually presented with this level of caricature.

In a second task Rhodes *et al.* presented the subjects with -50%, 0% and +50% caricatures of the same faces and asked them to name them as quickly as possible. They found that the +50% caricatures were identified faster, but no more or less accurately than the veridical and anticaricature images. Rhodes *et al.* interpret their results at two levels. The advantage of caricatures over anticaricatures they suggest supports the theory that faces are coded in terms of their distinctive features; 'the distinctiveness hypothesis'. The advantage of caricatures over veridical images, they suggest gives support to a hypothesis that memory representations for faces are schematized and exaggerated like caricatures; 'the caricature hypothesis'. They suggest that this hypothesis is supported by the observation that the interpolated best likeness was positive (+16%) and significantly shifted from the 0% veridical image.

The storage of distinctive aspects of a face produces the conceptual problem of how these distinctive aspects are abstracted from the face. Like Valentine and Bruce, Rhodes *et al.* suggest that faces are encoded relative to a norm face, which like the average face employed by the caricature generator, is abstracted from a number of faces of the same age, sex and race etc. Further, they suggest that the norm-based code on which face memory is based is holistic rather than piecemeal; i.e. only the configural aspects of the face are stored. Rhodes *et al.*'s norm-based coding model differs from Valentine's conception of a norm-based coding model at two levels, (i) Valentine suggested that faces are encoded relative to a single face norm, whereas Rhodes *et al.* postulate a number of different norms for different sub-groups and, (ii) Valentine suggested that the norm-based code is multidimensional and may include all visually derived aspects of a face, while Rhodes *et al.* suggest that the nature of the code is primarily configural.

6.5.1 Continuous-tone caricatures

It is important to note that line drawing representations of faces include a lot less detail than photographs. Consequently, the results of studies that use 'face-like' line-drawing stimuli should perhaps be interpreted with caution. More recently, Benson and Perrett (1991a; 1991b; 1991d; 1993) have developed a continuous-tone caricature generator capable of producing photographic quality images. Benson and Perrett (1991c) carried out a similar study to Rhodes *et al.* using photographs of faces caricatured at seven levels (-48%, -32%, 16%, 0% +16%, +32%, +48%). In a goodness of likeness ratings task they found that the interpolated best likeness degree of caricature was 4.4% (significantly different from 0%). In a face/name, match/mismatch task, subjects were presented with a name followed by a face caricatured at one of the seven levels of caricature. Benson and Perrett found an effect of caricature for the mismatch condition but not for the match condition: subjects' mismatch decision responses were fastest when the face was a 32% caricature. They suggest that the absence of an effect in the match condition can be attributed to the idea that faces are stored in two representations. A pictorial representation, in which the dimensions of a face are veridical, or 'true to life' and a more abstract representation in which the configural aspects of the face that deviate from a facial norm are emphasised.

An explanation of their findings is illustrated more clearly in terms of an example. If a caricature of Prince Charles' face is presented after his name, the higher level representation of the configural deviations for Prince Charles' face is highly activated by the caricature, however, at the pictorial level there is little activation of Prince Charles' representation. As a consequence of this dichotomy, any caricature advantage that might be found at the configural deviations level is offset by the disadvantage at the pictorial representation level. In the alternative case where the name and caricature face do not match (e.g. Prince Charles' name followed by the face caricature of Ernie Wise), the Ernie Wise caricature activates neither of the two representations for Prince Charles, and consequently a quick mismatch decision response can be made. Further, this mismatch response is made faster than the condition in which Prince Charles' name is followed by a veridical representation of Ernie Wise's face, because the caricatured face is *more* of a mismatch to the pictorial and configural representations of Prince Charles' face than the veridical representation of Ernie Wise.

The experiments reported in Chapter 7 apply the cross-domain self priming paradigm to an investigation of distinctiveness effects. Experiment 9 investigates the hypothesis that distinctive face primes will produce more self priming than typical face primes. Experiments 10 and 11 investigate the hypothesis that representations of faces in which the distinctive features have been exaggerated, caricatures, will produce more self priming than representations in which the distinctive features have been reduced, or veridical representations.

7 Self priming with distinctive and caricatured faces

7.1 Experiment 9

7.1.1 Introduction

Chapter 6 discussed Burton *et al.*'s (1990) account of distinctiveness, in terms of their interactive activation model. They suggest that FRUs associated with distinctive faces ('distinctive FRUs') are connected to visual character units (VCUs) that are shared with very few other FRUs ('distinctive VCUs'). In contrast, FRUs associated with typical faces ('typical FRUs') are connected to VCUs shared with a large number of other FRUs ('typical VCUs'). Hence, the effect of distinctiveness is attributed to the high levels of inhibition present at the levels of the FRUs and PINs following the presentation of a typical face compared to the low levels of inhibition observed following the presentation of a distinctive face. Figure 6.6 (Chapter 6) showed a simulation of this effect. Given that distinctive faces produce more rapid and higher activation of their FRUs and PINs, then it follows that distinctive face primes should produce a greater degree of self priming than typical face primes. Experiment 9 examined this hypothesis.

7.1.2 Method

7.1.2.1 *Distinctiveness and familiarity ratings*

Subjects: 20 subjects from the undergraduate and post-graduate populations of the University of Durham participated as subjects. Subjects were between the ages of 18 and 31 years and had normal or corrected to normal vision. Subjects were paid for participating.

Materials: Black and white photographs of 82 faces of famous celebrities were prepared. The prints were approximately 120 mm x 180 mm.

Procedure: The 82 faces were given to two groups of 10 students to rate. One group rated them for distinctiveness. Their instructions were as follows:

> *I would like you to assign a distinctiveness rating to each of the given faces on a scale from 1 to 7. Your rating should be based purely on the person's facial features and not on their personality. As a guide-line, distinctiveness is defined as something that distinguishes a face from the general population - a large nose, close set eyes, thin face etc. If you think that a face is very distinctive then assign it a rating of 7; if you think that it lacks any distinctive features then assign it a rating of 1. Feel free to use the ratings from 2-6 for faces that fall between these two extremes.*

The second group rated them for familiarity. Their instructions read:

> *Please indicate how familiar each of the given faces is to you by assigning it a familiarity rating on a scale from 1 to 7, where 1 is defined as 'never seen them before', and 7 'highly familiar'. Feel free to use the ratings from 2 to 6 for faces that fall between these two extremes.*

7.1.2.2 Results

The distinctiveness ratings attributed to the 82 faces were analysed using Kendall's Coefficient of Concordance. The result showed that there was a significant amount of agreement between subjects' distinctiveness ratings, $W = 0.48$, $x^2(81) = 386.04$, $p < 0.001$.

Two sets of 12 male faces were selected from the rated faces. One group contained faces that had been given a high distinctiveness rating (mean = 5.5, sd = 0.57) and the other group faces that had been given a low distinctiveness rating (mean = 2.3, sd = 0.34). A t-test confirmed that the distinctive and typical face sets were significantly different in terms of their distinctiveness ratings, $t(22) = 16.374$, $p < 0.001$. Mean familiarity of ratings of these two sets were balanced, so that they were as similar as possible (mean = 6.0, sd = 0.76 for high distinctiveness set and mean = 6.1, sd = 0.72 for low distinctiveness set).

7.1.2.2 *Self priming with distinctive and typical faces*

Subjects: 12 subjects from the undergraduate and post-graduate populations of the University of Durham participated as subjects. Subjects were between the ages of 18 and 32 and had normal or corrected to normal vision. Subjects were paid for participating.

Materials: The 12 distinctive and 12 typical faces obtained from the subjects' ratings were used as prime sets (see Appendix 5). The faces (distinctive and typical) were transferred to black and white slide transparencies in such a way that the face filled the 36 mm x 24 mm frame. The faces were used as primes. The target stimuli were black and white slides of the names of these faces, printed in upper case Helvetica font (e.g. TERRY WOGAN).

Apparatus: A three-field projection tachistoscope and three Kodak SAV 2050 projectors were used to present the stimuli. The slides were back-projected onto a white screen and subtended a horizontal visual angle of approximately 8°. Reaction times were recorded on an electronic timer, activated from the onset of the target name and terminated by a manual response made by the subject pressing one of two horizontally located buttons. The buttons were marked 'Yes' and 'No'; subjects were instructed to press the 'Yes' button if they thought the target name was familiar and the 'No' button if they thought that it was unfamiliar.

Design: There were three prime-target conditions; same, neutral and unrelated defined as follows:

Same: The prime face and target name were of the same person; e.g. Terry Wogan's face followed by the target name TERRY WOGAN.

Neutral: The target name was preceded by an unfamiliar face prime; e.g. unfamiliar face followed by the target name TERRY WOGAN. A single unfamiliar face was used as the neutral prime throughout the experiment.

Unrelated: The prime face and target name were of famous individuals who were not semantically related; e.g. Roger Moore's face followed by the target name, TERRY WOGAN. Unrelated prime target pairs were produced by mixing the faces and names within the distinctive and typical sets.

Each of the conditions contained 24 prime-target pairs; 12 pairs included faces and names from the distinctive face set and the other 12 from the typical face set. A further 72 prime-target pairs were added as 'No' response trials. These were created by replacing the 24 familiar target names with 24 unfamiliar invented names matched to the familiar target names in terms of length and titles etc. (e.g. Prince Andrew -> Prince Robert). Hence, there were 144 prime-target pairs in all. Presentation of all stimulus pairs was pseudo-random with respect to distinctiveness of prime, prime-target condition and familiar/unfamiliar target names. Prime-target pairs were counterbalanced such that the subjects saw all 24 target names within each of three prime-target conditions.

Procedure: On each trial the prime was presented for 250 milliseconds followed by an inter-stimulus interval of 250 milliseconds, after which the target was displayed for 2.5 seconds. Hence, the stimulus onset asynchrony (SOA) was 500 milliseconds. Each prime-target trial was separated from the next by approximately three seconds. Subjects were instructed to look at the prime but respond only to the target name by making a manual button-press response to indicate whether the name was familiar or unfamiliar. Half of the subjects made positive familiarity responses with their right hands and half with their left. Prior to starting the experiment, the subjects were presented with black and white slides of all 24 familiar and 24 unfamiliar target names written in Helvetica script (i.e. exactly as they were to appear in the main task itself). The names were pseudo-randomly presented with respect to familiarity and the subjects were required to make a familiarity decision to each name. The names were presented twice to ensure that the subjects were familiar with the target stimuli and practised in pressing the response keys. Following the target name presentation, a short practice trial was run containing some of the stimulus pairs described above. Immediately after the practice trial the main experimental trials were run.

7.1.3 Results

Mean correct reaction times for the familiarity decisions and error rates are shown in Table 7.1. Error rates were low and will not be considered further (see Table 7.1). For clarity, the mean correct reaction times are also plotted in Figure 7.1.

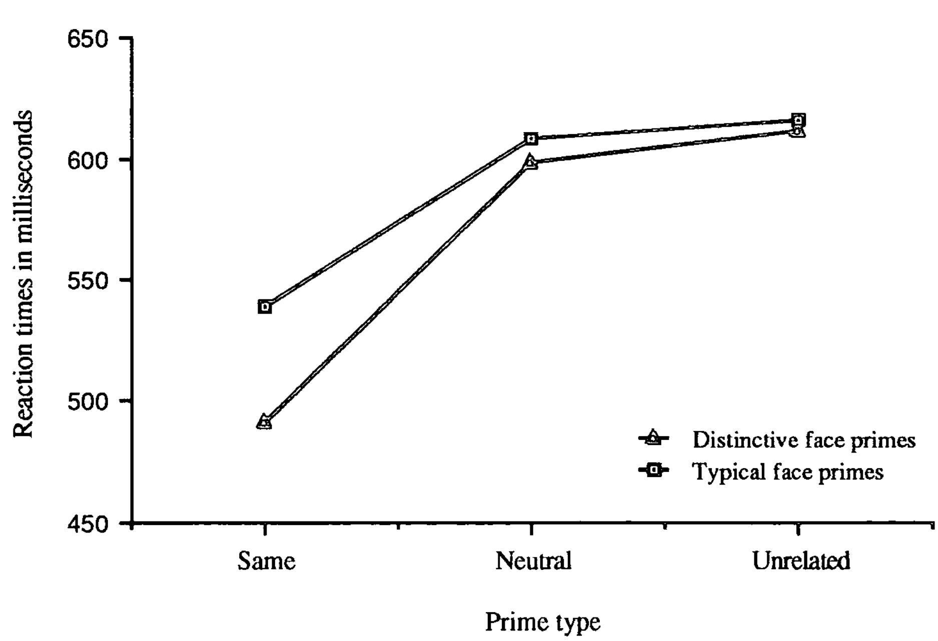

Figure 7.1 : Mean correct reaction times in milliseconds for responses to familiar target names preceded by distinctive and typical name primes at the three levels of prime type; same, neutral and unrelated.

