Attention and Automaticity in Social Judgments from Facial Appearance: Cognitive and Neural Mechanisms

Ramsey M Raafat

Experimental Psychology
UCL Division of Psychology and Language Sciences / Faculty of Brain Sciences
Supervisors: Nick Chater and Chris Frith

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Abstract

Recent evidence from behavioural and cognitive-neuroscience experiments has already yielded exciting discoveries into how we might code, process and perform judgments of facial social stimuli (indeed research into the latter provides a good vehicle for examining vision and object recognition in general). Nevertheless, the evidence regarding the role of top down control in face processing and the significance of the role of attentional capacity limits is contradictory or indeed absent in certain facial social trait judgments such as trustworthiness.

In this thesis, I seek to present a portrayal of these roles, directed by load theory. Load theory suggests that perception has limited capacity but proceeds automatically on all stimuli until capacity is exhausted. Whether this process applies to arguably exceptional stimulus classes such as faces is contentious. Moreover, how this is related to social facial judgments such as trustworthiness, as compared to other evaluations such as threat and dominance judgments is unknown, as up until now, research on face-attention interactions has focused on directing visuospatial attention to emotional visual information rather than to facial trait judgments such as trustworthiness. In spite of this, the theory's predictions are clear; increasing the perceptual load of a task should consume capacity, thereby reducing processing of stimuli external to that task.

Here I show that these predictions hold only for certain types of facial image evaluations but not for others. In a series of experiments that applied load theory, employing a combined visual search and face judgment task (where the level of attentional load in the search task was manipulated by varying the search set size of similar non-target letters), I find that under high perceptual load, observers become moderately less able to classify certain facial targets e.g. trustworthy ones as compared to dominant ones, even when these stimuli are fully expected and serve as targets. I also show the robustness of perceptual load effects by countering possible confounds and alternative explanations. Potential order effects are countered by reversing the order of the experiment, indicating that a possible attenuated short term memory imprint for the facial stimuli does not change the pattern of results previously experimentally demonstrated. Additionally, I find that high working memory load does not reduce social judgment evaluations under load, suggesting that perceptual biases during competitive interactions in visual processing are causative of the earlier demonstrated load effects. Following on from the modest but resilient results for trustworthiness modulation experimentally demonstrated here, the issue of bias for trustworthiness judgments is addressed in a signal detection paradigm (allowing bias to be discounted as a likely explanation of load effects).

In the wake of the relatively robust results for trustworthiness perceptual load modulation, a new avenue for trustworthy judgments under attention is explored, investigating the possible role of dopamine in such evaluations in a clinical cohort of Parkinson's disease (PD) patients (as contrasted to age matched controls). PD has been linked with facial expression judgment impairment, although, this impairment could be subordinate to other cognitive processes enmeshed in facial evaluation, such as selective attention. Our results once again point to a pervasive role for perceptual load modulation of facial judgments, rather than a specific attentional deficit of PD.

Finally, I explore the neurobiological correlates associated with facial social evaluations under perceptual load. In a neuroimaging study, I show neural responses to trustworthy facial images interact with attentional demands, demonstrating reduced activity under high perceptual load. I found high load only affects the facial components of trustworthiness (as compared to neutral faces) in cortical areas involved in social and facial processing (but not the facial signal components of untrustworthiness as compared to their neutral counterparts). The effects of load being specific to the trustworthy aspects of faces coheres with earlier presented behavioural results. As a final point, the demonstrated findings of negative-linear effects in the amygdala are consistent with prior research underlining the role of the amygdala in facial trustworthy judgments.

This research presented here, although subtle in some experiments, provides convergent evidence that top-down cognitive and neural mechanisms are involved in influencing the degree to which facial visual judgments are processed. The results demonstrate the role of attentional modulation in facial social judgments and illuminate a possible role of perceptual load and attention in the facial automaticity debate. Both the type of facial judgment and category of facial valence are factors which determine the efficacy of perceptual load effects in facial evaluations.

I, Ramsey M Raafat, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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There's no art
To find the mind's construction in the face.

- *William Shakespeare, Macbeth*
(Duncan, King of Scotland, act I, scene iv)

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1 General Introduction

"… in an information-rich world, the wealth of information means a dearth of something else: a scarcity of whatever it is that information consumes. What information consumes is rather obvious: it consumes the attention of its recipients. Hence a wealth of information creates a poverty of attention and a need to allocate that attention efficiently among the overabundance of information sources that might consume it" (Simon, 1971) pp. 40–41.

Overview

This Chapter provides an overview of the literature investigating face processing of both trait and emotional judgments, their interrelationships and their attentional modulations (contrasted with automaticity in processing) both at a behavioural and neural level. As this endeavour necessarily draws on multiple elements this review is somewhat extensive. Drawing on this background however will illuminate how perceptual load theory (Lavie, 1995) offers an attractive framework to explore the attention/automaticity debate (possibly its resolution) and extend both the debate and perceptual loads' reach into now frontiers with facial social judgments such as those of trustworthiness.

In the first part of this chapter (1.1), I will briefly review the significance of faces and face processing before moving onto a discussion of some of the limits in facial social judgment (1.2). I will review studies that have investigated the relationship between attention and face processing, situated within the attention and automaticity debate. To focus the review, this problem is considered mostly from a cognitive neuroscience perspective, underlined by experimental paradigms that have investigated this issue by manipulating attention during the processing of face objects.

In the last few decades, the field of cognitive neuroscience has witnessed an exponential increase in the research on the effects of emotion, faces and attention and is therefore explored in its own section (1.3). In the first part of this neurological basis section, I look at attractiveness studies as a starting point to consider the interrelationship of social facial trait judgments and emotional expressions (1.3.1). I then look at complementary evidence from neuropsychological studies (1.3.2), before regarding the role of attention in stimuli of social significance (such as whether famous faces are exempt from attentional load) and the neural evidence for load (1.3.3) - the load effects on perception described so far are supported by load modulations of neural processing in sensory and visual cortex, alongside other top-down attentional modulators such as anxiety (1.3.4).

The review will focus predominantly on recent findings that have studied how attention modulates face processing, while also introducing the facial trait judgment literature (typically studied separately from attention research) which generally focuses on attractiveness and more recently trustworthiness evaluations (although the latter being untested under any form of attentional modulation as this thesis seeks to do). I will review evidence both for and against the claim that facial processing is independent of attention. Research in this area is quite wide-ranging, but the idea of 'automaticity' is important, not only for understanding the notion of capacity limits in processing, but also for comprehending face processing mechanisms and how possibly more complex social judgments, ranging from trustworthiness to dominance evaluations are performed. The final part of this section (1.3.5) will then seek to draw together the research on the salience of emotional faces, facial trait perception and attention, suggesting that utilizing perceptual load theory (where having a standardized attentional task rather than changing its focus or orientation) and employing a standardized social judgment face space could aid in addressing some of the inconsistencies identified hitherto in this review, providing the motivation for the research presented in this thesis.

I conclude (1.4) by emphasizing that perceptual load theory manipulations provide an avenue for examining the automaticity of facial processing. If facial processing remains unaffected by the level of perceptual load in an ongoing task, this might suggest that the stimulus can be processed 'automatically', regardless of the amount of capacity available (as a core feature of automaticity is the independence of processing from influences that can affect attention, such as perceptual load). It is unclear how these notions tie to the automatic processing of famous faces and whether their resistance to attentional modulation relates to for example their high level of familiarity or simply reflects prioritized processing of faces in general.

The Chapter ends with the thesis overview (1.5) and how the questions raised in the review are to be investigated. Arguably, when one considers the bulk of the evidence, emotional processing may be considered to be capacity-limited, however the evidence has been inconsistent for potentially special items such as faces. Furthermore, up until now, research on face-attention interactions has focused on directing visuospatial attention to emotional visual information rather than to facial trait judgments such as trustworthiness. The studies in this thesis will seek to gain a greater understanding of the limits of face processing, facial social judgment and attentional capacities themselves and to explore whether attentional constraints may reduce the early resources available to process additional information, for previously unstudied social facial trait judgments such as trustworthiness and dominance.

A large percentage of the orchestra of society functions though individuals making local, rapid, seemingly automatic social judgments of those they encounter, based on the information of perhaps the principle and most paramount of social displays, the human face. Consequential social judgments such as trustworthiness depend on the micro aspects of this potent cue, with the aftereffects of their assessment rippling through into our relationships, social interactions and perceptions of others. In today's hyper-connected society, understanding and unravelling the mechanisms and modulators underlying such facial social judgments is an important goal on the path to deciphering the invisible internet that binds us all.

Advancing this goal will require the intertwining of concepts from across multiple levels of explanation to determine how we evaluate and process facial information. This endeavour should be pursued not only in general environments, but also under the cognitive constraints that we often find ourselves under; frequently a hasty glance is all we have to make a judgment of others. Deep questions can arise regarding how this facial glimpse is processed, ranging from ascertaining how certain faces manage to transmit trust, how faces may be construed as dominant, to how stable these evaluations are in a busy visual environment and whether they are thus contingent on processing resources such as attention.

This Chapter provides an overview of the literature investigating face processing of both trait and emotional judgments and the role of attention in modulating facial evaluations, contrasted with automaticity in processing, both at a behavioural and neural level. As this endeavour necessarily draws on multiple areas this review is somewhat extensive. There has been a wealth of methods and techniques used to investigate attention and automaticity in facial processing, yielding a myriad of conclusions and debate based on that research. However, as a preview of what’s ahead, this Chapter will draw on the prior research literature, addressing some of the inconsistencies within it and ultimately focus on perceptual load theory (Lavie, 1995) as an attractive framework that may help clarify the role of attention in face perception, thus providing the motivation for the research presented in this thesis. Moreover, as we shall see, earlier work has concentrated on the importance of emotional facial signals in capturing attention, rather than facial trait judgments such as those of trustworthiness. Examining such judgments offers the possibility of extending the attention and automaticity debate (and perceptual load theory’s reach) into new unstudied frontiers.