	Familiar targets			Unfamiliar Targets
	Same	Neutral	Unrelated	
RTs				
Distinctive primes	492	598	612	676
Typical primes	540	608	616	652
Errors				
Distinctive primes	2.1	3.4	2.8	2.5
Typical primes	5.0	4.5	3.4	3.1

Table 7.1: Mean correct reaction times in milliseconds and percentage error rates for correct familiarity decisions to familiar and unfamiliar target names preceded by distinctive and typical face primes in the three prime type conditions; same, neutral and unrelated.

7.1.3.1 Analysis by subjects

A two-factor ANOVA was carried out on the correct reaction times for familiar target names. The within-subject factors were distinctiveness (typical or distinctive face primes; repeated measure) and prime type (same, neutral and unrelated; repeated measure). There was a significant effect of distinctiveness, $F(1,11) = 8.07$, $p < 0.02$ indicating that overall, familiar target names preceded by distinctive primes were responded to faster than those preceded by typical primes. There was also a significant effect of prime type, $F(2,22) = 43.56$, $p < 0.001$. Planned comparisons showed that responses to target names preceded by the same primes were significantly faster than responses to target names preceded by neutral and unrelated primes (p's < 0.01), which did not differ. Therefore the overall priming effect was one of facilitation from the same primes without inhibition from the unrelated primes. Further, and of most interest, there was a significant interaction between distinctiveness and prime type, $F(2,22) = 4.75$, $p < 0.05$. Simple effects analyses showed that the significant interaction effect was attributed to a significant effect of distinctiveness for the same prime type condition only, $F(1,11) =$

25.796, $p < 0.001$; i.e. distinctive primes produced more self priming than typical primes.

7.1.3.2 Analysis by items

The reaction time data were also submitted to a two-factor ANOVA by items. As with the subjects analysis the within-subject factors were distinctiveness (typical or distinctive face primes; repeated measure) and prime type (same, neutral and unrelated; repeated measure). The results showed no main effect of distinctiveness. There was a significant effect of prime type $F(2,22) = 60.394$, $p < 0.001$. Planned comparisons showed the same pattern of effects of prime type found for the analysis by subjects. There was a significant interaction between distinctiveness and prime type, $F(2,22) = 3.555$, $p < 0.05$. Simple effects analysis showed that this was attributed to the effect of distinctiveness for the same prime type only, $F(1,11) = 7.576$, $p < 0.05$; i.e. distinctive primes produced more self priming than typical primes.

7.1.4 Discussion

7.1.4.1 Experimental hypothesis

The Burton *et al.* model predicted that distinctive face primes should produce more self priming than typical face primes. The significant interaction between distinctiveness (distinctive and typical) and prime type (same, associated and unrelated) in both subjects and items analyses supports this prediction. Further, the simple effects analysis showed that the interaction effect is restricted to the same prime type only.

The main effect of distinctiveness found in the subjects analysis suggests that overall target names preceded by distinctive face primes were responded to significantly faster than target names preceded by typical face primes. However, the simple effects analyses indicated that an effect of distinctiveness was restricted to the same prime type condition, as there was no effect of distinctiveness for the other two prime types ($F < 1$). This would suggest that the main effect of distinctiveness was forced through by the interaction between self priming and distinctiveness, and not as a result of any other factors, e.g. inconsistent degrees of familiarity between the distinctive and typical face prime sets. In the items analysis no main effect of distinctiveness was found.

Recently, Bruce, Dench and Burton (1992) have carried out a study in which they investigated the effects of repetition priming, semantic priming and facial distinctiveness in one experiment. Their results show that the effects of these three factors are additive rather than interactive. On the basis of this result they argue that the the three effects arise from different levels of the face recognition system. They attribute distinctiveness effects to the FRUs, repetition priming to the strengthening of FRU-PIN connections, and semantic priming to the PINs and SIUs.

Note that the fact that the study reported here found an interaction between facial distinctiveness and prime type (essentially the amount of self priming) does not contradict Bruce *et al.*'s findings. In Bruce *et al.*'s (1992) study the distinctiveness of the target stimuli was varied, whereas in this study, the distinctiveness of prime stimuli was varied. Subjects were not required to make any response to the faces in this experiment, whereas in Bruce *et al.*'s (1992) series of experiments they were. To that extent, although the results of Experiment 9 do not address the localisation of distinctive and self priming effects they are consistent with Bruce *et al.*'s findings. Further, they support the account offered by Burton *et al.* (1990); i.e. that distinctiveness effects are explained in terms of rapid and increased FRU activation inevitably leading to rapid and increased PIN activation, as a result of low levels of inhibition within the FRU pool.

7.1.4.2 Typical face primes and inhibition

Given that there is more inhibition present at the level of the FRUs and PINs following the presentation of a typical than a distinctive face prime, then one might expect to find inhibition from the typical unrelated prime. However, the results of Experiment 9 found no significant inhibition, from either the typical or distinctive face primes. In order to determine whether the observed effect was consistent with the IAC model, a simulation of the unrelated prime target condition was carried out under two conditions: (i) when the target name is preceded by an unrelated distinctive face primes, and (ii) when the target name is preceded by a typical face prime (Figure 7.2).

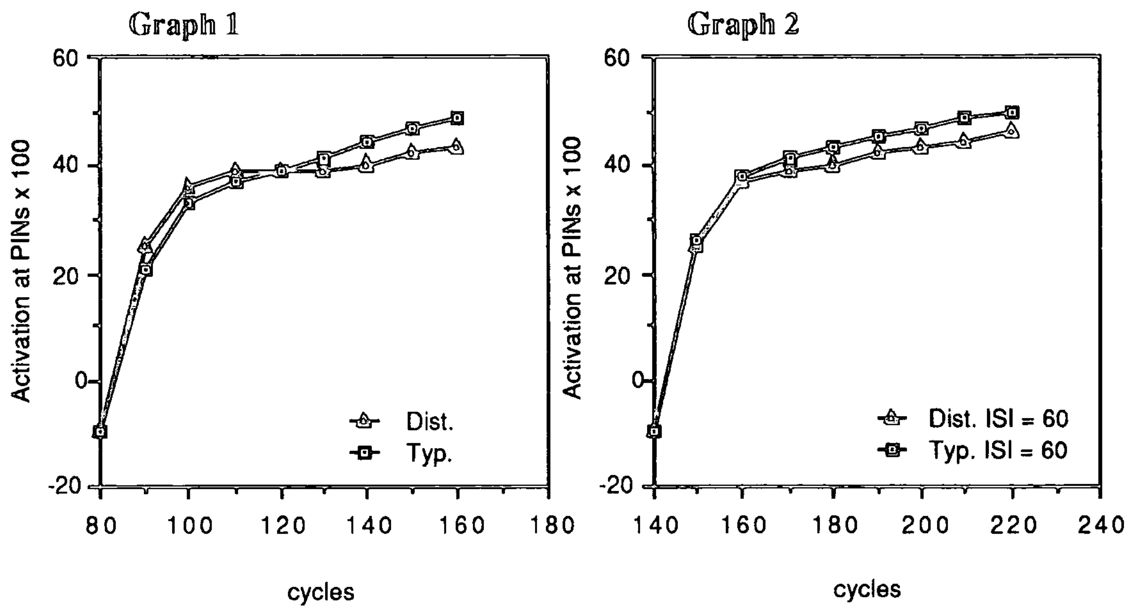

Figure 7.2 : The PIN activation curves following the presentation of a target name preceded by an unrelated prime are shown under two conditions. Graph 1 represents the activation of the target name PIN when it is preceded by a distinctive or a typical face prime input for 80 cycles. Graph 2 represents the activation of the target name PIN when the target is preceded by a distinctive or typical prime input for 80 cycles, and an ISI of 60 cycles, in which there is no external input. The graphs illustrate that the activation of the target name is not reduced when it is preceded by an unrelated typical face prime. Hence, the model predicts that there should be no more inhibition from the unrelated typical face primes than from distinctive face primes.

From Figure 7.2 there would seem to be no cost for responses to target names preceded by unrelated typical face primes compared to unrelated distinctive face primes. Indeed, if anything, the simulation suggests the typical face primes should produce slightly less inhibition. Examination of the facilitation values shows that typical face primes did produce a trend towards marginally less inhibition (typical unrelated facilitation = -8 milliseconds, distinctive unrelated facilitation = -14 milliseconds), although these values did not reach statistical significance.

The results of this experiment are also consistent with Valentine's multidimensional space coding models. Valentine (1991a; 1991b) has argued that both norm-based and exemplar forms of the model are able to account for the fact that distinctive faces are recognised faster than typical faces. Valentine (1991a; Valentine and Ferrara, 1991) has suggested that speeded recognition of distinctive faces reflects the fact that distinctive faces access their corresponding 'identity labels' faster than typical faces. In the above experiment a face prime was used to activate a person's identity label that was immediately 'tapped' with a name target.

7.2 Experiment 10

7.2.1 Introduction

A number of authors have suggested that caricatures are good representations of faces because they exaggerate the distinctive aspects of a face (Benson and Perrett, 1991c; Goldman and Hagen, 1978a; Perkins, 1975; Rhodes *et al.*, 1987). On this basis, given that distinctive faces produce more self priming than typical faces, one would predict that caricatured representations of faces should produce more self priming than anticaricatured and veridical representations of the same faces. Benson and Perrett (1991c) investigated the hypothesis that face caricatures should produce faster response times than veridical or anticaricature representations in a name/face match/mismatch decision task. Their results demonstrated that subjects' response times were faster to make mismatch decisions to caricatured stimuli rather than anticaricatured or veridical representations. However, no difference was observed among the response times for caricatures, veridical and anticaricatured representations in the match condition. Benson and Perrett suggest that the absence of an effect in the match condition can be attributed to the idea that faces are stored in terms of multiple representations.

A simpler, but similar explanation may underlie the effect if one considers the perceptual ratings data collected by Benson and Perrett. Benson and Perrett found an interpolated 'best likeness' degree of caricature of 4.4% i.e. on average, subjects regarded that a face caricatured at 4.4% should represent the best likeness of a face. Given that the stimuli used by Benson and Perrett in their match/mismatch task were caricatured at 16%, 32% and 48% it is perhaps not surprising that they did not find a facilitating effect from the caricature in the match condition. Further, the face stimulus remained on the screen for as long as it took the subjects to respond. Hence, on the match condition, the subjects had adequate time to view the face and realise that the face in front of them was obviously distorted. This does not exclude the possibility that a caricature image can access a representation of a face faster than a veridical or anticaricatured image. Benson and Perrett found some evidence of this effect in their mismatch condition. Here the subjects were being asked to decide that a name and face did not match. Consequently, the decisional process is not hindered by the fact that the face representation is a poor likeness of the name that preceded it. Indeed, Benson and Perrett argue that the effect of caricature is found for the mismatch condition because a caricature of a face is more of a mismatch to an unrelated name than a veridical representation.

It was reasoned that an effect of caricature would be found in a face/name task in which the subjects were not required to explicitly attend or respond to the identity of the face, and where the presentation of the face was too brief for the subjects to inspect it at leisure. In cross-domain face-to-name self priming, subjects are instructed to attend only to the identity of the target name in order to make a familiarity response. Further, earlier experiments reported in this thesis found self priming with a design in which the prime was presented for only 250 milliseconds, a period that was considered too short for subjects to study the structure of the face image. For this reason, the following experiment used a cross-domain self priming design to investigate the hypothesis that caricatured face primes produce more self priming than anticaricatured or veridical face primes.

7.2.2 Method

Subjects: 15 subjects from the post-graduate and undergraduate populations of the University of Durham participated as subjects. Subjects were between the ages of 18 and 37 years and had normal or corrected to normal vision. Subjects were paid for participating.

Materials: The names and faces of 10 famous individuals were used as stimuli. The names were employed as targets, printed in upper case Helvetica script (e.g. MARGARET THATCHER). The faces were distorted at five levels of caricature, -50%, -25%, 0%, 25% & 50%, to give 50 different priming agents in total. All stimuli were black and white slides.

7.2.2.1 Preparation of stimuli

The faces were caricatured according to the following four stage procedure (see also Figure 7.3; for a more detailed account see Benson and Perrett 1991d). All caricatured stimuli were prepared by Dr. P.J. Benson and Dr. D.I. Perrett at the Department of Psychology, University of St. Andrews.

Frame grabbing: A JVC BY-160 video camera and RS-110 remote control unit were used to frame-grab black and white photographs of the faces into a video store on a pc-based Pluto 24i 24 bit graphics utility processor. The Pluto image files were then transferred to a UNIX-based Silicon Graphics IRIS 3130 24-bit colour workstation using a file transfer protocol. The inter-pupillary distance was standardised across all faces.

Feature Delineation: 186 points were manually positioned on to each of the photographic images to create delineated images of each of the faces containing 50 feature contours (Figure 7.3a). Each discrete feature was represented by a fixed number of

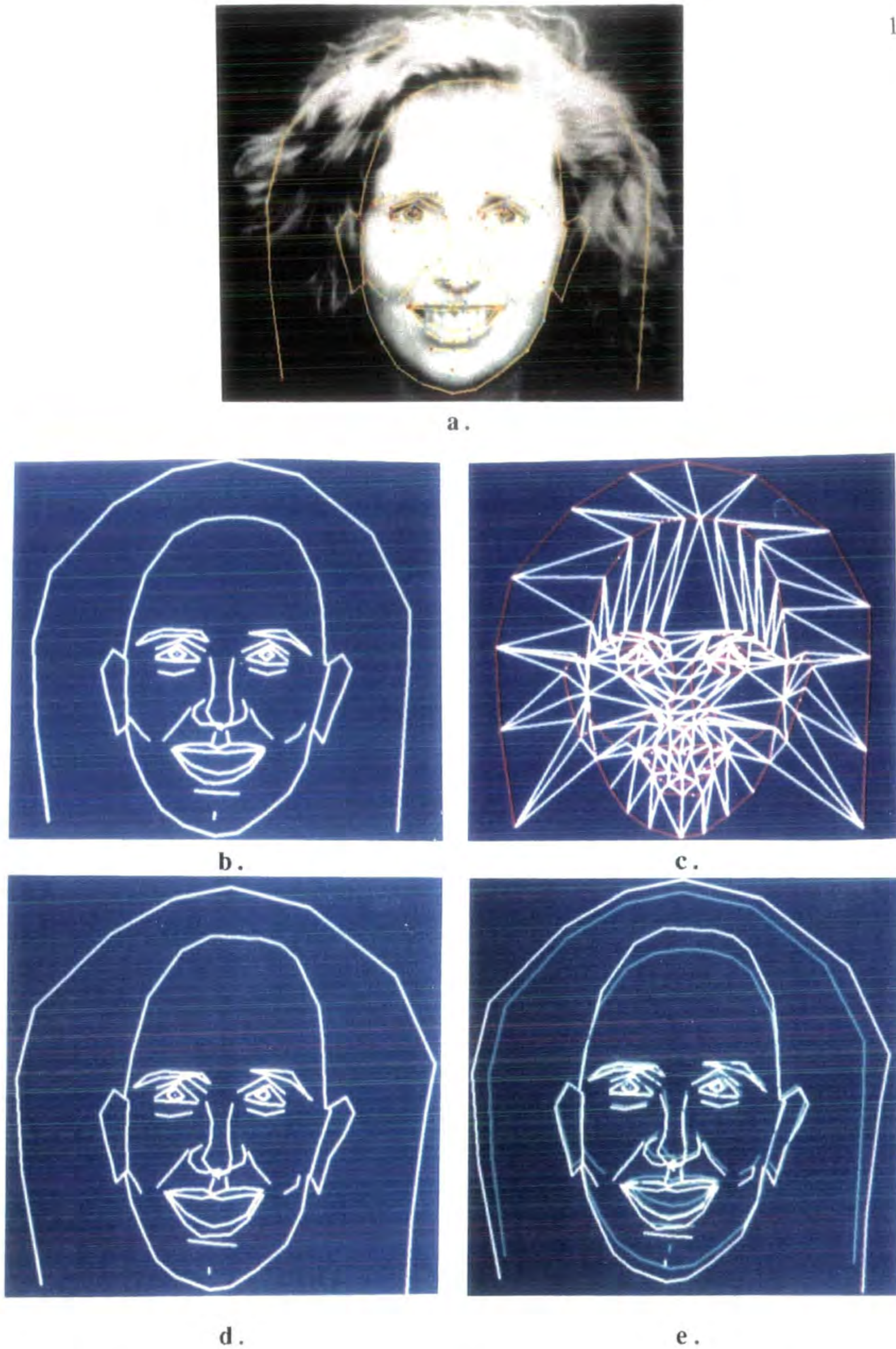

Figure 7.3: The five images shown above illustrate the basic stages involved in producing a caricatured image.

a. 186 points are positioned manually onto a photograph of a face to create a delineated image containing a set of 50 feature contours.

b. A veridical line drawing image of the face is abstracted from the delineated image.

c. A veridical image is divided up into a number of triangles depicting the inter-relationship of the data point positions on the face. By comparing the X/Y coordinate database of the delineated image to a prototype face, the points of deviation are realised and can be accentuated by the desired degree.

d. A 50% line drawing caricature a face formed by accentuating the deviations between the delineated face and the prototype by 50%.

e. The caricature (white line drawing) is shown superimposed over the original veridical image of the face.

points in order that there was conformity across all faces with respect to the number, but not the position, of the points depicting each feature. The number of points describing each feature ranged from 1 (the pupil) to 13 (the outer hair line). For those faces in which features were masked, e.g. the hair covering the ears, an approximation of the features' position was made. The resulting delineated image was stored as an x/y coordinate database.

Caricature generation: Caricatures were produced by comparing the coordinate database set of the target face to that of an average or norm face. A number of norms were used. Each was abstracted by averaging the feature positions of a number of faces of the same sex and age to the target face. Each of the target faces was computationally scaled such that the inter-pupillary distance matched that of the corresponding norm's. By exaggerating or decreasing the distance between the feature point locations of the target face and the norm face, caricatures and anticaricature configurations of the target faces were defined.

Caricature rendering: Continuous-tone caricatures were produced by mapping the original pixel intensities image on to the destination caricature or anticaricature image space using reference data. The reference data were derived from joining adjacent feature points and the points around the boundary of the image points delineating the hair outline. The result was a series of 340 triangular tessellations (Figure 7.3c). Triangles were used because they can define line deformation from the norm to the distorted image geometrically. Both veridical and caricature data were tessellated to obtain a correlated set of triangular areas. These distinct triangular areas provide the rendering process with the basis on which to select the pixel intensity values in the source image and the position in the caricature image. Where the caricature image triangles were larger than those in the target image, 'shrinking' of the spatial distribution of the pixels occurred. Similarly, 'stretching' occurred when the distorted image triangles were larger.

Figure 7.4: An example of one of the familiar faces (Anneka Rice) used in Experiments 10 and 11 caricatured at five levels; -50%, -25%, 0%, +25% and +50%.

Figure 7.4 shows Anneka Rice distorted at the five levels of caricature used in this experiment.

Apparatus: A three-field projection tachistoscope and two Kodak SAV 2050 projectors were used to present the stimuli. The slides were back projected onto a white screen and subtended a visual angle of approximately 8°. Reaction times were recorded on an electronic timer, measured from the onset of the target name and terminated by a manual response made by the subject pressing one of two buttons. The buttons were labelled 'Yes' and 'No'. Subjects were instructed to press the 'Yes' button in response to familiar targets and the 'No' button in response to unfamiliar targets.

Design: Three prime-target conditions, each with five sub-levels of prime caricature were used in this experiment. Same: -50%, -25%, 0%, 25%, 50%, neutral: -50%, -25%, 0%, 25%, 50% and unrelated: -50%, -25%, 0%, 25%, 50%. They were defined as follows:

Same: The target name and prime face were of the same person; e.g a caricature of Margaret Thatcher's face followed by the target name MARGARET THATCHER.

Neutral: The famous target name was preceded by a caricature of an unfamiliar face; e.g. unfamiliar caricature followed by the target name MARGARET THATCHER. The same unfamiliar neutral prime face caricatured at the five levels was used throughout.

Unrelated: The face prime and target name were of famous persons who were not semantically related; e.g. a caricature of Anneka Rice's face followed by the target name MARGARET THATCHER.

Both the same and unrelated conditions contained 50 prime-target experimental trials, and the neutral condition contained 25 prime-target pairs (five prime-target pairs at each of the five levels of caricature). In addition, a further 125 prime-target pairs were added as 'No' response trials, where the 10 famous target names were replaced by 10 unfamiliar invented names matched for length e.g. Ronald Reagan -> Andrew Waters.

Hence, in total there were 250 prime-target pairs. Presentation of all stimulus pairs was pseudo-random with respect to prime type and familiar/unfamiliar target names. Prime target pairs were counterbalanced such that all subjects saw all 10 familiar faces at all five levels of caricature and in the neutral condition, the neutral face primes at all five levels also.

Procedure: On each trial the prime was presented for 250 milliseconds followed by an inter-stimulus interval of 250 milliseconds, after which the target was displayed for 2.5 seconds. Hence, the stimulus onset asynchrony (SOA) was 500 milliseconds. Each prime-target trial was separated from the next by an interval of approximately three seconds. Subjects were instructed to look at the prime but respond only to the target name by making a manual, button-press response to indicate whether the name was familiar or unfamiliar. Half of the subjects made a positive familiarity response with their right hands and half with their left. Prior to starting the experiment, the subjects were presented with black and white slides of all 20 familiar and unfamiliar target names written in Helvetica script (i.e. exactly as they were to appear in the main task itself). The names were pseudo-randomly presented with respect to familiarity and the subjects were required to make a familiarity decision to each name. The names were presented twice to ensure that the subjects were familiar with the target stimuli and practised in pressing the response keys. Following this, a practice trial was run containing 10 of the stimulus pairs described above. Immediately after the practice trial the main experimental trials were run.

7.2.3 Results

Mean correct reaction times and percentage error rates to familiar and unfamiliar target names are shown in Table 7.2. Subjects' response times to target names preceded by the neutral prime were collapsed to give one overall mean for each subject. For clarity the mean facilitation values, measured relative to the neutral prime condition, are shown in Figure 7.5. Error rates were low and will not be considered further.

	Familiar Targets											Unfamiliar Targets
	Same					Neu	Unrelated					
	-50%	-25%	0%	25%	50%		-50%	-25%	0%	25%	50%	
RTs	518	511	506	499	499	561	562	577	579	569	570	595
Errors	2.5	2.5	1.7	3.3	1.8	1.9	2.5	3.5	1.2	2.5	2.5	1.7

Table 7.2: Mean correct reaction times and percentage error rates to familiar and unfamiliar target names preceded by same, neutral and unrelated primes, at the five levels of caricature; -50%, -25%, 0%, 25%, 50%.