One of the primary currencies in cognitive function especially for perceptual judgments, particularly in the internet attention economy era, is the currency of attention (Davenport & Beck, 2001). The faculty of attentional selection generally plays a critical role in perception (Huang, Treisman, & Pashler, 2007). Powerful illustrations of this critical role are provided by studies of the so called “change blindness” paradigm (Rensink, O'Regan, & Clark, 2000), the phenomenon that occurs when a change in a visual stimulus goes unnoticed by the observer. Rensink and colleagues, have demonstrated that only a small number of objects from a natural scene can be monitored for detecting adjustments within it; this resource constraint can lead to some oft surprising effects of “blindness” to quite large visual scene changes (a common method of testing is the flicker paradigm, where an image is altered during a “flicker" sequence which may distract the perceiver's attention (Rensink, O'Regan, & Clark, 1997)). The latter phenomenon illustrates how attentional selection can be an important component to resolve which elements of our complicated and busy visual environment are engaged within a specific eye fixation. Ensuing cognitive processes such as trait judgments may then be informed and influenced by this selection.

How this attentional selection operates in the social sphere however is controversial. Although there is evidence that the processing of both facial and emotional stimuli is fast (Bar, 2001), it is not certain whether attentional selection is required for the processing of facial social judgment stimuli or proceeds automatically. The property of automaticity is often claimed to be imperative for the processing of facial displays, both to rapidly process emotional behaviours during social exchanges and also to rapidly detect and respond to certain significant circumstances such as threat situations (Ekman, 1992). Nevertheless, how diverse facial social judgments ranging from the hierarchical power/dominance dimension to the crucial factor of approach/avoidance trustworthiness, interact with these displays especially under attentional constraints, is still debated. Exploring this domain is complicated, if not only because it draws on disparate and often separate areas of investigation; namely facial processing, attention and social judgments research. Examining them holistically (which is what this thesis seeks to do), thus requires one to draw on interdisciplinary research.

Overall, evidence for the role of modulators, such as attention, on facial stimuli processing and consequent social judgments is complicated and contradictory. Although by considering processes such as perceptual or attentional load (Lavie, 1995; Pessoa, Kastner, & Ungerleider, 2003; Pessoa & Ungerleider, 2003; Roper, Cosman, & Vecera, 2013), we may gain illumination and insight into the complicated and intricate mechanics of facial social judgments. The evidence regarding the role of top-down control in face processing and the significance of attentional capacity limits is contradictory or indeed absent in certain facial social judgments such as trustworthiness. This current state of affairs provides the motivation for the reported research. Perceptual load theory (Lavie, 1995) offers an attractive framework to ascertain the limits of attentional modulation on facial judgments processing, not only with regard to the theory itself and whether it permits exceptions to certain stimulus classes such as faces, but also as an avenue into the novel identification of the role of attention on the closely allied realm of social judgments such as trustworthiness.

To lay the foundations for the research ahead, a prerequisite is to explore some of the domains discussed above, highlighting those aspects which are relevant to this thesis.

In the next sections I briefly review some of the studies that prompted the questions addressed in this thesis. I begin appropriately enough with the facet that is instrumental for social judgments, and one which we are all intimately and personally acquainted with; the human face **(1.1)**. This is followed by a look at the role of limits and attention in facial processing and a description of load theory with an examination of the experimental evidence supporting load theory thus far **(1.2)**.

I then further delineate the extensive evidence the automaticity and attention debate has generated, supported with the neuropsychological and imaging literature and a range of criticisms of that evidence **(1.3)**. This is somewhat extensive, as it crosses both the attention and face processing literature, although hopefully at the end **(1.4)** a clearer portrayal of the field (and structure of this thesis **(1.5)**) will be in view.

1.1 Faces: The Social Gateway

“Who sees the human face correctly: the photographer, the mirror, or the painter?” mused Picasso, perhaps thinking of how attention, emotion, judgment and perception intertwine to interpret that ever present yet ever malleable canvas, the human face. The role of perception and attention in their cognitive dance, particularly in the social sphere is still an open question. Within this sphere, an essential constituent, frequently signalled by facial cues, is the appraisal of agents and their intentions. This facial appraisal and judgment is a pivotal aspect of understanding social situations. Research into social judgments (the judgments and perceptions in social contexts or of social stimuli and how we form impressions about them) has long been associated with psychology. Although there are numerous stimuli that support us in our judgments of other people, one stands out; the feature which arguably best distinguishes a person, the face. The facial canvas aids us in inferring information about structures (often termed personality) that drive behaviour; structures such as, mood, intelligence or trustworthiness.

The endeavour to relate an individual’s facial features to his or her personality attributes or character has most likely existed since time immemorial. In every ancient culture, one encounters beliefs that the face is a window to a person’s true nature and that there is some form of connection between facial appearance and personality. This idea has been taken up and discarded at various times in history, although arguably twentieth-century science attempted to rehabilitate it, beginning within the framework of personnel selection procedures by psychologists such as Hollingworth. Hollingworth and colleagues sought to examine the consensus in impressions from facial appearance by examining the reliability of photographic intelligence judgments (Hollingworth, 1922). Intriguingly, given the longstanding assumption that such attributions are considered to be erroneous by orthodox science, a meta-analysis of these early studies found an average, although weak correlation of .30 between personnel intelligence and the facial judgments of said personnel (indicating the possibility of a relationship (most likely a complex one) between them - (Zebrowitz, Hall, Murphy, & Rhodes, 2002)).

Following on from Hollingworth's early work, psychologists have sought to both extend and carry out more systematic research on the social perception of faces, exploring judgments ranging from sexual orientation (Rule, Ambady, dams Jr, & Macrae, 2008) to aggressiveness (Carré, McCormick, & Mondloch, 2009). The social facial judgment studies of aggression are particularly interesting, not only because they may be determined from faces at better than chance accuracy, but also because in this instance a putative biological mechanism underlying these evaluations can be hypothesized. As men's facial masculinity is a cue of present, past, and even prenatal testosterone levels, it can potentially also be used as a cue of other testosterone-related traits, such as male competitive responses (Pound, Penton-Voak, & Surridge, 2009).

Experimental psychologists have also sought to bring evolutionary and ecological theoretical perspectives to bear on a range of facial social evaluations; ranging from the evolutionary psychology of facial attractiveness (Rhodes, 2006) to how fear and anger co-evolved to mimic mature and babyish faces in order to enhance their communicative signal strength (Sacco & Hugenberg, 2009).

Overall, these recent studies have shown that there is surprisingly consensus in social facial judgments and that it is straightforward and undemanding to make evaluations based on facial appearance, confirming the role of the face as one of the most, if not the most, important source of social information in human interaction. Faces are multi-dimensional stimuli transmitting information ranging from identity to emotion, indeed evolutionarily important judgments such as physical attractiveness can occur in less than a second (Johnston & Oliver-Rodriguez, 1997). It has been speculated that this processing depends on the subtle interaction and feedback between physical markers on the face, conceivably fitness indicators (Miller, 2000) and putative fitness monitors (Johnston, 2000). It is not surprising then, that from very brief exposures, individuals construct (though perhaps dubious in their veracity) trait or social judgment inferences about others (Rule et al., 2010).

The fact that judgments such as attractiveness can be performed with such rapidity and ease suggest the importance of these evaluations, although this does not necessarily imply that all facial judgments are processed, or indeed treated equally (such as those independent of emotional cues). A point adequately illustrated by Bar and colleagues who had participants judge the level at which they perceived faces to belong to a threatening person (or an intelligent one in the second part of this experiment) (Bar, Neta, & Linz, 2006). The judgments were made on faces with a neutral expression. The "correctness" of first impressions on faces presented briefly was inferred from their consistency with judgments made when the same faces were presented for a considerably longer exposure to a different group of participants. The evaluations thus pertained to personality rather than to a certain temporary emotional state such as anger. Their findings demonstrated that survival related traits were judged more quickly; threat in faces was consistently detected at 39 ms and 1700 ms exposure times, in contrast judgments of intelligence were not consistent at such rapid speeds (Bar et al., 2006).

We have established that face perception is fundamental to human social interaction. Many different types of important information are seemingly visible in faces, although the processes and mechanisms involved in extracting this information are most likely to be complex and specialized. From the cognitive perspective, research into face perception can be construed as aiming to achieve two objectives, clarifying the different operations involved in face processing and how they interact with each other, and secondly, describing what kinds of facial cues are used to perform these operations. We shall discuss the second objective later in this thesis, although concerning the first aim, the literature heavily relies on the cognitive architecture proposed by Bruce and Young (Bruce & Young, 1986) or its subsequent iterations (e.g. Gobbini & Haxby, 2007) **-** see **Figure 1-1**. This model is largely modular, with independent streams of identity and expression processing.

Theories about the cognitive processes involved in adult face perception have principally come from two sources: research on normal adults and the study of those with neurological impairments in face perception such as prosopagnosia (Aviezer, Hassin, Perry, Dudarev, & Bentin, 2012; Humphreys, Avidan, & Behrmann, 2007). In spite of the wealth of background research in this areas, how the brain represents different aspects of faces nonetheless remains contentious (Rotshtein, Henson, Treves, Driver, & Dolan, 2005). Alongside the two-pathway inspired framework, there are of course other possible and prominent models of facial identity and expression recognition (e.g. (Calder & Young, 2005)). As a simplification, the facial processing debate has tended to focus on two perspectives, that is specialized modules (Kanwisher, McDermott, & Chun, 1997; Kanwisher & Yovel, 2006) versus the proposal that face perception is mediated by distributed processing (Ishai, 2008) – (this is notwithstanding the many other debates as to whether face processing is holistic or configural (Yovel & Kanwisher, 2008; Yovel et al., 2008), whether face recognition ability is dichotomous, normally distributed (Russell, Duchaine, & Nakayama, 2009) or indeed the capacity is heritable (Zhu et al., 2010)).

In general, the leading models of face processing have been agnostic on facial social judgments or trial perception, concentrating primarily on the demarcation between identity and non-identity related aspects of face perception. However, Haxby and Gobbini (2011) have indicated that they consider social trait judgments as being dependent on mechanisms involved in processing changeable facial aspects (implying that in **Figure 1-1** panel-**a**, either the cognitive module of "expression analysis" is responsible for judgments such as trustworthiness, or there would be some form of information flow (arrow) stemming from or parallel to it, to some form of putative "trait module"). Haxby and Gobbini's premise was grounded in Todorov and colleagues' emotion overgeneralisation hypothesis (Todorov, Baron, & Oosterhof, 2008a), discussed further in the following sections, which proposed that facial social judgments are triggered by subtle emotional cues perceived in faces by mechanisms typically responsible for facial expressions.