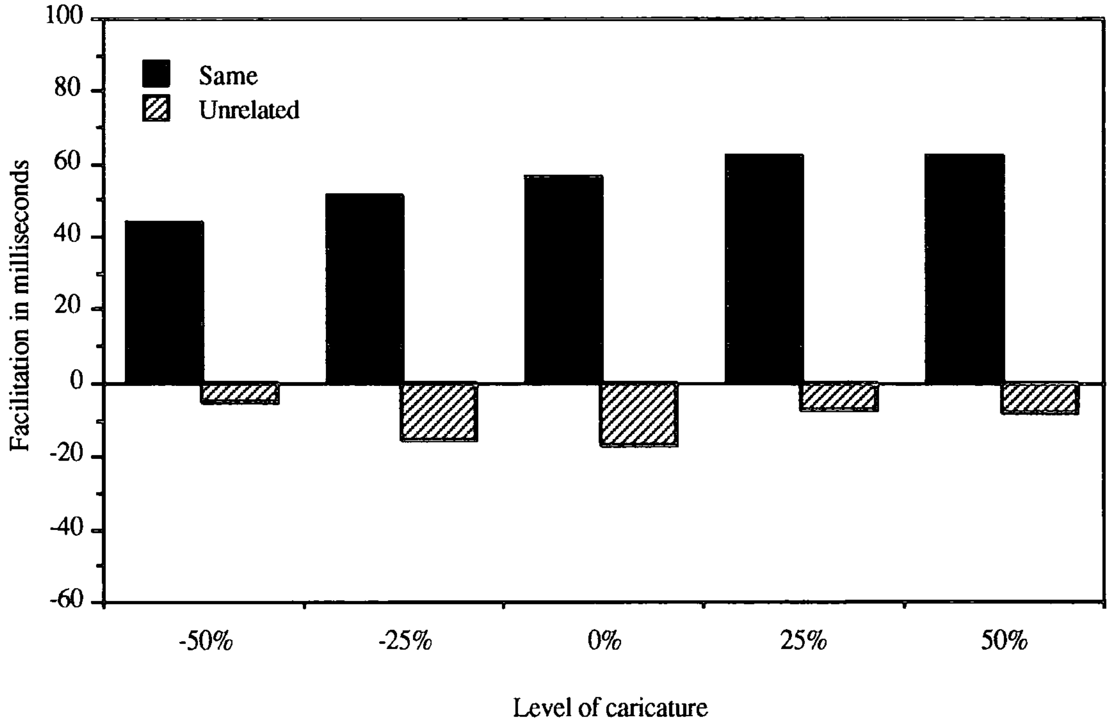

Figure 7.5: Mean facilitation values from the same and unrelated prime types at the five levels of caricature; -50%, -25%, 0%, 25%, 50% to familiar target names. Facilitation rates were calculated relative to the neutral prime-target condition i.e. facilitation = neutral - prime type (same/unrelated).

7.2.3.1 Analysis by subjects

A one-factor repeated measure ANOVA was carried out on the correct reaction time data to familiar target names. Prime type was the factor under investigation and had 11 levels (same: -50%, -25%, 0%, 25%, 50%, neutral (pooled) and unrelated: -50%, -25%, 0%, 25%, 50%; repeated measure). The results showed a significant effect of prime type, $F(10, 110) = 14.673$, $p < 0.001$. Newman-Keuls tests ($\alpha = 0.01$) showed that responses to target names preceded by all of the same caricature primes (-50% -> 50%) were faster than those to targets preceded by neutral or unrelated caricature primes (-50% -> 50%). Responses to targets preceded by all of the unrelated caricature primes (-50% -> 50%) did not differ from the responses to targets preceded by the neutral caricature primes. Planned comparisons on the five levels of same prime type showed no significant difference between any of the five levels. No other significant effects were found. In short, there was no effect of caricature.

7.2.3.2 Analysis by items

A one-factor repeated measure ANOVA by items was carried out on the data. Prime type was the factor under investigation and had 11 levels (same: -50%, -25%, 0%, 25% and 50%, neutral (pooled) and unrelated: -50%, -25%, 0%, 25% and 50%; repeated measure). The results showed a significant effect of prime type $F(10, 90) = 9.171$, $p < 0.001$. Newman-Keuls tests ($\alpha = 0.01$) carried out on the data, showed exactly the same results to that found in the analysis by subjects. Planned comparisons between the five levels of same prime type showed no significant effects.

7.2.4 Discussion

The results of both the subjects and items analyses showed that there was no effect of caricature on the amount of facilitation from the five levels of same prime caricatures (-50%, -25%, 0%, 25% and 50%) all of which produced positive facilitation. Further, none of the five levels of unrelated prime caricatures (-50%, -25%, 0%, 25% and 50%)

produced inhibition. The overall result is consistent with Posner and Snyder's (1975b) theory of automatic priming.

Although the results of the analyses showed no significant difference between the mean facilitation observed among the same caricature primes, there was a distinct trend in the data towards increasing self priming with increasing degree of caricature. It was reasoned that a significant effect might be found if a more sensitive design was used.

One factor that may have contributed to dampening any possible effect of caricature, was the large number of stimulus repeats. Subjects saw each of the 10 faces in 10 of the prime type conditions (the neutral condition included an unfamiliar face prime). As the experiment went on the subjects would have become more familiar with the primes. As such, they may have required less information to activate the relevant PINs. For example, the presence of long blond hair may have been sufficient to activate the PIN for Anneka Rice without reference to the internal, distorted features of the face. It was reasoned that by restricting each subject to viewing each face at only one level of caricature, this 'limited information' effect could be reduced. Ideally, each subject should see each prime stimulus only once. However, the limited number of caricatured stimuli available (10) made this impossible.

Experiment 11 set out to examine self priming with caricatured stimuli, using a design in which stimuli were counterbalanced across subjects such that each subject saw each face at only one level of caricature. This design meant that subjects saw only two faces at each level of caricature. In order to collect enough data to allow analysis of the means, subjects were presented with the same stimulus block four times. It was thought that this would not affect the amount of self priming, as Bruce, Dench and Burton (1992) have shown that repetition of the same experimental block does not affect the amount of semantic priming observed on each subsequent presentation.

7.3 Experiment 11

7.3.1 Method

Subjects: 20 subjects from the undergraduate and post-graduate populations of the Department of Psychology, University of Durham participated in the experiment. Subjects were between the ages of 19 and 32 years and had normal or corrected to normal vision. Subjects were paid for participating.

Materials and Apparatus: The same basic materials and apparatus used in Experiment 10 were used in this experiment.

Design: The 10 faces to be used as primes were divided into five sets of two faces. These five sets were counterbalanced to give five blocks of experimental trials. The blocks were arranged such that each block contained each of the 10 faces but at different levels of caricature. Table 7.3 illustrates the arrangement of the stimuli.

Experimental Block 1					
Caricature	-50%	-25%	0%	25%	50%
Face Block	1	2	3	4	5
Experimental Block 2					
Caricature	-50%	-25%	0%	25%	50%
Face Block	2	3	4	5	1
Experimental Block 3					
Caricature	-50%	-25%	0%	25%	50%
Face Block	3	4	5	1	2
Experimental Block 4					
Caricature	-50%	-25%	0%	25%	50%
Face Block	4	5	1	2	3
Experimental Block 5					
Caricature	-50%	-25%	0%	25%	50%
Face Block	5	1	2	3	4

Table 7.3: The arrangement of stimuli in the five experimental block sets. Stimuli were arranged such that faces appeared as primes (same and unrelated) at only one level of caricature. Subjects were presented with only one of the five experimental blocks.

The same prime type conditions used in Experiment 10 were used in this experiment; same: -50%, -25%, 0%, 25%, 50%, neutral: -50%, -25%, 0%, 25%, 50% and unrelated: -50%, -25%, 0%, 25%, 50%. Each subject block included 30 prime-target pairs to which a familiar response was required to the target. In addition to the familiar prime-target pairs, a further 30 'No' response trials were added. The 'No' response trials were created by replacing familiar target names in the familiar prime-target pairs with invented unfamiliar names, matched to the familiar names for length e.g. Ken Dodd -> Tim Best. Thus, each experimental block contained 60 prime-target pairs.

Procedure: On each trial the prime was presented for 250 milliseconds followed by an inter-stimulus interval of 250 milliseconds, after which the target was displayed for 2.5 seconds. Hence, the stimulus onset asynchrony (SOA) was 500 milliseconds. Each prime-target trial was separated from the next by an interval of approximately three seconds. Subjects were instructed to look at the prime but respond only to the target name by making a manual button press response to indicate whether the name was familiar or unfamiliar. Prior to starting the experiment, the subjects were presented with black and white slides of all 20 familiar and unfamiliar target names written in Helvetica script (i.e. exactly as they were to appear in the main task itself). The names were pseudo-randomly presented with respect to familiarity and the subjects were required to make a familiarity decision to each name. The names were presented twice to ensure that the subjects were familiar with the target stimuli and practised in pressing the response keys. Half of the subjects made a positive familiarity response with their right hand and half with their left. Following the presentation of the target names, a practice trial was run containing 10 of the stimulus pairs described above. Immediately after the practice trial the subjects were presented with one of the five experimental blocks described above. The presentation of the block was repeated four times, each time in a different pseudo-random order.

7.3.2 Results

Mean correct reaction times and percentage error rates to familiar and unfamiliar target names are shown in Table 7.4. Subjects' response times to target names preceded by the neutral prime were collapsed to give one overall mean for each subject. For clarity the mean facilitation values, measured relative to the neutral prime condition, are shown in Figure 7.6. Error rates were low and will not be considered further.

	Familiar Targets											Unfamilia r Targets
	Same					Neu	Unrelated					
	-50%	-25%	0%	25%	50%		-50%	-25%	0%	25%	50%	
RTs	505	518	508	514	472	561	599	598	611	603	618	616
Errors	1.5	1.2	1.6	1.5	1.7	1.5	2.0	2.6	1.7	1.6	1.2	1.2

Table 7.4: Mean correct reaction times and percentage error rates to familiar and unfamiliar target names preceded by same, neutral and unrelated primes, at the five levels of caricature; -50%, -25%, 0%, 25%, 50%.

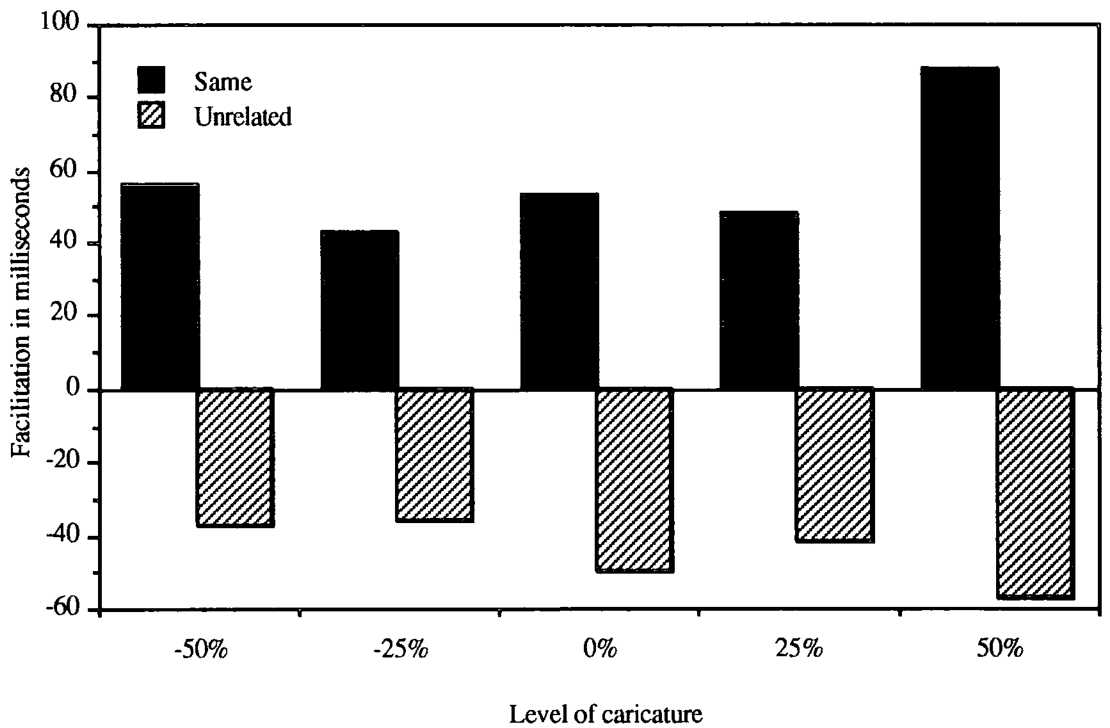

Figure 7.6: Mean facilitation values from same and unrelated primes at the five levels of caricature; -50%, -25%, 0%, 25% and 50% to familiar target names. Facilitation rates were calculated relative to the neutral prime-target condition i.e. facilitation = neutral - prime type (same/unrelated).

7.3.2.1 Analysis by Subjects

A one-factor repeated measure ANOVA was carried out on the correct reaction time data to familiar targets. Prime type was the factor under investigation and had 11 levels (same; -50%, -25%, 0%, 25%, 50%, neutral, unrelated; -50%, -25%, 0%, 25%, 50%; repeated measure). The results showed a highly significant effect of prime type, $F(10,190) = 35.810$, $p < 0.001$. Newman-Keuls tests ($\alpha = 0.05$) showed that responses to targets preceded by the same 50% face were faster than those preceded by any of the other 10 face primes. Further, responses to target names preceded by all same caricature primes (-50% -> 50%) were significantly faster than responses to target names preceded by the neutral caricature primes, and responses to target names preceded by all unrelated caricature primes (-50% -> 50%) were significantly slower than those preceded the neutral caricature primes. Planned comparisons between the five levels of same prime type showed that the +50% same primes produced more facilitation than all other four levels of prime type ($p < 0.01$). No other significant effects were found.

7.3.2.2 Analysis by items

A one factor repeated measure ANOVA by items was also carried out on the data. As in the analysis by subjects, prime type was the factor under investigation. The results showed a significant effect of prime type, $F(10,90) = 18.668$, $p < 0.001$. Newman-Keuls tests ($\alpha = 0.05$) showed that responses to target names preceded by all five levels of the same primes (-50% -> 50%) were faster than responses to target names preceded by neutral or unrelated primes (-50% -> 50%). Responses to target names preceded by the 0% unrelated prime were slower than those preceded by the neutral primes. No other significant effects were found. Planned comparisons of the five levels of the same prime types showed that the 50% same primes produced more facilitation than both the -50%, $F(1,90) = 4.665$, $p < 0.05$, and 25%, $F(1,90) = 6.324$, $p < 0.05$. The +50% 0% comparison just missed significance ($p = 0.09$).

7.3.3 Discussion

7.3.3.1 Experimental hypothesis

The results of the subjects and items analyses produced slightly different results. However, given that the caricatured face primes were rotated across subjects, i.e. no one subject saw a face prime at more than one level of caricature, the results of the subjects analysis are perhaps more informative.

The principal result of interest is the finding that 50% face caricatures produced significantly more self priming than faces caricatured at the other 4 levels (-50%, -25%, 0% and 25%). To that extent, the results of Experiment 11 confirm the experimental hypothesis that caricatured face primes produce more self priming than veridical or anticaricatured face primes. Note that with planned comparison testing, the results of the items analysis show a significant effect of caricature, in that responses to target names preceded by the 50% same prime are faster than responses to target names preceded by the -50% and -25% same primes.

7.3.3.2 Facilitation from the five levels of the same prime

It is worth noting that all five levels of caricature for the same prime condition produced significant facilitation. Benson and Perrett (1991c) found that less than 5% of their subjects selected a -32% anticaricature of a face as 'best likeness' and that subjects made the highest number of errors on a name/face match/mismatch task when the face was a -32% caricature and matched the name. Despite the poor perceptual processing of anticaricature stimuli in Benson and Perrett's study, Experiment 11 showed that the amount of facilitation observed from the -50% same caricature prime was about the same as that from the veridical (0% caricature) prime. This effect may merely reflect the fact that subjects were presented with the faces and names of a limited number of stimuli (10). Hence, as they were being presented with the face stimuli, if the anticaricature of a particular face did not activate the relevant FRU the first time, by the second or third presentation the subject may have worked out who the distorted image represented. Undoubtedly, the optimum design to study effects of this sort would be one in which stimuli are not repeated. However, as discussed in Experiment 10, the limited number of stimuli available made this impossible.

7.3.3.3 Facilitation with inhibition

In addition to facilitation from the five levels of same caricature primes, the subjects analysis showed that inhibition was present from all five levels of unrelated caricatured primes (-50%, -25%, 0%, 25%, and 50%). It is not clear why inhibition should be found in this experiment, but not in Experiment 10. In Posner and Snyder's (1975b) theory of automatic priming, the presence of inhibition infers that subjects were using conscious strategies. However, it is highly improbable that the effect of caricature can be attributed to conscious strategies. The data suggest that the 50% caricature activated the face representations fastest. Whether decisional processes were then used at a later stage to make a familiarity decision is incidental.

7.3.3.4 Modelling effects of caricature

The results of Experiment 9 are consistent with Burton *et al.*'s simulation of the distinctiveness effect. However, it is unclear whether Burton *et al.*'s model can account for the caricature effect found in Experiments 10 and 11. The distinctiveness effect was explained in terms of the fact that distinctive FRUs share their VCUs with only a small number of other FRUs. A similar explanation may underlie the caricature effect. Given that the caricature generator (Benson and Perrett, 1991d; Brennan, 1985) exaggerates the idiosyncratic components of a face, (i.e. those features that differ from an average or norm face), one might argue that in a caricatured image, the distinctive VCUs receive a higher input because they are being activated by 'superfidelity' representations (Perkins, 1975) of the VCUs. Further, the typical VCUs receive the same amount of activation, as the visual components of the face relating to these VCUs have not been altered. A number of attempts were made to simulate this effect in the same model that was used to demonstrate the distinctiveness effect. However, they were unsuccessful.

7.4 General Discussion

Experiment 9 demonstrated that distinctive face primes produce more self priming than typical face primes. Experiment 11 extended this finding to show that faces whose distinctive features have been exaggerated, caricatures, produce more priming than their veridical representations and representations in which their distinctive features have been reduced, anticaricatures.

7.4.1 Accounting for effects of caricature in exemplar and norm-based coding models

The results of both Experiments 9 and 11 are consistent with Valentine's conception of multidimensional space (Valentine, 1991a; Valentine, 1991b; Valentine and Endo, 1992; Valentine and Ferrara, 1991). Valentine (1991a; 1991b) has suggested that both norm-based coding and exemplar-based coding models can account for the fact that distinctive faces are recognised faster than typical faces. Valentine and Endo (1992) have recently argued that the results of their cross-cultural study on the perception of different race faces have shown that the exemplar-based coding model produces a more accurate account of the data. However, following Nosofsky (1986), Valentine points out that in order to apply the exemplar-based coding model to the results of studies investigating the recognition of distinctive and typical faces, it must be assumed that when a subject makes a positive familiarity decision to a face, the subject is accessing an identity-specific label associated with that face. In the case of familiar faces it was suggested (see Chapter 6) that this identity label could be a PIN in Burton *et al.*'s IAC model. This explanation seems desirable for two reasons; (i) it draws together two areas of research, Valentine's multidimensional face space and the Burton *et al.* IAC model, that have developed somewhat independently, and (ii) it avoids having to confirm the conceptually difficult problem that a face familiarity decision constitutes identification rather than recognition.

All that requires to be demonstrated is that a face familiarity decision constitutes the retrieval of an identity specific label, a PIN. This is verified to some extent by the experiments in this thesis which show that cross-domain self priming exists, i.e. face primes activate identity specific labels, the PINs, which in turn can be accessed by names. Further, distinctive face primes produce more cross-domain self priming, an observation that can be accounted for in terms of Valentine's exemplar-based coding model, i.e. distinctive faces produce faster retrieval of their PINs, because distinctive faces are stored in areas of low exemplar density. An explanation of the caricature effect found in Experiment 11 can be found if caricatures are considered as 'super-dimensional representations' of their dimensions in multidimensional space. Hence, caricatures produce faster retrieval of their corresponding PINs, because they are more efficient at accessing multidimensional face vectors than veridical and anticaricatured representations.

8 Summary and Conclusions

8.1 Introduction

In this final chapter a brief synopsis of Burton, Bruce and Johnston's (1990) account of priming effects in terms of their IAC model is presented. Following this a number of criticisms of the model's architecture are discussed. Given that a number of authors have recently called for a instance-based approach to the representation of faces in memory (Bruce, 1988; Brunas *et al.*, 1990; Ellis *et al.*, 1990; Ellis *et al.*, 1987), the appropriateness of an IAC network as an implementation of the face recognition system is discussed. Finally, a summary of the experiments carried out in this thesis is presented along with the main conclusions to be drawn from these studies.

8.1.1 From a modular account to an implementation

Burton, Bruce and Johnston (1990) have presented an interactive activation and competition model of face recognition. Basically, Burton *et al.*'s IAC model is a computer implementation of the recognition route of Bruce and Young's (1986) functional model of face recognition. Consequently, the architectures of the two models share a number of components. Bruce and Young laid out a macro-structural account of face recognition in the form of a modular logogen-based account. The IAC model is also logogen-based, but by simulating the activation of individual representational units, Burton *et al.* have presented a micro-structural account in their implementation. By allowing the experimenter to observe the activation of individual units and their effects on other units, the Burton *et al.* model adds a further dimension to the predictive power of a functional model of face recognition.

Despite the structural similarities between these two models, one important conceptual point distinguishes them. Bruce and Young suggested that a face familiarity decision is based on the activation of the face recognition units (FRUs), likewise they suggested that the recognition of all other person-identity traits; e.g. names, took place at the level of their representational unit, e.g. name recognition units. Burton *et al.* have presented an ultimately more parsimonious account and argue that the recognition of all person-identity traits, faces included, take place at the PINs. Further, while Bruce and Young were unclear as to whether identity-specific semantic information was stored within, or accessed by the PINs, Burton *et al.* are unequivocal that semantic information is stored within separate structures the semantic identity units (SIUs), accessible only via the PINs. The status of the PINs in the IAC model is therefore one of mediators, receiving inputs from all other areas of the face recognition system and signalling the recognition of all person identity traits.

8.1.2 Previous accounts of repetition and semantic priming

Models of face recognition (Bruce and Young, 1986; Ellis, 1986; Hay and Young, 1982) have been influenced by logogen theory (Morton, 1979). Hence, it was natural in these models to locate repetition priming effects at the level of representational units; e.g. face priming occurs at the FRUs. The Burton *et al.* IAC model also has its foundations in logogen theory. However, Burton *et al.* suggest that repetition priming is better explained in terms of the strengthening of connections between modules rather than lowering of recognition thresholds of representational units. In the lexical literature Allport and Funnell (1981) have presented a similar account as an explanation of repetition priming with words.

Semantic priming presents something of a puzzle for logogen-based models. Chapter 1 discussed the fact that the Bruce and Young (1986) model found difficulty in accommodating semantic priming effects. This problem basically stemmed from the assumption that the recognition of a face was signalled by the activation of its representational unit. In the Burton *et al.* model separate units, the PINs signal recognition. In accordance with this architecture, Burton *et al.* account for semantic priming (e.g. from Charles to Diana) in terms of the indirect activation of Diana's PIN from Charles' PIN via semantic identity units (SIUs) that they are both connected to (e.g. Royalty, son called Prince William etc.). In other words, Charles primes Diana because they are both associated with the same semantic information. This account is distinct from automatic spreading activation (ASA) accounts (Anderson, 1976; Neely, 1977; Posner and Snyder, 1975a). The ASA accounts would suggest that Charles primes Diana because Charles and Diana are connected to each other by a strong excitatory pathway (or stored within close proximity of each other) within a hierarchical semantic network. Chapter 1 discussed the fact that a number of authors have rejected the semantic network account of semantic priming in favour of an associatively-based account. It is therefore appropriate that Burton *et al.* have presented a model in which persons are related to other persons by virtue of the fact that they are associated with the same semantic attributes. In this sense the IAC model represents an associatively-based representation of semantic priming. Intuitively, one might think of an associatively-based account of semantic priming as episodically-based, i.e. Charles primes Diana because Charles and Diana are seen together (once upon a time). Nevertheless this is not the only sort of associatively-based account. Further, it is interesting to note that not all semantic priming effects fit neatly into an asociatively-based account of the episodic variety. In the lexical literature priming has been observed from a category name to a category exemplar, e.g. BIRD-robin (Neely, 1977) . It is not unreasonable to assume that a similar effect might be found with faces or names, e.g. ROYALTY-Prince Charles. It is important to note, therefore, that an associatively based account of the sort described by Burton *et al.* accommodates this effect much more readily than an episodically-based account of semantic priming could.