Moving beyond the cognitive models discussed above to the neuroanatomy of facial processing, imaging studies have demonstrated that emotional faces can modulate activity in extrastriate visual areas, amongst them, regions associated with face processing (Vuilleumier, Armony, Driver, & Dolan, 2001a) implying that the processing streams of identity and expression at least have an interaction at this point. While some researchers e.g. (Pourtois, Schwartz, Seghier, Lazeyras, & Vuilleumier, 2005) have demonstrated the effect of familiarity in facial processing regions such as the Fusiform areas by the modulation of neural signals, whether this is due to intrinsic visual computations or modulation from (extrastriate) areas involved in emotional processing (Vuilleumier, 2005) is currently undetermined.

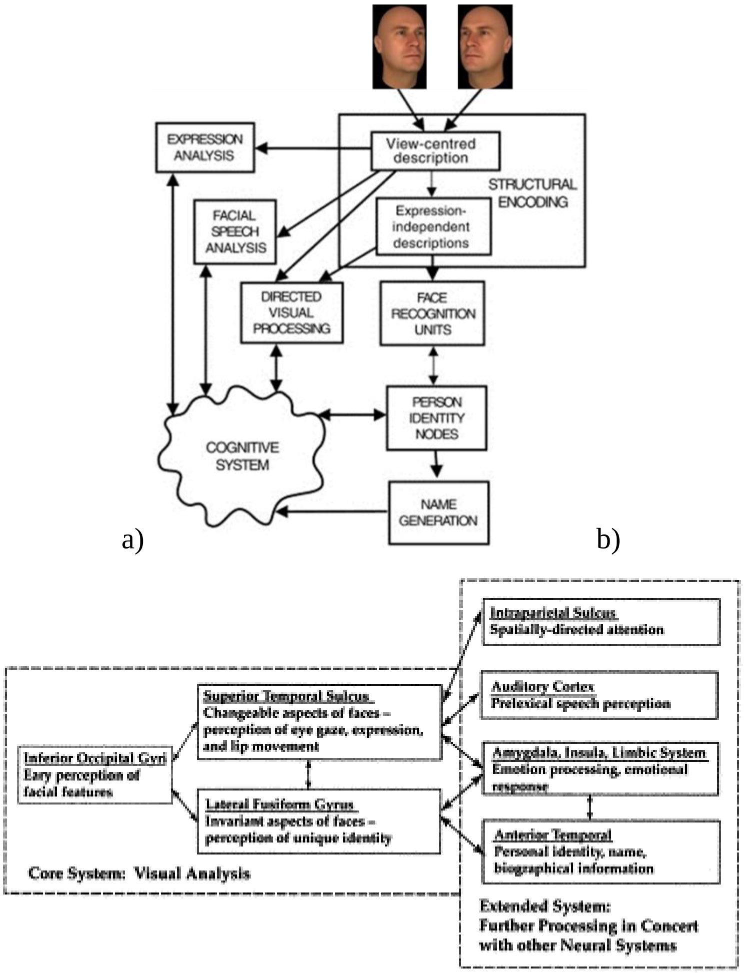


Figure 1-1 Influential face processing models of Bruce and Young (1986) and Gobbini and Haxby (2007) a) Bruce and Young's functional model of face processing includes separate parallel routes for recognizing facial identity, facial expression (and lip speech) - adapted from Bruce and Young (1986). The cognitive model highlights the sequential order of face processing operations for recognition and retrieval of person knowledge. The model suggests that visual recognition (which is mediated by face recognition units) precedes the access to person knowledge (mediated by personal identity nodes). Subsequent modified iterations of the Bruce and Young (1986) framework - b) propose a general model of the distributed neural systems for face perception that includes a core system for the analysis of the visual appearance of faces. This is coupled with an extended system involved in extracting the further information that a face can convey (Gobbini & Haxby, 2007).

Although, facial perception has well identified, neuroanatomical correlates in the brain, the field of social neuroscience research (Adolphs, 2003), has also spearheaded the probing of the neural correlates of social trait judgments from faces (e.g. (Todorov, Said, Oosterhof, & Engell, 2011)). (I will explore the neuroimaging literature relating to emotional and trait judgments in greater depth in section **1.3**).

A multiplicity of models and hypotheses have also been proposed that seek to explain our daily appraisals facial expressions, rather than the cognitive architecture underlying them. These models are often assembled themselves from other models; e.g. the overgeneralization hypotheses, derived from the ecological theory of social perception, combines the "wisdom of the good genes" and the "perceptual by-products" hypotheses to provide an explanation for the traits attributed to faces that vary in attractiveness as well as other qualities (Montepare & Dobish, 2003). In the latter model for example, traits that may be truthfully revealed by face qualities such as emotion or age are mistakenly perceived in people who simply bear a resemblance to one of those categories. Whether, there is indeed some form of overgeneralisation in facial social judgments or some propensity to automatically characterize facial traits is not resolved (although I shall discuss this further in the following section (**1.2**)). However, examining modulators of facial social judgment (such as attention) may be helpful in indicating how robust these trait categories are and potentially shed light on facial social judgment processing.

Simply drawing on our own experience, it is clear that facial appearance plays a profound and versatile role in our social communication; arguably a substantial part of our lives is conducted responding to people on the basis of information conveyed by their facial appearance and our personal interpretation of it. This influence of faces is shown in our judgments of people as well as in our behaviour (Zebrowitz & Collins, 1997). Whether, or to what degree these judgments are accurate may well depend on the trait dimension (Hall, Andrzejewski, Murphy, Mast, & Feinstein, 2008), as both underweighting and overweighting occur (e.g. the magnitude of the correlations between perceived intelligence and attractiveness may be two to three times higher than the magnitude of the correlations between actual intelligence and attractiveness (Zebrowitz et al., 2002). However, people may be able to judge extroversion and conscientiousness accurately from the face at levels slightly above chance (Penton-Voak, Pound, Little, & Perrett, 2006).

The putative mechanisms through which positive (or negative) correlations between trait judgments from faces and personality characteristics develop is still debated, ranging from self-fulfilling processes (Zebrowitz, Andreoletti, Collins, Lee, & Blumenthal, 1998) to acquired cultural encoding of facial patterns (Scherer, Clark-Polner, & Mortillaro, 2011). However, irrespective of the mechanisms that enable facial judgments, it is indubitable that we perceive a face as a powerful salient social stimulus, having emotional and informative (trait) significance and which as a consequence may have special access to visual attention.

The highly sophisticated nature of face processing, indicates that perception of the facial object class is one of the most highly developed visual skills and one of the most important social proficiencies that we develop (Bruce et al., 1986). Yet in spite of our increasing knowledge, there are still many unresolved questions in this domain. For example, to what degree does this developed perceptual ability require attention for facial social judgments? Does this apply to all facial judgments, both trait and emotional evaluations? Furthermore, is the apparent rapidity in its processing of complex visual stimuli suggestive of automaticity in its functioning? These questions in some form have been widely debated in the research literature, although up until now, research on face–attention interactions has focused on directing visuospatial attention to emotional visual information such as angry faces rather than to facial trait judgments such as trustworthiness. Nevertheless, the link between faces, emotion and attention has been the target of a large conceptual and empirical literature and it is to that we now turn to seek to find answers to our questions.

1.2 Limits in Facial Social Judgment: Attention and Automaticity

Throughout the day we are bombarded by an overwhelming amount of perceptual information. In the context of information-processing, selecting some information over others enables us to concentrate on some feature of incoming stimuli which may vie for our limited processing resources. This process of selection, or attention is a crucial in making sense of the constant input from multiple sources that we continually receive. Although given the current state of knowledge it is perhaps challenging to satisfactorily define attention, I will adhere to Mesulams' (1999) definition that selective attention is a preferential allocation of limited processing resources to events, or task goals that have become behaviourally relevant (Mesulam, 1999).

In the previous section we discussed the processing of facial expressions, these constitute a class of visual stimuli of immense biological and social importance to us and thus we may expect them to be privileged over other stimulus categories in capturing visual attention, it this hypothesis that this section will investigate.

The study of attention has been of interest to the field of psychology since its earliest days, with multiple theoretical frameworks proposed to account for its workings (for a review of mainly British work on selective attention in the last century see the wonderful review (Driver, 2001)). Nevertheless, many important ideas about attention can be traced to philosophers in the 18th and 19th centuries (preceding the foundation of psychology as a separate discipline). For example, pioneering ruminations on the nature of attention are evident in the writings of the mid-eighteenth century German enlightenment philosopher Christian Wolff, where the need to ignore other sensory objects due to limited capacity was highlighted (Hatfield & Wright, 1998).

The important notion of limited capacity is often presented nowadays within the conceptual and metaphorical structure of a bottleneck. A substantive amount of research has gone into determining exactly where in the processing stream, such a bottleneck may occur. Early research was stimulated by the so called "Cocktail Party Effect", investigating how one can attend to a conversation with ambient noise, usually other boisterous speakers (Cherry, 1953). The fact that one can selectively attend to another calling your name from afar, amongst all the other sounds potentially clamouring for your attention, suggests that a large slice of information that we receive is processed automatically and unconsciously; although the nature and parameters of this slice is still an on-going debate (Bargh & Chartrand, 1999). This selective capacity is not just limited to the auditory domain, visual selection processes can parse visual stimuli based on properties ranging from their object features to their spatial ones (Vecera & Rizzo, 2003). This attentional process can come to the fore in social situations such as the cocktail party above. The selection of relevant information, such as facial expressions from the many simultaneous cues available during interpersonal interactions is crucial for mutual comprehension. Within these social situations, to detect important events, a hypotheses is that some perceptual processes must automatically analyse sensory inputs prior to full attention (Öhman, Lundqvist, & Esteves, 2001). Consequently automatic processing of emotionally and socially significant information may play a role in instigating or reallocating attention (Vuilleumier & Schwartz, 2001b). In fact the importance and readily apparent emotional/trait salience of faces, combined with the presence of brain regions which suggest neural specificity of processing, make faces an ideal candidate for pre-attentive or automatic processing (Öhman, 2002). A characteristic of automaticity is that it demands relatively few attentional resources, and hence is expected to encounter little disruption from competing stimuli or tasks that use those resources (Schneider & Chein, 2003).