8.1.3 A new insight into an old phenomenon

The IAC model has no difficulty in accounting for the observations that semantic priming can cross stimulus domains; e.g. from faces to names (Young *et al.*, 1988) and that it is short lived (Bruce, 1986; Dannenbring and Briand, 1982). Further, Burton *et al.* offer a new interpretation of the short time course of semantic priming. Chapter 2 presented a simulation that illustrated the models account of semantic priming (Figure 2.4); i.e Charles' PIN activates Diana's PIN indirectly via SIUs that they have in common. A separate simulation showed that the activation of both Charles' and Diana's PINs is abolished when an input to an unrelated FRU follows the input to Charles FRU (see Figure 2.5). This occurs because each PIN is connected to all other PINs by inhibitory connections. Therefore, when an input to an FRU (e.g. Charles) is followed by an input to a second unrelated FRU (e.g. Eric Morecambe), any activation in Charles', or Diana's PINs is inhibited by Eric Morecambe's PIN.

In the lexical literature Dannenbring and Briand (1982) demonstrated that semantic priming effects were short lived. Using a very similar design Bruce (1986) replicated this effect with faces. However, in both of these studies the prime-target ISI was confounded with the number of intervening stimuli between the prime and target. Both studies found that one intervening stimulus was enough to abolish any semantic priming effects while repetition priming effects were long lasting. Subsequently, both studies concluded that the activation a face (or word) receives from a semantically associated face (or word) dissipates quickly. Hence, semantic priming is not found across long prime-target ISIs. However, Burton *et al.* suggest that it is not the length of the prime-target ISI that governs the time course of semantic priming as much as the presence/absence of unrelated items in the ISI between prime and target.

In short then, the Burton *et al.* model would seem to present a good account of the repetition and semantic priming effects. Nevertheless, there are a number of problems that Burton *et al.* must address if they are to present an account of all of the present data.

8.2 Appropriate implementations for modelling face recognition

8.2.1 Problems with an IAC account of face recognition

Chapters 2 and 6 discussed Schreiber, Rousset and Tiberghien's (1991) distributed network of face recognition; FACENET and Valentine and Ferrara's (1991) model of distinctiveness effects in face recognition. Both models are distributed networks (auto-associator and back propagation). Simulating face recognition on these parallel distributed processing (PDP) networks seems desirable for a number of reasons. Both of these networks can be used to display distinctiveness effects because they have the property of being able to extract prototypes from a set of distorted exemplars. Further, because the representations in these models are instance based, they have no trouble in accounting for the graded effects of repetition priming produced by varying the degree of visual similarity between a prime and a target stimulus (Bruce and Valentine, 1985; Ellis *et al.*, 1987; Ellis *et al.*, 1993). More recently, Brunas, Young and Ellis (1990) have found more evidence in support of instance-based representation of faces. Brunas *et al.* found equivalent amounts of priming from internal (eyes, nose, mouth etc.) and external (hair, head shape) face section primes as from complete face primes onto face targets. This part-whole completion phenomenon is also a feature of PDP networks. There would therefore seem to be a number of reasons in favour of distributed representations of faces as opposed to logogen-based accounts.

Undoubtedly the weakest feature of the Burton *et al.* model is the lack of a detailed account of 'front-end' processing, i.e. pre-FRU. The structure of the IAC network at present cannot accommodate graded repetition priming effects and part whole completion. Given that instance based approaches to face perception have been called for more recently (Bruce, 1988; Brunas *et al.*, 1990; Ellis *et al.*, 1990; Ellis *et al.*, 1987), it is perhaps doubtful whether the Burton *et al.* will be able to account for these additional observations purely in terms of an IAC implementation. A further problem regarding IAC models is their inability to learn. At present there are no satisfactory accounts of learning processes in IAC models. To that extent they have difficulty in accommodating effects with previously unfamiliar faces that the PDP models have no difficulty modelling. Chapter 7 highlighted this problem in terms of the inability of Burton et al's model to account for distinctiveness effects with unfamiliar faces.

The problems discussed above, however, are directed towards the 'front-end' section of the model. These problems might be overcome if the present FRUs and VCUs were replaced with a PDP network. Whether it is desirable to incorporate a PDP and IAC based networks in the one model is debatable. Nevertheless, conceptually this might produce a more complete account of the present data.

8.2.2 Problems with distributed accounts: in support of an IAC account

Perhaps the most attractive feature of the Burton *et al.* IAC model is its ability to account for short SOA effects, such as semantic priming and self priming. Chapter 1 discussed that even the most recent and advanced PDP models of word recognition (Seidenberg and McClelland, 1989) have difficulty in accommodating semantic priming effects. However, Schreiber, Rousset, Tiberghien (1991) have suggested that their PDP account of context effects in face recognition, FACENET, may be able to account for semantic priming with faces in terms of context. Hence, Prince Charles primes Princess Diana, not because they are associated with the same semantic information, but because they have been seen together in the same contexts, or associated with the same contexts. The PDP status of FACENET is attractive as it may provide an explanation of part-whole completion, distinctiveness effects and graded repetition priming effects. However, if a model of this sort is to achieve any credibility as an account of semantic priming then Schreiber *et al.* must demonstrate that it shows basic properties of semantic priming i.e semantic priming from the model should have a short time course and cross stimulus domains (FACENET has only one 'person domain' at present; faces). Further, the same architecture should demonstrate the properties of repetition priming, i.e. repetition priming in the model should be long lived and should not cross domains. Finally, given the results of this thesis the model should show a short lived cross-domain self priming effect.

Work is at present going on to address the criticisms of the Burton *et al.* model cited above, (Burton, 1992). Despite these criticisms the Burton, Bruce and Johnston (1990) IAC implementation would seem to provide the most parsimonious and workable existing account of the data it set out to model. In addition, the model presents a number of predictions. The aim of this thesis was to test a number of these predictions through experiment.

8.3 Testing the predictions of the model

8.3.1 Cross and within-domain self and semantic priming

Simulations with the model indicate that for short SOAs a person's face should prime the recognition of their name (or *vice versa*); this is the phenomenon of cross-domain self priming. Further, the model predicts that cross-domain self priming should produce the same amount of facilitation as within-domain self priming; face/face or name/name. Experiments 1 and 2 (Chapter 3) set out to test these predictions, and found confirmation of their existence for a 500 millisecond SOA design. The same experiments investigated semantic priming alongside self priming and replicated Young, Hellawell and de Haan's (1988) finding that cross-domain and within-domain semantic priming produce equivalent degrees of facilitation. Experiments 1 and 2 also confirmed a third prediction of the model, that the facilitation from a same person prime (self priming) should exceed that found from an associated person prime (semantic priming).

The observation that within and cross-domain designs produce equivalent degrees of self and semantic priming (for a design in which stimulus items are repeated across prime conditions) is consistent with Burton *et al.*'s suggestion that familiarity decisions to names and faces are mediated by the same units, the PINs. It is certainly more difficult to envisage how this effect could be found without invoking a common 'recognition level' for person-identity.

8.3.2 Self priming and strengthened connections

The design employed in Chapter 3 was adapted from Young *et al.* (1988). Young et al. showed semantic priming was found both for a design in which the stimulus items were repeated across prime type conditions and a design in which they were not repeated. Consequently, given the problems in obtaining suitable semantic associates, Experiments

1 and 2 adopted a design in which the stimulus items were repeated across prime type conditions. Closer examination of the IAC model suggested that whereas cross and within-domain semantic priming should produce equivalent degrees of semantic priming for a design in which items are repeated across prime type conditions, the same effect should not apply to self priming. Given that the model accounts for classic long-term repetition priming effects (Bruce and Valentine, 1985; Ellis *et al.*, 1990; Ellis *et al.*, 1987; Ellis *et al.*, 1993) in terms of the strengthening of connections, then the presentation of a name prime stimulus should increase the connection strength between its corresponding NIU and PIN. Consequently, more facilitation should be found from the within-domain same prime than the cross-domain same prime. This occurs because for the within-domain same prime condition the presentation of the target name will benefit from the strengthened NIU-PIN connection and thus produce more rapid and higher activation of its PIN. In the cross-domain condition a face prime precedes the name target. This has the effect of increasing the strength of the FRU-PIN connection for that person. However, because the target is a name, this strengthened FRU-PIN connection does not affect its speed of recognition.

In Experiments 1 and 2 the target names were presented prior to the start of the experimental trials and the stimulus items were repeated across prime type conditions. Hence, the NIU-PIN connection strengths corresponding to all target names were strengthened prior to the subjects being presented with the experimental trials. This would explain why no prime domain x prime type interaction was found for self priming in both of these Experiments. Experiments 3 - 6 set out to determine whether the predicted effect of greater within-domain self priming held for a design in which the subjects were not presented with the target names prior to viewing the experimental trials and the stimulus items were not repeated across prime type conditions. The results of these experiments confirmed the prediction. Experiment 3 demonstrated greater within-domain priming for a design in which targets were names and the primes were faces and names. It was important to determine that this within-domain priming effect reflected the structure of the recognition system, and not other factors; e.g. an artifact of the subjects being more familiar with the names than the faces of the persons used as stimuli. Using the same stimuli, Experiment 4 demonstrated the effect for a design in which targets were faces and the primes faces and names; i.e. a greater within-domain (face/face) than cross-domain self priming effect was found. Therefore, Experiment 4 confirmed that the effect found in Experiment 3 could not be attributed to more fluent recognition of the name stimuli alone.

8.3.3 Semantic priming

In Experiments 3 and 4 the greater within-domain effect for self priming was attributed to the added effect of strengthening the recognition unit (FRU/NIU)-PIN connections. Strengthened recognition unit-PIN connections play no part in cross-domain priming; however, they do not contribute to semantic priming either. Therefore, Experiment 5 set out to replicate Young *et al.*'s (1988) finding that cross and within-domain designs should produce equivalent degrees of semantic priming for a design in which stimuli are not repeated. Experiments 3 and 4 were designed with Experiment 5 in mind, and therefore they used related pairs as stimuli. However, the results of an unreported pilot experiment indicated that subjects felt that some of the persons whose names and faces were used as stimuli in Experiments 3 and 4 were not members of related pairs. A number of subjects were therefore asked to rate the names of 'related' persons for degree of association, and from these ratings the name pairs that received the top 20 ratings were selected. These 20 related pairs were used in Experiment 5 to test the prediction that cross and within-domain semantic priming should produce equivalent degrees of semantic priming. The prediction was confirmed. Nevertheless, the stimulus sets used in Experiments 3, 4 and Experiment 5 were not identical. For completeness, a further experiment (Experiment 6) was run in order to replicate the results of Experiment 3 with the reduced stimulus set used in Experiment 5. The results of Experiment 6 produced the predicted effect, i.e. greater within-domain (name/name) than cross-domain (face/name) self priming. A more convincing demonstration of the observed pattern of effects in Experiments 5 and 6 was sought in terms of a three-way interaction between

Experiment, prime domain and prime type. The results of this analysis did not produce this three-way interaction. Nevertheless, looking at Experiments 5 and 6 individually, the observation that the same stimulus set produces an interaction between domain and prime type for self priming but not for semantic priming supports the conclusion that these effects cannot be accounted for purely in terms of subjects being more familiar with the names than with the faces of persons used as stimuli.

A third possible explanation of the greater within-domain than cross-domain self priming effect that should be excluded is that of visual similarity between the prime and target. One might argue that the results of Experiments 3, 4 and 5 might be an artifact of the greater degree of visual similarity between the prime and target in the same prime within-domain condition. For Experiments 3 and 6 the within-domain prime-target condition was name/name and the primes were printed in lower case letters (with the exception of the first letter of the forenames and surname) and the targets in upper case letters. Similarly, in Experiment 4 the within-domain condition was face/face; where the face primes were different views of the faces used as targets. Hence, there was some degree of visual similarity between the primes and targets in the within-domain same prime conditions in these three experiments. However, given that prime domain x prime type interaction was not observed in Experiments 1 and 2 an explanation in terms of visual similarity seems unlikely. In Experiments 1 and 2 the within-domain condition was name/name and the primes were either printed lower case (Experiment 1) or handwritten lower case (Experiment 2). Thus, although one might argue that the degree of visual similarity between the prime and target was maximal in Experiments 1 and 2 for the within-domain same person prime condition, no interaction effect was found between prime domain and prime type. It is argued that the contrast in results between Experiments 1 and 2 and Experiments 3, 4 and 6 reflects the strengthening of recognition unit-PIN connections and not visual similarity between the prime and target. The visual similarity explanation seems less appropriate, because it is difficult to envisage why the repetition of stimuli across prime type conditions should have abolished the effect.

Taken together then, the results of Experiments 1, 2, 3, 4, 5 and 6 are consistent with the Burton *et al.* model. For a design in which stimuli were not repeated across conditions, more within-domain self priming than cross-domain self priming was observed. This result was replicated three times, twice where the within-domain condition was name/name and once when it was face/face. However, no prime domain x prime type interaction was found for semantic priming. This contrast between self priming and semantic priming for within and cross-domain designs supports Burton *et al.*'s account of semantic priming, repetition priming and self priming.

Whereas short term within-domain self priming has much in common with the classic long-term repetition priming effects recorded in the literature (Bruce and Valentine, 1985; Ellis *et al.*, 1990; Ellis *et al.*, 1987; Ellis *et al.*, 1993) cross-domain self priming is a distinct phenomenon. Burton *et al.*'s explanation of cross-domain self priming is principally PIN based. This account is supported by the observation that, like semantic priming, cross-domain priming does not persist over long prime-target intervals (Bruce and Valentine, 1985; Ellis *et al.*, 1987). Further, it is argued that cross-domain priming is automatic, and is not a post-access strategic effect. This conclusion is supported by the finding that self priming has been reported in the absence of inhibition (Experiments 1, 3, 9 and 10), an observation that satisfies Posner and Snyder's (1975b) constraint for automatic priming. In addition, de Haan and his colleagues have demonstrated cross-domain self priming (face/name) in two patients with face recognition impairments: (i) LF, a prosopagnosic who shows covert recognition of faces in implicit tests of face recognition (de Haan *et al.*, 1992), and (ii) NR, a patient with a number of cognitive dysfunctions of which face recognition impairments is the most striking (de Haan, Young and Newcombe, 1992). However, unlike LF, NR only showed covert self priming from a face prime that he was unable to identify overtly if he was able to give a positive response to the face in a forced choice familiarity decision task; i.e. he showed covert recognition for a selective group of faces. Because both of these brain injured subjects demonstrate self priming in the absence of overt recognition of the face prime, it is highly improbable that they are using the identity of the face prime to facilitate the recognition of the target name in any conscious strategic sense. Further, given that their overall patterns of responses are consistent with those found for normal subjects, it seems likely that the same cognitive systems underlie the effect in normal and brain injured subjects.

8.4 Investigating the time course of self and semantic priming

The Burton *et al.* model not only offers an opportunity to look at the activation of individual FRUs and PINs but it also allows the experimenter to monitor the activation of these different units across time (cycles). It is important to note, however, that by generating a hypothesis based on the change in activation of units across cycles, one makes the assumption that the model's measure of time is transferable to linear real time (milliseconds). Experiment 7 and 8 investigated a number of predictions derived from the PIN activation curves of two semantically associated PINs; Charles and Diana (Figure 5.1; Chapter 5). Following an input to Prince Charles' FRU the activation of Prince Charles' and Princess Diana's PINs were noted over time. The activation of the two PINs were observed to converge after the point where the input to Prince Charles' FRU ceased. The area after the end input point is analogous to an ISI between prime and target. Therefore, the simulation indicated that as prime-target ISI is increased the difference between self and semantic priming found in earlier experiments reported in this thesis should decrease.

Self and semantic priming were therefore studied across four different prime-target ISIs (20, 250, 750 and 1250 milliseconds) with a constant prime presentation time of 250 milliseconds. The results did not uphold the prediction and no significant interaction was found between prime type and ISI. This result may merely reflect a problem with matching cycles to time. The shortest prime-target ISI investigated was 20 milliseconds. However, an ISI of 20 milliseconds may correspond to an ISI in the model of 20, 100 or 500 cycles. Indeed, one cannot rule out the possibility that cycles reflects a logarithmic-based measure of time.

Experiment 8 used a similar design to investigate a more fundamental observation from the Burton *et al.* model; that self priming is a necessary concomitant of semantic priming, and that self priming should be evident at shorter prime presentation times than semantic priming. Self and semantic priming were investigated across four SOAs (25, 50, 100, 250 milliseconds) with no prime-target ISI. At the shortest prime presentation time (25 milliseconds), semantic priming was found to produce the same amount of facilitation as self priming. This finding is clearly inconsistent with the Burton *et al.* model as it predicts that self priming should exceed semantic priming for all SOAs with no prime-target ISI. It may be worthwhile to examine this effect more closely. One possible line of investigation would be to examine self and semantic priming with primes presented below the subjects' recognition thresholds. It might also prove interesting to compare the amount of facilitation observed from same and associated primes in prosopagnosic subjects. Both of these designs exclude the possibility of the subject(s) using conscious strategies, therefore the results should reflect automatic processing alone.

Significant inhibition was found in all but the 25 millisecond SOA condition in the subjects analysis and all but the 25 and 50 milliseconds SOA conditionds in the items analysis. In Posner and Snyder's terms, this would indicate that subjects were adopting response strategies in all but the 25 and possibly 50 millisecond SOA conditions. It seems surprising that a subject can adopt a response strategy in the space of 50, or even 100 milliseconds. Nevertheless, some explanation of the significant inhibition is required.

8.5 Facilitation and inhibition

Posner and Snyder (1975b) argue that significant inhibition is an indicator of subjects' use of conscious strategies. They suggest that semantically related items in memory are connected by excitatory pathways; e.g. DOG is connected to CAT by an excitatory pathway. However, they also suggest that no inhibitory pathways exist between words that are unrelated. Hence, inhibition cannot be viewed as a component of automatic activation and therefore it must be seen as a conscious strategy. In Burton *et* *al.*'s model however, direct connections between within pool items are inhibitory. Excitatory connections between related PINs that account for semantic priming are indirect, via the SIUs. Thus Charles' PIN is connected to Diana's PIN by an inhibitory connection (-0.1) but he is also connected to her by excitatory connections (+1.0), albeit indirectly via the SIUs. Further, Charles' PIN is connected to all other unrelated PINs (e.g. Eric Morecambe) by inhibitory connections (-0.1) only. Hence, whereas in Posner and Snyder's account of spreading semantic activation inhibition cannot be attributed to automatic effects, because there are no inhibitory connections, in Burton *et al.*'s model the picture is less clear cut. In Burton *et al.*'s model we should be less confident at attributing inhibitory effects to conscious strategies alone, because by introducing inhibitory connections, the interpretation of inhibition must be re-assessed. Figure 8.1 shows the activation of Prince Charles' PIN resulting from an input to his FRU preceded by one of two prime type simulations (i) Neutral prime: no input, but the system is left to cycle for 80 cycles, and (ii) Unrelated prime: input to Eric Morecambe's FRU for 80 cycles.

From Figure 8.1 it is clear that the activation of Charles' PIN is slower when it is preceded by an input to an unrelated FRU, Eric Morecambe. Therefore, Burton *et al.*'s model predicts that some cost may be associated with unrelated primes. Further, the amount of inhibition that a PIN_a exerts on a PIN_b is determined by the activation of PIN_a: the greater the activation of PIN_a the more it inhibits PIN_b; the "rich get richer effect" Grossberg (1976) (see Chapter 2). Further, two factors might increase the activation of a PIN, the number of cycles an input to an FRU (or NIU) is run, and the strength of the connection between the FRU (or NIU) and its corresponding PIN. Both of these factors were manipulated in Experiments 7 and 8. Prime presentation times and prime-target ISI may have influenced the level of activation while repetition of stimuli would have ensured that the connection strengths between the FRUs and PINs were highly strengthened. In other words, the Burton *et al.* model can offer an account of the presence of inhibition at SOAs that one would expect too short for subjects to employ strategies. This seems attractive as it is difficult to envisage how subjects can evoke conscious strategies when the prime-target SOA is 50 or even 100 milliseconds (Experiment 8).

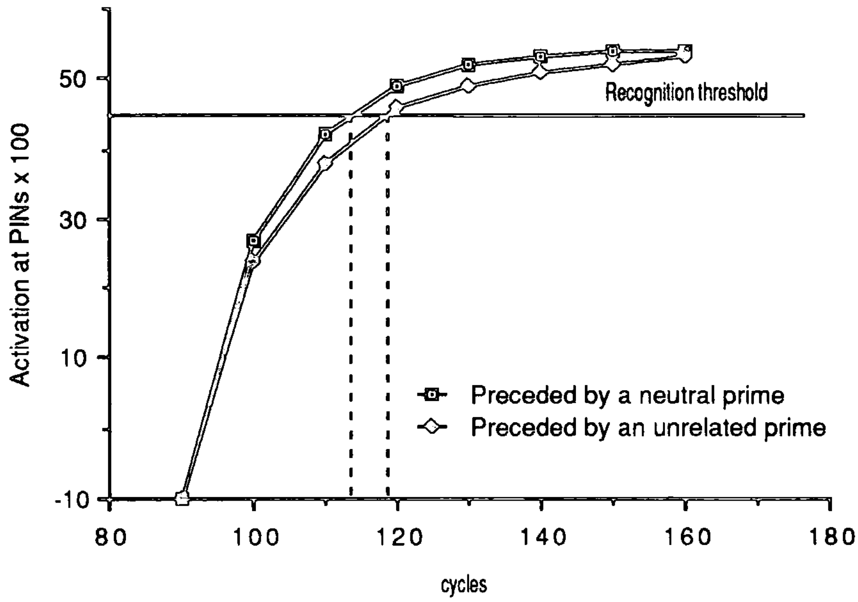

Figure 8.1: A simulation of a familiar target presentation preceded by a neutral prime or an unrelated prime. The distance between the two dotted lines represents the difference in cycles for a target preceded by a neutral prime and a target preceded by an unrelated prime to cross recognition threshold.

8.5.1 Inhibition and name prime stimuli

Where inhibition was found in Experiments 3, 4, 5 and 6, the inhibition seemed to be restricted to name prime stimuli; a similar observation has been reported by Bruce and Valentine (1986). In Experiments 3 - 6 , the prime target SOA was 500 milliseconds, and this may have been a sufficient time for the subjects to employ strategies. However, it is not entirely clear why inhibition should be restricted to the name prime stimuli. Experiment 1 found a significant main effect of prime domain; targets preceded by printed name prime stimuli were responded to faster overall than targets preceded by face prime stimuli. In Experiment 2 the printed name prime stimuli were replaced with handwritten name primes, and the main effect of domain was lost. On the basis of this result, it was argued that the main effect of prime domain found in Experiment 1 might be attributed the possibility that printed name primes require less processing effort, or attentional capacity than face primes. Therefore, in the former case it is easier for the subject to switch their attention to the processing of the target. Indeed, one cannot rule out the possibility that the subjects are processing the prime and target as a compound cue (Ratcliff and McKoon, 1988). It may then follow that Experiments 4, 5 and 6 may have shown inhibition from the name primes only, because the name primes require less processing effort and therefore more attentional capacity was available to devote to conscious strategies. However, this does not explain why inhibition was not found in Experiment 1, where the subjects were obviously processing the name primes with ease.