It is challenging to place an absolute mark on the developmental trajectory of attention; however infants' attention becomes increasingly flexible and voluntary within their first few months. As demonstrated by Wentworth and colleagues, the infant is already future-oriented by this age. When 2- and 3-month-olds viewed a series of pictures that alternated in a left–right sequence, they quickly engaged in anticipatory looking, shifting their focus to the location of the next stimulus before it appeared (Wentworth & Haith, 1998). This ability to shift attention from one stimulus to another, thought to be related to development of structures in the cerebral cortex controlling eye movements, generally improves by 3 to 4 months of age (Posner & Rothbart, 2007). In contrast, developmentally, the ability to become aware of facial expressions appears at approximately seven months, of which notably the capacity to detect threat illustrates the importance of facial emotional and social recognition (Phelps, Ling, & Carrasco, 2006). As in the latter case of threat, a variety of studies have shown that certain facial expressions may be detected better or faster than neutral expressions. Furthermore, as I will discuss in this section, this finding is relatively robust when the faces are manipulated by attention in multiple ways ranging from visual search, covert orienting, to suppressed awareness of the critical face stimuli (effected by masking or binocular rivalry). This detection advantage is also supported by exogenous emotional cuing (when a face induces a rapid covert shift of attention to the cued location); target detection is more rapid when a threatening face is exchanged as opposed to a neutral one (Koster, Crombez, Van Damme, Verschuere, & De Houwer, 2005)(note if the face is inverted no such effect is demonstrated, indicating that the effect is not due to low level differences).

Attentional resources are especially at a premium in multi-agent complex social environments. In such environments, there are often too many items for the cognitive system to fully analyse at one time, a state of affairs exacerbated by processing capacity limitations. A significant function of attentional processes should then be to prioritize the processing of important stimuli, to direct more cognitive processing towards those aspects of the world that are more important than others (Compton, 2003), which may then lead to enhanced perceptual analysis, memory, and motor action. Of course a natural question is what determines what is important? If faces are considered highly important signalling mechanisms by the agent, then from this perspective, if there are capacity limitations, facial social judgment processing might be intimately linked to attentional mechanisms, especially those judgments requiring swift evaluation of their affective or trait meaning, not only for when they are relevant for behaviour, but also when they are task-irrelevant but potentially important (e.g. agent signals such as threat or trustworthiness). Research investigating facial attentional processes and their modulation, often looks at the impact of attention on the processing of fear, anger and disgust, contrasting it with the processing of other “fundamental” or universal expressions (Ekman, 1999), such as happiness, sadness and surprise. It is the judgment of these facial expressions, refracted through the prism of attention which I will delineate further in the following paragraphs.

Positive facial expressions (e.g. happy faces) also evidence a detection advantage (Brosch, Sander, Pourtois, & Scherer, 2008) even in infants (Brosch, Sander, & Scherer, 2007). In fact Hahn and Gronlund (Hahn & Gronlund, 2007), found shallower reaction time slopes for angry as opposed to happy face targets when participants had to search for any discrepant face among neutral items (although not using naturalistic stimuli). However, when there was a specific top-down goal for happy targets, the presence of angry distracters among neutral faces did not slow performance, suggesting that the involuntary attentional biases in search may depend on the combined influence of endogenous goals and stimulus characteristics. Whether this reveals anything specific to face processing is imprecise as many other classes of stimuli may have similar effects on attentional mechanisms, e.g., snakes, spiders, guns and syringes are also detected rapidly in visual search tasks relative to neutral or positive stimuli e.g. (Blanchette, 2006; Brosch & Sharma, 2005). Nevertheless, this rapidity in detection may indicate that the processing of facial expressions, like other types of certain salient stimuli is automatic, directing attention to the target and boosting the competitive saliency of a signal among distracters (Frischen, Eastwood, & Smilek, 2008).

With specific regard to faces, there has been a variety of methods to investigate automatic effects of facial expressions on behaviour, employing experiments where affective reactions can be evoked, even when the stimulus is processed minimally (Murphy & Zajonc, 1993). Techniques ranging from subliminal presentation after masking (Kiss & Eimer, 2008), binocular rivalry (Anderson, Siegel, & Barrett, 2011; Williams, Morris, McGlone, Abbott, & Mattingley, 2004; Ritchie, Bannerman, &

Sahraie, 2012), continuous flash suppression (Yang, Hong, & Blake, 2010) to visual adaption (where the appearance of faces can be strongly affected by the characteristics of faces viewed previously) (Moradi, Koch, & Shimojo, 2005).

These techniques and experiments provide some support to suggest that facial expression information is an attribute of faces that may recruit processes that are engaged automatically and independent of observers' attention. However, although these characteristics indicate a level of automaticity, there is a caveat in their interpretation as automatic, due to the polysemous nature of the term. It is possible that the conceptual division between automatic processes and attentional control is, like most dichotomized divisions a useful first approximation. A clarification of what is meant by automaticity is often required, with usage ranging from processing aspects of which we are not aware and are effortless, and hence difficult to alter or suppress, to information processing that is intentional, effortful, hence controlled and conscious (for an extensive review see (Moors & De Houwer, 2006)). Furthermore, this does not preclude a spectrum of processing, between fully conscious, voluntary processing and fully unconscious, automatic processing. Nevertheless, despite the semantic difficulties in automaticity, the claim that attentional processes evidence sensitivity to top-down control and resource limitations has less ambiguity (and it is this definition that this thesis favours). Illustrative of resource limitations is the simple observation that detection speed is dependent on the number of distracters in a search display (Öhman et al., 2001), while evidence of sensitivity to top-down control is provided by the fact that the affective characteristics of a face improve reaction time search performance (Hahn et al., 2007). The role of top-down control is underscored by research that shows that personality-related differences and clinical conditions, ranging from anxiety to depression (Ewbank et al., 2009) can modulate the type of information (positive or negative valence) that captures attention (Williams, Moss, Bradshaw, & Mattingley, 2005) indicating that the observer's state can modulate social facial judgment.

Although research into the attentional limits in facial social judgment has been complemented by studies at all levels of analysis, reaching from the electrophysiological up to the functional imaging level (Hopfinger, Luck, & Hillyard, 2004), as the prior paragraph intimated, within all these manipulations and levels of analysis, it is useful to remember the fundamental constraint which remains; as processing capacity is limited, selective attention to one element of the visual field should necessarily occur to the detriment of others. It is due to this finite capacity, that competition may be induced among visual items in order to settle on or select the most important information at any given time (Desimone & Duncan, 1995). This selection within a finite capacity formed a crucial part of the initial attention debate, contrasting early selection views, capacity limited perception proponents (Broadbent, 1958) and unlimited capacity, late selection perception advocates (Deutsch & Deutsch, 1963). In the middle of these standpoints, the perceptual load model of attention offered a way out (Lavie, 1995; Lavie & Tsal, 1994; Lavie, Hirst, de Fockert, & Viding, 2004), by a form of an amalgam of early and late selection views. The model suggested that the level of perceptual load required by a task determines whether early or late selection will occur. In this framework, perception has a limited capacity, in alignment with the early selection view, however, it proceeds automatically on all stimuli in alignment with late selection, whether relevant to the task at hand or not, until all capacity is expended. This model yields the early selection prediction that when the task processing requirements necessitate a high level of perceptual load that consumes all available attentional capacity, task-irrelevant stimuli will not be perceived. Conversely, when the task processing requirements necessitate a low level of perceptual load, any spare attentional capacity will discharge involuntarily, ensuing in the perception of irrelevant stimuli, as implied by the late selection prediction. While the latter describes the framework, operationally and experimentally, increased perceptual load generally denotes that either the number of different-identity items that need to be perceived is increased (this provides an early hint for the paradigm adopted in the majority of experiments in this thesis) or for the same number of items perceptual identification is more demanding on attention (Lavie, 1995). A précis of this model is in essence that the level of perceptual load can adjust the focus of selective attention to be more biased toward early selection (i.e., less interference from the ignored information) or toward late selection (i.e., more interference from the ignored information).

The predictions of perceptual load theory have been supported by diverse behavioural and neuroimaging studies (see the Perceptual Load section **2.2** in the following Chapter and (Lavie, 2010) for a more detailed review), over a varied range of stimuli distractor images, from locations to familiar objects. As an illustration of one of these studies carried out by Lavie et al (Lavie, Lin, Zokaei, & Thoma, 2009), subjects performed a letter-search task while attempting to ignore a wide range of meaningful but task-unrelated distractors e.g. an image of a spider or car, this attention task was then followed by a surprise memory-recognition task. The results of this study demonstrated that even when the distractor objects are presented directly where the subjects are looking, they can only recognize having previously seen these distractors when the task at exposure involved a low load. Moreover, recognition memory fell to chance levels in task conditions of high perceptual load. Additional studies employing irrelevant distractors have demonstrated the importance of lower perceptual load in eliciting response competition and negative priming effects on target reaction times, the effects of which are eliminated when the task imposes a high level of perceptual load, (that is with a search display of six items as opposed to two) (Lavie & Fox, 2000). These findings have been replicated in diverse ways e.g. with meaningful 3D objects as distractors (Lavie, Ro, & Russell, 2003) or with distractors presented directly at fixation (Beck & Lavie, 2005).

The research reviewed above provides support for the selection mechanism proposed by load theory, endorsing the view that the extent of distractor processing is indeed determined by the level of perceptual load in a task. The theory also proposes that high level cognitive control functions such as working memory sustain prioritisation (between relevant targets and irrelevant distractors) of current behavioural goals. Loading working memory should therefore diminish the cognitive system’s ability to exert such control, leading to increased (rather than decreased, as in perceptual load) interference from irrelevant distractors competing with targets for processing (see **Figure 1-2** for an application to facial stimuli). So far in the research that we have reviewed, the majority of perceptual load effects have been established using moderately neutral distractor stimuli. A hypothesis which is not clarified is whether the processing of social stimuli, indeed one of the most potent social stimuli, the face, is also influenced by load or whether its processing proceeds in an automatic fashion (there have been some inconclusive studies on perceptual load effects on (principally famous) faces, which we shall examine in the following section (**1.3.3**)).

The approach adopted in the research literature to regular, non-emotional stimuli, suggests that the automaticity of facial social processing can be tested by attentional manipulations if they fully consume available attentional resources. Accordingly, automaticity in processing emotional facial expressions might transpire only when the attentional system is not completely occupied by the main task, so that some attentional resources may be "spared" and "spill over" to emotion processing (Pessoa, McKenna, Gutierrez, & Ungerleider, 2002).