Explanations of inhibition in experiments of this sort obviously present problems for interpretation. What seems clear, however, is that all of the inhibitory effects found in the Experiments reported in this thesis cannot be accounted for in terms of the Burton *et al.* model alone. Priming is undoubtedly a multi-faceted phenomenon, that reflects a number of cognitive components; e.g. automatic memory activation, early perceptual processing and strategic processing. The Burton *et al.* model reflects only one of these aspects, the automatic component. Therefore, in some cases it is necessary to evoke other non-automatic explanations to account for inhibition effects. Experiments 7 and 8 in particular seem to require such explanations. Further, in Experiments 7 and 8 the same stimulus set of the faces and names of 16 persons was repeated a number of times. It might be argued that conscious strategies can be become more fluent with repetition of the same stimuli and that conscious strategies are more likely to arise using designs of this form. Experiments 7 and 8 also highlight the problem of matching the model's simulation of time, cycles, to real time. Undoubtedly such detailed investigations of the time courses of self and semantic priming require cautious interpretation as it is difficult to determine the relationship between cycles and milliseconds.

8.6 Applications of self priming

One application of self priming has already been discussed; as an indirect test of face recognition in brain injured people who demonstrate face recognition impairments. However, there are a number of other topics that might benefit from this paradigm. Self priming produces an indirect test of processing and recognition of the prime. In

Experiments 3, 4 and 6 the same prime condition did not involve an exact repetition of the same stimulus item as prime and target. For the name/name design, the primes were written in lower-case letters and the targets in upper-case letters, and in the face/face design the prime and target were different views of the same faces. Given that the same prime condition did not constitute the repetition of the same item, it might be interesting to explore this aspect further, and determine whether a graded self priming effect is found when the degree of similarity between the prime and target stimulus is varied for a within-domain face/face design. Roberts and Bruce (1989) investigated repetition priming in a serial choice reaction time task. Subjects were presented with a number of faces and asked to make a familiarity response to each one. Contrary to earlier findings (Bruce, 1986) they found that a familiarity response to a face was speeded by the same amount when the face was preceded by an identical or a different view of the same face. Further, they found more fluent recognition of a face when it was preceded by a face of the same view, regardless of its identity. It might prove interesting to investigate these same results in a design in which the subjects are not required to respond to the prime. Roberts and Bruce's results also beg the question as to whether the similarity in angle of pose, sex or expression etc. between a unfamiliar neutral prime face and a target face might affect the speed of a familiarity decision response to the target face.

In Experiments 9 - 11 a further application of self priming was identified; an indirect test of distinctiveness effects.

8.7 Self priming with distinctive and caricatured face primes

Experiments 1 - 7 established that self and semantic priming are found for designs with and without stimulus repeats. Having established the existence and nature of self priming, the paradigm was applied to an investigation of distinctiveness effects in face recognition. Experiment 9 found that distinctive face primes produce more self priming than typical face primes, while Experiment 11 showed that caricatured face primes produce more self priming than anticaricatured or veridical face primes. These results were discussed in terms of the Burton et al. IAC model and Valentine's exemplar-based coding model of face recognition (1991a; Valentine and Endo, 1992; Valentine and Ferrara, 1991) .

Following Nosofsky (1986), Valentine (1991a) argued that in order to apply the exemplar-based coding model to face recognition, one must assume that a familiarity decision constitutes the retrieval of an identity-specific label. Given the architecture of Valentine, Bredart, Lawson and Ward's model of face, name and word retrieval, Valentine (1991a) suggests that 'label retrieval' constitutes the retrieval of identity-specific semantic information from the PINs. Consequently, he argues that the face familiarity decision denotes the identification of a face rather its recognition.

There are direct parallels to be drawn between Valentine's conception of a familiarity decision in terms of his exemplar-based coding model and Burton *et al.*'s conception of a familiarity decision in terms of the IAC model. In both, the recovery of an identity-specific label is central to making a positive familiarity decision. However, in the case of the Burton *et al.* model the identity-specific labels (PINs) contain no other semantic information. Hence, while in the Valentine *et al.* (1991) model the recovery of an identity-specific label (identification) is contingent with the ability to recover semantic information, in the Burton *et al.* model it is not.

Burton *et al.*'s explanation seems more desirable for at least one reason. De Haan, Young and Newcombe (1991) have recently reported a patient, ME, who performs normally on tests of face recognition, i.e. she is able to indicate whether faces are familiar or unfamiliar. Further, her response times to execute this task are comparable with controls of her own age. ME is also able to match pictures of faces with their corresponding names. Yet despite her apparently normal performance on these task she is very poor at retrieving semantic information about the same faces. These results seem more consistent with Burton *et al.*'s interpretation of the processes underlying the face familiarity decision than Valentine's (1991a). However, a hybrid of Valentine's exemplar-based coding model and Burton *et al.*'s IAC model could produce a more complete picture of the processes underlying face recognition than either do alone.

In addition to the observation that a familiarity decision to a face involves the recovery of an identity-specific label, the structure of the IAC model and the results of this thesis support the hypothesis that the presentation of a face alone leads to the retrieval of the same identity-specific label. The verification that self priming exists indicates that the process of label retrieval is, in Fodor's (1983) terms, mandatory and unstoppable. If label retrieval required conscious effort, then 'automatic' self priming and semantic priming should not be observed. Further, the observation that distinctive and caricatured face primes produce more self priming fits well with both Valentine's exemplar-based model (1991a; 1992; Valentine and Ferrara, 1991) and Burton *et al.*'s IAC model. However, problems were encountered trying to model an effect of caricature with the Burton et al. implementation. Both models suggest that distinctive faces are recognised faster than typical faces, because in both models distinctive faces access their identity-specific labels faster than typical faces. In terms of the Burton *et al.* model, distinctive faces produce both faster and greater activation if their corresponding PIN. Both of these factors may contribute to the fact that distinctive faces prime their corresponding names more than typical faces in a self priming task. In terms of Valentine's exemplar-based coding model distinctive faces are stored in areas of lower exemplar density than typical face areas, and consequently are accessed more easily.

The results of Experiment 11 showed that caricatures produce more self priming than veridical or anticaricatured representations of faces. As an explanation of this effect, caricatures are envisaged as super-vector exemplars of their memory representations. Consequently, they are able to access their representation in multidimensional space and retrieve their label faster than veridical or anticaricatures of the same faces.

The results of the Experiments in this thesis have, for the main part, supported the predictions of the model developed by Burton, Bruce and Johnston (1990). Parallels have been made with Valentine's (1991a; 1991b; 1992; Valentine and Ferrara, 1991) exemplar-based coding account of distinctiveness effects in face recognition. It is suggested that both accounts together, present a more workable account of face recognition and distinctiveness effects than either do alone.

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Appendices

Appendix 1: The 8 related pairs used in Experiments 1 and 2

Prince Charles	Princess Diana
Queen Elizabeth	Prince Philip
Princess Anne	Mark Phillips
Prince Andrew	Sarah Ferguson
Victoria Wood	Julie Walters
Ronnie Corbett	Ronnie Barker
Bobby Ball	Tommy Cannon
Eric Morecambe	Ernie Wise

Appendix 2: The arrangement of the 40 related pairs used in Experiments 3 and 4

Group A	Group B	Group C	Group D
Prince Charles	Margaret Thatcher	Jerry Hall	Gareth Hale
John Travolta	Griff Rhys-Jones	Ronnie Corbett	Christopher Lee
Neil Kinnock	Dudley Moore	Paul Simon	Elizabeth Taylor
Bob Geldof	Nancy Reagan	Julie Walters	Mikhail Gorbachev
Queen Elizabeth	Kylie Minogue	Princess Anne	Terry Scott
John Lennon	Prince Andrew	Bob Mortimer	Stan Laurel
Billy Connolly	Wallis Simpson	Tim Rice	Bobby Ball
Eric Morecambe	Dawn French	Sebastian Coe	Jayne Torvill
Eddie Large	Bill Beaumont	Stephen Fry	Eric Sykes
Maggie Philbin	Barbara Bush	Norman Pace	Ian St. John

Group E	Group F	Group G	Group H
Oliver Hardy	Olivia Newton-John	Vic Reeves	Steve Ovett
Christopher Dean	Raisa Gorbachev	Art Garfunkel	June Whitefield
Paula Yates	Pamela Stephenson	Keith Chegwin	Peter Cushing
Glenys Kinnock	Mel Smith	Mark Phillips	Richard Briers
Prince Philip	Ian Botham	Jason Donovan	Felicity Kendal
Paul McCartney	Dennis Thatcher	Sarah Ferguson	Ronnie Barker
Hugh Lawrie	Jimmy Greaves	Ronald Reagan	Jennifer Saunders
Princess Diana	Edward VIII	Victoria Wood	Mick Jagger
Sid Little	Hattie Jacques	Tommy Cannon	Ernie Wise
Richard Burton	Andrew Lloyd-Webber	Peter Cook	George Bush

Appendix 3: The arrangement of the 20 related pairs used in Experiments 4 and 5. The related associates of members of group A were in group B, and similarly the related associates of members of group C were in group D.

Group A	Group B	Group C	Group D
Princess Anne	Mark Phillips	Nancy Reagan	Ronald Reagan
John Travolta	Olivia Newton-John	Ronnie Corbett	Ronnie Barker
Neil Kinnock	Glenys Kinnock	Stephen Fry	Hugh Lawrie
Jayne Torvill	Chris Dean	Griff Rhys-Jones	Mel Smith
Queen Elizabeth	Prince Philip	Prince Charles	Princess Diana
Stan Laurel	Oliver Hardy	Kylie Minogue	Jason Donovan
Prince Andrew	Sarah Ferguson	Mikhail Gorbachev	Raisa Gorbachev
Eric Morecambe	Ernie Wise	Bobby Ball	Tommy Cannon
Eddie Large	Sid Little	Margaret Thatcher	Dennis Thatcher
Paul Simon	Art Garfunkel	Dawn French	Jennifer Saunders

Appendix 4: The 8 related pairs used in Experiments 7 and 8

Prince Charles	Princess Diana
Queen Elizabeth	Prince Philip
Margaret Thatcher	Dennis Thatcher
Ronald Reagan	Nancy Reagan
Stephen Fry	Hugh Lawrie
Mel Smith	Griff Rhys-Jones
Neil Kinnock	Glenys Kinnock
Eric Morecambe	Ernie Wise

Appendix 5: The names of the 12 distinctive and 12 typical faces used in Experiment 9

Distinctive faces	Dist.	Fam	Typical faces	Dist	Fam
Kenneth Williams	6.4	6.3	Jason Donovan	1.8	6.7
Ken Dodd	6.0	5.6	David Steel	1.8	5.0
Rowan Atkinson	5.8	6.8	Phillip Schofield	2.0	6.3
Les Dawson	5.7	6.1	Mel Gibson	2.2	5.1
Boy George	5.4	6.4	Michael Aspel	2.2	5.8
Bruce Forsyth	5.3	6.8	Emlyn Hughes	2.2	5.1
Mikhael Gorbachev	5.1	6.9	Roger Moore	2.3	5.1
Rod Stewart	5.1	5.9	Boris Becker	2.5	6.3
Telly Savalas	6.2	4.1	Hugh Lawrie	2.9	6.1
Patrick Moore	5.0	5.9	Terry Wogan	2.6	7.0
Mick Jagger	4.8	6.1	Tom Cruise	2.6	6.0
Ronald Reagan	4.6	6.7	Jonathon Ross	2.6	6.8
Mean	**5.5**	**6.1**	**Mean**	**2.3**	**6.0**

Appendix 6: The 10 faces caricatured at five levels of caricature (-50%, -25%, 0%, +25% +50%) in Experiments 10 and 11.

Caricatured faces

Anneka Rice
Margaret Thatcher
Cyril Smith
Bob Monkhouse
Harold MacMillan
John Cleese
George Cole
Stephen Fry
Jonathon Ross
Ken Dodd

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