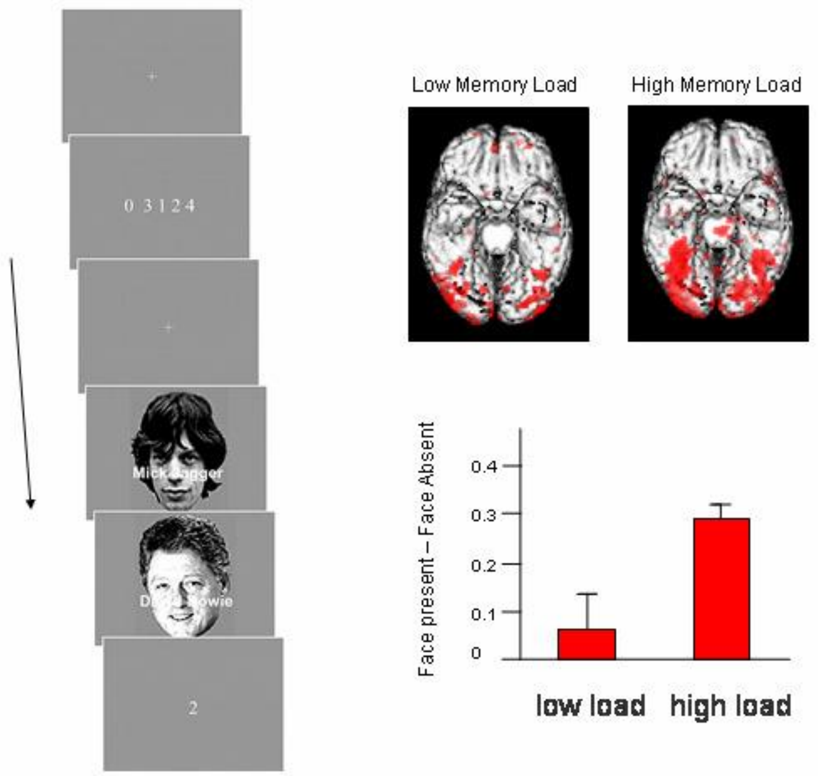


Figure 1-2 The effect of working memory load on face processing: neurobiological correlates
The trial structure is displayed left. At the onset of each trial, participants were presented with a set consisting of the digits 0 to 4 in either a fixed ascending order (i.e. '01234', low load) or a random order (as shown, high load). At the end of the trial a probe digit was presented, participants were required to report the digit that followed it in the original set (above the correct answer would be '4'). For the period of the retention interval participants carried out a Stroop-like task (MacLeod, 1991), classifying names as politicians or singers while attempting to ignore distracter faces that appeared on some trials and were either congruent or incongruent with the name. The results on the right indicate the discrepancy between the conditions for face present and face absent which is greater and the spatial extent of voxels where the difference reached statistical significance is larger under high than under low working memory load. This is suggestive of more processing of distracter faces when the availability of working memory to control attention was reduced. Adapted from (de Fockert, Rees, Frith, & Lavie, 2001).

There is a diverse neuroimaging literature delving into the issue of automaticity in facial processing (Vuilleumier et al., 2001a), which I will further pursue in the next section **1.3**, however, behavioural research indicates that emotional influences from both facial expressions and other stimulus materials may be reduced under conditions of higher attentional load (Okon-Singer, Tzelgov, & Henik, 2007; Erthal et al., 2005). The dependence of emotional perception on attention has also been observed in studies of object-based attention (Mitchell et al., 2007). These findings are informative about the cognitive processes that influence facial social processing and by extension any putative automaticity.

It is worth mentioning (although this thesis does not address these conflicting perspectives) that some form of automatic processing could occur either as an innate ability or develop and be automatized early in life (Pascalis et al., 2011).

The independence of processing from influences that can affect attention can be considered a core feature of automaticity, yet the term is often used in multiple ways. In an attempt to clarify the term, Bargh (Bargh, 1994) postulated the informative point of view that automatic social processes are marked by “four horsemen”; lack of awareness, lack of intention, lack of control, and efficiency - although not all automatic processes may possess these features (Okon-Singer et al., 2007). For example, in recent study where emotional negative scenes were presented together with a competing task under different levels of load, interference was produced by negative emotional scenes on the judgment of a concurrent letter target presented at a different location, despite the fact that the presence of these scenes was task-irrelevant and detrimental for optimal performance (Okon-Singer et al., 2007). Crucially in the latter study, this interference was found only when sufficient attention was available for target processing, not when processing load was increased by additional letter distractors. The conclusion being that emotion processing is "automatic" (in that emotional distractors cannot be fully ignored even when they are counterproductive), but at the same time that it is contingent on task demands and attentional resources (in that interference is suppressed by additional competition) uniting the differing views of attention and automaticity.

A similar dissociation between the effect of attentional load and voluntary control has also been observed in experiments with masking procedures (Bahrami, Carmel, Walsh, Rees, & Lavie, 2008), in which the visual representation of a stimulus that is not consciously seen, can nevertheless be modulated by the task difficulty for another concurrent visible stimulus. These results suggested that visual spatial attention can only affect consciously perceived events and that early unconscious processing of orientation depends on the allocation of limited attentional capacity. It is not clear whether similar distinctions may apply to the processing of facial expressions and judgments (see section **1.3**), where social signals and emotional meaning appear to be highly salient, perhaps due to them being fitness enhancing messages or instrumental for social communication (Kappas, 1997).

There is evidence that the processing of social facial and emotional information is prioritized, fast and interferes with the on-going processing of other information and has some form of autonomy

(Pessoa, 2005), yet the effect of task load as a resolution to the automatic, attentional processing debate is far from clear. Some studies are consistent with the possibility of facial social judgment as an automatic process (e.g. see (Tracy & Robins, 2008)). The findings from the latter research suggest that overall, emotion and cognitively complex social expressions (such as embarrassment and shame) can be accurately recognized and discriminated from each other very quickly (i.e., within 600 ms). Importantly for the prior discussion, this occurred under cognitive load (although there were exceptions such as contempt). Further evidence for the automaticity route, albeit on a related tangent are demonstrated in a number of studies that have found that subliminally displayed emotional expressions can influence observers' behaviours without their awareness. Subliminal expressions have been shown to generate effects ranging from automatic facial mimicry to influencing subsequent behavioural choices and judgments; where for example, subliminal presentation of negative expressions induces perceivers to subsequently judge a beverage less favourably (Dimberg, Thunberg, & Elmehed, 2000; Winkielman, Berridge, & Wilbarger, 2005).

This brief tour though what I consider some of the important facial social attentional behavioural research indicates the strong debate that still exists regarding the role of facial social and emotional processing, attention, and whether it can persist automatically, that is irrespective of factors related to attentional task demands. To successfully sail between the Scylla and Charybdis of attention and automaticity in emotional face processing and social judgment is likely to require a deep understanding of its components. Ultimately, this will necessitate a more elaborate delineation and specification at both the behavioural and neural level (which we shall turn to in the next section **1.3**).

It is worth reiterating that while much of the discussion on attention here is of a functional nature, where "attention" selects relevant information at the cost of competing and irrelevant distractors, this does not necessarily imply that the attendant mechanisms and effects of attention are singular. Attention is in fact most likely contingent on numerous components, such as orienting to sensory events and targeting and sustaining alertness in order to process high priority signals (Petersen & Posner, 2012). However, it is this very inability to fully currently characterize attention, that make certain methodologies and frameworks, such as perceptual load (Lavie, 1995) more attractive to study attentional effects on social judgments than others (as under perceptual load, attention is sustained and only the capacity is modulated). Arguably this approach makes research more tractable as opposed to other lines of attack, for example such as modulating the range of the attention spectrum, or employing the presence of covert attention to ascertain its influence on social judgments (e.g. on attractiveness (Sui & Liu, 2009)).

The characterization of attention as a singular phenomenon has enabled productive research into how capacity limits influence the effectiveness of processing, irrespective of the stimulus attention act upon. The influence of this characterization has resulted in an explosion of research in the field of cognitive neuroscience, where researchers have sought to identify whether the processing of salient emotional visual stimuli such as faces take places in an automatic fashion independently of top-down factors such as attention. Accordingly, it is to this field I will focus on next.

1.3 Beneath The Facade: The Neurological Basis of Facial Social Signalling - Who's Attending?

Peeking under the hood by means of neuroimaging and neuropsychological studies is particularly insightful with regards to both how attentional limits may affect social facial judgments and their operation in general. Because of this, although the research literature in these areas is deep and cavernous, it is nevertheless impossible to ignore. The following section is somewhat detailed and reflects the recent explosion of imaging studies in cognitive science, incorporating some important and noteworthy studies, but also illustrating the challenges even at a neural level of isolating coherent or localizable functions in social facial judgment. Such functions seem to be distributed, most likely incorporating many subcomponents that could be activated in differing tasks and contexts, notwithstanding the complexities when attention is brought into consideration. Nonetheless, any endeavour seeking to understand modulators of social facial judgment requires a familiarity with this literature and its diverse strands, and it is to that we now turn.

1.3.1 The interrelationship of social trait facial judgments and emotional expression

I have discussed the role of emotion and attention. However, the social judgments that we perform, range not just from emotional facial inferences but also to trait characteristics; in fact the difference between the two, particularly from the perspective of neuronal processing is not always so clear (as we shall see later in our discussion of face spaces), a view corroborated by neuroimaging findings. For example, the processing of happy facial expressions and attractiveness have common underlying neural mechanisms (O'Doherty et al., 2003) and there might even be a mutual dependency between the two (Golle, Mast, & Lobmaier, 2014).

The interrelationship of social facial judgments and emotional expression is arguably indistinct, the former is considered a more trait-like, stable aspect of a face, while the latter, the emotional expression, is deemed more transient. Moreover, it is unclear to what degree the functional neuroanatomy of social judgments on faces reflects genuine social versus basic emotional and cognitive processing (although they them may be separable neuro-architecturally (Bzdok et al., 2012)).

In terms of social judgments, trustworthiness and attractiveness in a face are often considered to convey particularly crucial social information, both due to what can be construed as a reward; assessing facial trustworthiness is pivotal for the gain of social cooperation (Cosmides & Tooby, 2000), while assessing attractiveness is often considered important for mate fitness estimates (Langlois et al., 2000). Reflecting this importance, the primary drivers in neuroimaging research on social judgments as illustrated by the aforementioned study in the last section (Sui et al., 2009) have been attractiveness evaluations and the arguably closely allied judgment of trustworthiness (Winston, O'Doherty, Kilner, Perrett, & Dolan, 2007; Todorov & Engell, 2008b; Aharon et al., 2001; Adolphs, Tranel, & Damasio, 1998).

Attractiveness is particularly interesting as a social judgment, as what seems as a potentially ambiguous classification can be (predicated on the supposition that perceptions of attractiveness are akin to reward) tied to well established reward related neural architecture, particularly the triumvirate of reward-related brain regions (for a review of the reward system see (Schultz, 2000) and for review of their relation to faces see (Little & Jones, 2009)). Indeed, one of this trio (the other two being the nucleus accumbens and the anterior cingulate cortex) the medial orbitofrontal cortex, is activated dependably across attractiveness papers (Said, Haxby, & Todorov, 2011; Winston et al., 2007; Aharon et al., 2001; O'Doherty et al., 2003), with greater activation as attractiveness increases (the anterior cingulate cortex also shows greater activation to attractive faces than to unattractive faces, according to at least two studies, (Winston et al., 2007; Cloutier, Heatherton, Whalen, & Kelley, 2008)).

The nucleus accumbens has also been reported to be more activated to attractive faces (Cloutier et al., 2008) although there have been conflicting findings For example Kampe and colleagues found that the gender of an observed face in relation to the gender of the observer did not influence the response in the ventral striatum (subsuming the nucleus accumbens)(Kampe, Frith, Dolan, & Frith, 2001). This might indicate that features depicting attractiveness (such as facial form and symmetry) are low level cues that are processed independently of gender. Furthermore, they did not observe any activation associated with attractiveness in isolation, but only as an interaction with eye gaze. If we again assume that the dimension of attractiveness constitutes a reward, eye gaze from an attractive face represents a favourable outcome. However, in one of the above studies (Cloutier et al., 2008), although the putative reward circuitry (e.g., nucleus accumbens), showed a linear increase in activation with increased judgments of attractiveness, further analysis also revealed sex differences which distinguished attractive and unattractive faces, but only for male participants (Cloutier et al., 2008). This implies that brain regions sensitive to reward are recruited during the perception of attractive faces, although multiple components such as gender and gaze may interact (with dissociable roles of the somatosensory and superior temporal cortices for processing social face social signals, such as gaze direction and emotion expression (Pourtois et al., 2004)).

Focusing on attractiveness facial judgment architecture almost seems like an impoverished view of the rich social judgments that we employ day to day. Yet this focus is important, as physical attractiveness is associated with a variety of positive social attributes, such as trustworthiness (Schmidt, Levenstein, & Ambadar, 2012), and an impairment of social facial judgment in domains such as the latter can have detrimental social consequences (Adolphs, Sears, & Piven, 2001).

It has been widely accepted that the amygdala has a key role in many facets of emotional processing and social behaviour in humans (Costafreda, Brammer, David, & Fu, 2008) and in particular processing of emotional facial expressions. While the results from neuroimaging studies have been complicated and to some extent inconsistent (discussed further in sections **1.3.2** and **1.3.2**), studies support the idea that the amygdala is a key neural substrate for processing facial displays of affect and faces in general (Fitzgerald, Angstadt, Jelsone, Nathan, & Phan, 2006). It is not surprising then that, amygdala activation is a robust feature in social judgment studies. For example, trustworthiness was found to be the optimal predictor of implicit amygdala responses to faces among 14 personality trait dimensions, counting attractiveness, aggressiveness and intelligence (Todorov et al., 2008b), although such effects may be indicative of a more general response to negative valence and facial features (for example faces that are perceived to be threatening resemble anger). Indeed, amygdala response activation is better predicted by consensus ratings of trustworthiness than by an individual's own judgments (Engell, Haxby, & Todorov, 2007), suggesting that the amygdala has a key role in categorizing faces according to face properties commonly perceived to signal untrustworthiness.

Given both the paucity of evidence regarding the role of attention in the processing of social judgments and the arguably indistinct interrelationship of social facial judgments and emotional expression means we can draw on the research of emotional processing to speculate on social judgment processing. Most likely just as for emotional facial expressions, social judgments are processed early, as electrophysiological evidence for the role of early (non-conscious) processing of negative valence faces indicates, facial expressions such as fear can be processed at a relatively early stage in the flow of information processing (Pegna, Landis, & Khateb, 2008). Healthy participants who performed a fearful face detection task in which backward masked fearful and non-fearful faces were presented at durations ranging from 16 to 266 ms produced strong electrophysiological signals as early as 170 ms post-stimulus onset (strong N170s were produced - the N170 is a component of the event-related potential that reflects the neural processing of faces) (Pegna et al., 2008). This early appearance implies that the process does not require time-consuming computations and hence such rapidity can be construed as indicative of some form of automaticity. Similar, brief exposures-times to faces are also often sufficient for subjects to perform trait discriminations as well. For example, in facial attractiveness research, one of the most comprehensively studied facial social judgments, extremely short exposure to faces (100 ms) are adequate for subjects to discriminate between different levels of facial attractiveness (Locher, Unger, Sociedade, & Wahl, 1993), perhaps even less time is required (13ms according to (Olson & Marshuetz, 2005)).

These findings that people can make trait inferences after extremely brief exposures, or have early identifiable electrophysiological responses to facial expressions suggests that such inferences are made automatically. However, this requires us to think a little about the concept, are we clear by what we mean by the term?

Automatic processing can be assessed in a variety of ways, rapidity of processing is one, although many cognitive of processes are rapid, and rapidity does not necessarily mean in and of itself immune from modulation. Arguably, determining whether some putative automaticity function can be disrupted by another cognitive process such as explicit attention provides a better index of automaticity. For example, fMRI results showing modulation of fusiform cortex responses to faces by spatial attention in the human brain (Vuilleumier et al., 2001a) - (see **Figure 1-3**) indicate that visual system modules that may have been thought to proceed automatically, are amenable to higher-level attentional influences. However in contrast, adopting the adaptive evolutionary perspective and assuming that emotional (and perhaps social) conspecific information has a privileged role in biasing the allocation of attentional resources is consistent with behavioural findings demonstrating a greater tendency of emotional relative to neutral faces to capture attention in a relatively automatic and involuntary manner, across various visual tasks (Pourtois, Grandjean, Sander, & Vuilleumier, 2004). For example, in the latter visual event-related study (employing a dot-probe paradigm) Pourtois and colleagues demonstrated specific electrophysiological correlates (e.g. enhanced P1 component amplitudes (P1 also called the P100, because it is the first positive-going component and its peak is normally observed at around 100 ms)) underlying involuntary attentional biases (when the probe replaced a fearful face as compared with a neutral face) towards the spatial location of emotional faces.

Pourtois and colleagues results' converged with a prior fMRI study that used fear conditioning with angry faces in a dot-probe paradigm. Cueing effects were not simply produced by the distinctive visual features of emotional expression in faces, but were contingent on their emotional value (Armony & Dolan, 2002). The results of this study showed greater activation in amygdala as well as in frontal and parietal areas when the dot-probe was preceded by the face that had acquired a negative valence by conditioning, suggesting that emotional responses could modulate attentional systems and influence spatial orienting. This suggest a much more interactive and recursive interchange between ideas of automaticity and attention than just rapidity in processing and discrimination.

Expressions are features of certain states, that is, certain facial expressions signify emotional states, but features of those expressions most likely are also recruited in and influence social judgments, consequently judgments of expressions and explicit social judgments such as that of trustworthiness say, would be expected to have some overlap with emotional ones. Determining important features of this processing, such as whether some putative automaticity function can be disrupted by another cognitive process such as explicit attention is still an open debated area of research.

The processing of stimuli with emotional or social value can be biased in several ways. One way is by bottom-up, sensory-driven mechanisms, such as stimulus salience. Another way is by attentional top-down feed-back (generated in areas outside the visual cortex e.g. attentional modulation driven by fronto-parietal networks (Ungerleider, 2000)). The evidence for the nature and parameters of this biasing is complicated and contradictory particularly with regards to whether the processing of certain types of facial judgments, emotional or trait are considered automatic or can be modulated by attention.

The interrelationship of social facial judgments and emotional expression imply that research into modulators such as attention of emotional judgment will have relevance for those of social judgments (although this proposition is not yet experimentally demonstrated). Given this interrelationship, to seek to elucidate further the role of attention in facial processing let us turn to neuropsychological research to see if research in that area can support or undermine the idea that top-down signals related to attention can modulate facial judgments.

1.3.2 Neuropsychology and damaged attention

Neuropsychological studies (how the structure and function of the brain, particularly applied to lesion studies relates to specific psychological processes and behaviours), have also been a powerful source of evidence in seeking to uncover the tumultuous relationship between attention, automaticity and facial expression processing.

Overall, neurophysiological studies lend some support to the automatic processing viewpoint. Studies of blindsight and neglect patients converge to advocate that certain social signals such as emotional facial expressions may be processed in the absence of awareness (e.g. facial expressions are perceived without primary visual cortex (Pegna et al., 2008)). A possible explanation of this surprising result might be due to the fact that the ability to process unseen emotional signals might extend an evolutionary advantage with regards to threat-detection. This explanation is subsumed into the broader assertion that for evolutionary reasons, certain types of face processing should be invariant to attentional constraints; although of course how this argument extends to the full gamut of facial social judgments is unknown. For example, whether evolution has provided the brain with a ‘special toolkit’ for facial trust evaluation is undetermined (Marzi, Righi, Ottonello, Cincotta, & Viggiano, 2014).

The importance (of at least negatively valenced stimuli) in attentional processing is underscored in patients with visual field defects (without any subjective awareness of stimuli presented in the blind field). For example, testing these patients with a go-no go task, where they were asked to discriminate emotional facial valence, produces a facilitative effect for them when fearful faces were presented in the blind field (Bertini, Cecere, & Ládavas, 2013). While these results once again suggest the importance of negative valence stimuli in attentional processing, they also could mean that implicit visual processing for unseen facial (fearful) stimuli might be mediated by a spared sub-cortical and short-latency pathway. The presence of multiple pathways, potentially complicates the disentanglement of the facial visual processing circuitry (Bertini et al., 2013) and the inferences we can make about what type of expressions may be processed automatically, immune to the effects of modulators such as attention (as competing secondary pathways may be operating in parallel).

Further neuro-architectural evidence to help elucidate how facial stimuli are processed with regard to attention can be found with spatial neglect patients, a behavioural syndrome occurring after brain injury. Spatial neglect, is a loss of awareness contralateral to the brain lesion in which primary visual cortex may be functional. In neglect patients, performance for a given stimulus can be contingent on whether additional stimulation is delivered at the same time. In such circumstances, neglect patient deficits' only becomes apparent when two relevant stimuli are presented simultaneously, where they would typically miss one of the stimuli in their deficit field; this deficit during double simultaneous stimulation is known as `extinction' (as the appropriate event is said to `extinguish' the other event from awareness). Examining patients with spatial neglect and visual extinction from brain damage does suggest that faces are privileged in summoning attention and seem to have a special advantage over other stimuli (such as names or shapes) in visual processing and attention orienting mechanisms (Vuilleumier et al., 2002; Vuilleumier, 2000). Indeed, spatial neglect patients presented with happy and angry facial expressions show reduced extinction effects relative to neutral faces when presented simultaneously across both visual fields (Fox, 2002). In fact, despite hemisphere damage and abnormal spatial biases in attention (pervasive attention biases towards the neglected side) visual search in neglect patients is still reliably influenced by emotional expression in faces, which are detected more rapidly than neutral face targets in visual search tasks (Lucas & Vuilleumier, 2008).

In sum, visual neglect patient studies do appear to support the claim that faces call attention more than other visual stimuli. However, while visual neglect patients generate revealing insight into the underlying architecture of deficits in attention, unravelling the actual processing here is complicated as visual neglect may be a disorder of not only guiding attention in space, but time as well. Some neglect patients have an abnormally acute and extended attentional blink. The attentional blink or dwell time is a measure of the ability to allocate attention over time (temporal attention), where the ability to detect a second object is impaired if it appears within 400ms of the first (Husain, Shapiro, Martin, & Kennard, 1997)), meaning that that visual neglect could be a disorder of directing attention in time, as well as space. As a consequence, studies which manipulate spatial or object attention in healthy participants are crucial to support or disconfirm these clinical findings about how attention interacts with expression processing in the non-clinical population.

Neuropsychological patient studies have emphasized the causal interplay between attentional and emotional modulation of visual processing, however, their findings that emotional processing is obligatory also find support in functional neuroimaging work.

In influential and widely cited study Vuilleumier and colleagues (using event-related fMRI) demonstrated that responses in the amygdala to fearful faces (often considered as a "signature" of emotional processing) and visual cortex were not modulated by the focus of attention (see **Figure 1-3**), consistent with the view that the processing of emotional items does not require attention (Vuilleumier et al., 2001a). Although amygdala activation to fearful faces was found to be unaltered during inattention, activation in fusiform cortex was reduced, potentially separating out processing roles. Moreover, the right fusiform activity was greater for fearful than neutral faces, independently of the

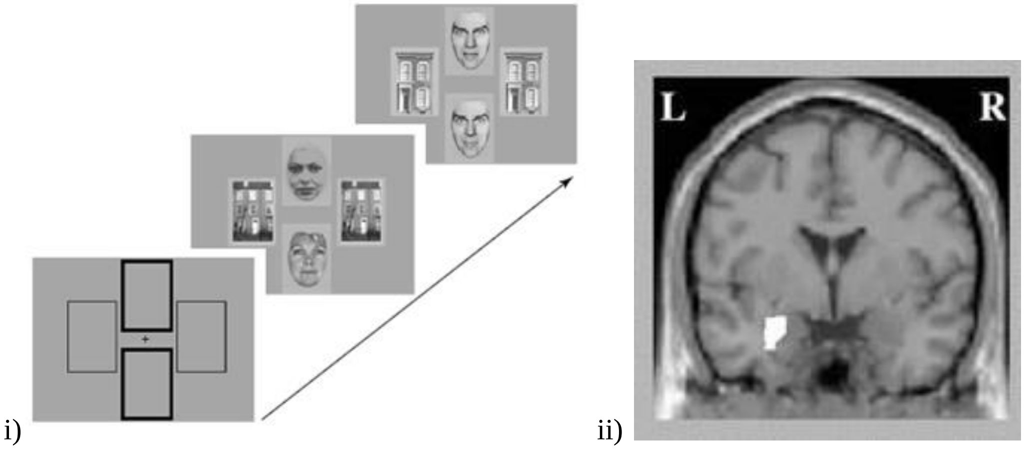


Figure 1-3 Is attention required for the processing of emotional stimuli?
i) The task illustrated (on the left), had two types of faces (fearful or neutral) and two houses appearing on each trial (200 ms). Subjects were scanned while attending only to the vertical or horizontal pair of images. (ii) Group results illustrated on the right were superimposed on a single-subject T1-weighted MRI (activated voxels at $p < 0.05$), corrected for whole brain, activation increased in the left amygdala to fearful vs. neutral faces irrespective of the spatial attention direction Adapted from (Vuilleumier et al., 2001a) and (Vuilleumier, 2005).

attention effect on this region (Vuilleumier et al., 2001a). Although these results do indeed reveal differential influences on face processing from attention and emotion, the fact that the amygdala response to threat-related expressions was unaffected could imply that such processing may be relatively "automatic", as it arose without any requirement for explicit judgment of facial expression (and thus signifying that expression processing in the amygdala does not depend on fully attentive processing in the visual cortex).

A similar study, which used a more attentionally consuming competing task than that use by Vuilleumier and colleagues (Vuilleumier et al., 2001a) found comparable results (Williams, McGlone, Abbott, & Mattingley, 2005). Williams and colleagues showed participants pairs of peripheral semi-transparent face-house composites (using happy and fearful faces), requesting them to match either the faces (attend face) or houses (attend houses). They found that activity in the amygdala differed according to the valence of the facial expression and the category of the attended stimulus. For happy faces, activity in the amygdala was greater in the attend-face than in the attend-house condition, whereas for fearful faces, activity was greater in the attend-house than in the attend-face condition. These results suggest that while differential amygdala responses to fearful versus happy facial expressions are tuned by mechanisms of attention, the amygdala nonetheless gives preference to potentially threatening stimuli under conditions of inattention (Williams et al., 2005).

The idea that the processing of certain (usually threat- related) stimuli in the amygdala are unconstrained by the availability of attentional resources may be appealing and coheres with the claim that (emotional) faces call attention more than other visual stimuli. Nonetheless, this view is not unanimous, for example there is evidence for suppression of differential amygdala response to fearful and neutral faces under condition of inattention in the literature (Pessoa et al., 2002). These discrepant results may be explained by resorting to the important notion of the perceptual attentional demands of the tasks used to divert attentional resources from the faces (Williams et al., 2005). According to Lavie (1995, 2000) amygdala activation may depend on the attentional resources and that automaticity in processing emotional facial expressions might transpire only when the attentional system is not completely occupied by the main task, implying that some attentional resources may be "spared" and "spill over" to emotion processing (Pessoa et al., 2002).

Overall, while findings suggest that the complex visual stimuli of faces and expressions are capable of capturing attention, it is unclear whether this is preserved when resources are more fully consumed and whether the processing that takes place is dependent on the perceptual attentional load demands (as suggested by the perceptual load theory framework), could there be thresholds for how attention modulates facial information?

1.3.3 Leading to load theory - attention and stimuli of social significance are (famous) faces exempt from attentional load?

The last section suggested that attentional resources can "spill over" to (emotion) processing (Pessoa et al., 2002). This fits with the aforementioned predications of perceptual load theory (discussed in section **1.2 -** Limits in facial social judgment), where for example, as in the many studies of perceptual load, interference, for instance by meaningful 3D distractor pictures on a name-categorization task (e.g. fruits versus musical instruments) depends on the level of perceptual load (the number of letter-strings) in the task (Lavie et al., 2003).

One may think that the ability to attend to socially significant information such as faces would be an inherent property of our attentional system, and somewhat supporting this position is the observation that in contrast to the effects of perceptual load on objects, interference by famous distractor faces are unaffected by the level of perceptual load in a famous-name categorization task (pop stars versus statesmen) (Lavie et al., 2003). A possible interpretation for this result is that people are more susceptible to interference by distractor stimuli of social significance, such as famous faces. Such an interpretation is supported by the fact that interference and priming effects were created regardless of whether attention was fully engaged in a task of high perceptual load (Lavie et al., 2003). Although in contrast, long-term explicit recognition memory of distractor faces presented in the experiment, either famous or anonymous, did depend on the level of load in the relevant task, being no better than chance in tasks of high load (searching for a target letter among similar non-target letters) (Jenkins, Burton, & Ellis, 2002; Jenkins, Lavie, & Driver, 2005).

The results of the aforementioned behavioural studies are also supported by a relatively recent novel electrophysiological study. This study, employing perceptual load theory, explored the capacity of attention to prime (famous) faces on short-term repetition effects in event-related potentials (ERPs). The results revealed ERP repetition effects in terms of an N250r at occipito-temporal regions, suggesting priming of face identification processes, which were unaffected by perceptual load. This study indicated that task-irrelevant face processing is relatively preserved under perceptual load, and thus supports the notion of face specific attentional resources, at least for famous faces (Neumann & Schweinberger, 2008). This ERP accords with the outcomes described by a similar behavioural study by Jenkins and colleagues, although memory for faces, including immediate recognition, was affected by concurrent demands for (nonface) shape processing capacity at exposure in their study (Jenkins, Lavie, & Driver, 2003).

Given these coherent findings, can we conclude that face processing may be “modular” in the sense of proceeding independently of attention or in relying solely on face-specific processing resources (Jenkins et al., 2003)? Although some aspects of face-processing may depend upon face specific mechanisms, the boundary conditions on such claims should be cautiously considered due to the use of famous celebrity faces’ in these studies, which may skew our interpretations. Well-known and recognizable faces may access strong mental representations and thus require little attentional capacity or indeed be processed in an atypical fashion (Buttle & Raymond, 2003). For instance, the actual task of judging the positive or negative qualities of famous faces strongly modulates amygdala activation to those faces, but processes negative information less flexibly than positive information (Cunningham, Van Bavel, & Johnsen, 2008b).

What are we to make of this result that famous distracter faces are processed irrespective of the level of the perceptual load task? These observations seemingly aligns with some of the earlier neuropsychological studies, suggesting that facial visual stimuli have attentional priority, perhaps due to being stimuli of high social significance. However, there are studies showing that top-down effects such as attentional load may be effective in impacting the neural processing of emotional facial stimuli, which are also presumably stimuli of high social significance (Pessoa et al., 2002).

Consistent with the notion that task load was important in determining the extent of processing of the face stimuli, Pessoa and colleagues (Pessoa et al., 2002) revealed that differential amygdala responses to emotional facial expressions can be eliminated by high “perceptual load” (in an important riposte to the earlier work of Vuilleumier and colleagues (Vuilleumier et al., 2001a)). In this study, the authors suggested that the neural processing of facial emotional stimuli is not automatic and requires some degree of attention, similar to the processing of other stimulus categories. They claimed that the failure to modulate the processing of emotional stimuli by attention in prior studies was caused by a failure to fully engage attention by a competing task (although their study manipulations had slight differences to perceptual load tasks as they measured attended/unattended processing, rather than high/ low modulation of perception).

Pessoa and colleagues findings of differential amygdala responses to emotional facial expressions under load have been complemented by similar findings that emotional influences from both facial expressions and other stimulus materials may be reduced under conditions of higher attentional load (Okon-Singer et al., 2007; Erthal et al., 2005). Moreover, also consistent with the perceptual load hypothesis (Lavie et al., 2003), other studies have indicated that amygdala activation is likely contingent on the unoccupied attentional resources for facial expressions and hence only observed when attention is not fully consumed by a distracting task (Mitchell et al., 2007; Silvert et al., 2007). Both Mitchell et al and Silvert et al only found increased activation in the amygdala and fusiform cortex under conditions of low attentional load for the main task, but not under conditions of high load (also see (Pessoa, 2005)).

A possible criticism to some of the results discussed in this section is that the elimination of emotion processing under high load may be because the distractor was not salient enough. As noted by Lavie, (Lavie, 1995) there is no “gold standard” for determining “high” perceptual load without being circular. However, even increasing the affective salience of a (threatening) face distractor (so that the influence of distractor intrusion was manipulated in addition to perceptual load) did not make them more resistant to modulation by attention (Yates, Ashwin, & Fox, 2010).

A number of studies have thus cast doubts on the tempting and appealing idea that the processing of facial expressions (conceding that many of the examples exploring this issue employ threat-related stimuli) is unconstrained (particularly in the amygdala) by the availability of attentional resources (that is, that amygdala activation can be affected by load). How these effects are mediated are unknown, although given that a complete suppression of amygdala responses to unattended faces may occur only when there are scarcely any attentional resources available for their processing (Pessoa, 2005), could mean that inattention or reduced perceptual capacity could make the emotional expression of faces with reduced attention more ambiguous, leading to undifferentiated amygdala activation (Whalen et al., 1998). This implies that when attention is reduced in facial expression processing, not only could amygdala activation be reduced, but amygdala responses could also gradually lose their specificity (Silvert et al., 2007).

Taken together, much of the neuroimaging results in this section suggest that emotional facial processing will be severely reduced if the perceptual load of an attended task exhausts capacity limits, where Lavie’s theoretical perceptual load framework (Lavie, 1995) provides an explanation for this conclusion.

The long-running debate over the of role selective attention in processing ‘‘special’’ status stimuli such as faces can lead one to discount the effects of other modulatory influences that may have a role, along with attention, in gating the processing of facial stimuli. For example, factors such as trait anxiety may affect attentional capacity and attentional control engendering selective biases which interact with facial processing. A more detailed discussion of how anxiety is related to emotion perception and its role in the allocation of attention is provided in the following section.

1.3.4 Anxious about attention - additional top down modulators

I have focused primarily on attention as a top-down modulator in expression/trait processing; however effective goal-directed behaviour can be contingent upon not only the mechanics of attentional control capacities but also the extent that a task or goal burdens an individual's attentional control capacities.

Trait anxiety one of the well-studied factors that has been revealed to affect attentional control and disrupt task performance (amongst other such as depression, which are associated with differential affective processing of in particular adverse or deleterious information (Williams, Peeters, & Zautra, 2004).

Of the numerous studies on the effects of trait anxiety in attention, it is research exploring the consequences of cognitive load on distraction in the presence of task-irrelevant emotional stimuli that concern us here. Research has indicated that the presence of anxiety in certain circumstances overrides the blocking effects of high perceptual load (Cornwell et al., 2011). Cornwell and colleagues showed that when participants were threatened by shock, greater amygdala responses to fearful compared to neutral distractor faces were preserved under conditions of high attentional demand. While a recent eye movement study indicated that even though emotional information captures and holds attention more strongly than neutral information, cognitive load still appeared to hamper emotion processing, and that anxiety was associated with greater costs to performance under load (Berggren, Koster, & Derakshan, 2012). Moreover, there is evidence to suggest that the anxious have smaller reductions under load (MacNamara, Ferri, & Hajcak, 2011) and research measuring distraction by fearful faces suggest that such faces do influence the capacity for attentional control (Ladouceur et al., 2009).

It is important to bear in mind however, the effect of cognitive load on emotion processing in general. Reductions in emotional biases for anxious individuals may indicate a more general effect of cognitive load on emotional processing. For example, using stimuli form the IAS (International Affective Picture System (Lang, Bradley, & Cuthbert, 2008) where pictures ranged from images of scenes with burn victims to angry faces), Van Dillen and colleagues found that the task load (the complexity of an arithmetic task) down-regulated the brain's response to negative stimuli (Van Dillen, Heslenfeld, & Koole, 2009).

Overall anxiety research suggests that increasing attentional load can disrupt attentional control processes and this effect is exacerbated in individuals with high levels of trait anxiety. The research is also suggestive that there may be of a role of emotional valence by load (Berggren, Richards, Taylor, & Derakshan, 2013) - (although possibly valence by itself may not the most important governing factor for attentional capture but rather the arousal value of stimuli (Vogt, De Houwer, Koster, Van Damme, & Crombez, 2008)).

This discussion on anxiety highlights the important of valence, or how positive or negative an emotion feels (Russell, 1980). This is an important dimension of any social stimulus, and as a consequence we would similarly expect the general population to also be acutely aware of this dimension in facial social judgments.

There has been much interest in the extent to which valenced (particularly aversively-related) stimuli may have a special status in their ability to capture attention or to be processed independent of attention in social judgments, especially as first impressions can be formed very quickly, evidently based on whatever information is available within the first 39 ms (Bar et al., 2006). Valenced information seem to be prioritized, insofar as rapid first impressions appear to be less consistent when the judgments were about intelligence, while survival-related traits are judged more quickly, particularly threat judgments (Bar et al., 2006). The importance of valence is explored further in the next section.

1.3.5 Facing perceptual load attention and automaticity

How can we draw a close to this attention and automaticity debate, particularly as its very border still requires clarification? It seems that any attempt to summarize the attention and automaticity debate ends up in a protracted unresolved manner. This may be simply because there are multiple potential influences. For example perceptual load attentional selection is susceptible to an age-related impairment (Schmitz, Cheng, & De Rosa, 2010), thus age may have an important role in the diverse results neuroanatomical (and behavioural results) reviewed in the last two sections. The plethora of methods and paradigms in this section alone, notwithstanding the behavioural data discussed in the prior section, has not determined unequivocally the circumstances and situations in which automaticity in facial social judgment could occur (although as I have already remarked, the challenge is that automaticity is somewhat amorphous concept that can incorporate a number of properties according to different authors.

We have reviewed strong evidence that face expression recognition may occur rapidly in a stimulus driven fashion, and the cortical and subcortical regions (particularly of prominence in the literature, the amygdala), are involved in this type of” automaticity”. However, we have provided evidence for the possibility of executive control in social facial judgments also. Considering perceptual load theory is useful here. The theory suggests that some aspects of social and emotional face processing may be stimulus driven and unintentional (even rapid) when perceptual resources or task demands are low. Conversely and converging with a host of similar studies such as visual search and Stroop studies, the theory suggests that demanding top-down or executive processing priorities can alter the output of any putative automatic processes. This perspective also yields a bridge and more complex interpretation into how differences in selective attention or perceptual load conditions might influence neural and particularly amygdala activation on top of other more automatic processes; the conclusion is that both types of effects may occur simultaneously (although the possibility of their occurrence may still have some ultimate perceptual load capacity limit). There is research supporting this viewpoint, independent additive effects of spatial attention and emotion were evident in the fusiform cortex, although not in the amygdala (Vuilleumier et al., 2001a). This idea of concurrency may be arguably corroborated by event-related potential - ERP studies; repetition effects for faces were not reduced by high perceptual load, that is the ERP was equivalent regardless of perceptual load; perhaps suggesting that a putative face-selective attention module supports encoding under high load

(Neumann, Mohamed, & Schweinberger, 2011). This interaction between task demands (which may be contextual) and the diverse results in neural and behavioural data reviewed here may reflect the complexity of facial expression processing or simply the diverse methods of probing the cognitive facial social/emotional appraisal system. Employing standardized stimuli and procedures may help to clarify these disparate results (a point I shall return to later).

The neurological based literature inspecting both attention and automaticity and facial trait processing is a vast terrain, particularly for emotional judgments, although how these factors interrelate on more complex social judgments such as trust, reduces that terrain markedly, due to the paucity of research in this specific area (although again to reiterate, emotional and trait judgments are in general highly correlated). As a consequence, any endeavour to summarize it seems fraught with difficulties. Nevertheless in this attempt, I have considered various aspects of facial trait and emotional expression processing in social judgment, focusing primarily on the key issue throughout these literatures; namely the (inter) relationship between attention and automaticity in facial processing.

One core feature of automaticity is the independence of processing from influences that can affect attention. This key feature highlights the question as to whether facial emotional and social judgment processing can meet some form of the requirements of automaticity. To rephrase, do top-down effects such as attention interfere with facial processing?

The diverse array of neurological based research that I have reviewed suggests the existence of reciprocal influences between expression processing and selective attention (or conscious awareness) (Vuilleumier, Armony, & Dolan, 2003). These results for the most part indicate that the amygdala and perhaps other regions in the superior temporal sulcus and prefrontal areas tend to exhibit an interaction to facial expressions. Such an interaction can depend on stimulus-driven, more automatic facets, yet can also be contingent on task-dependent responses or attentional capacity resources. This is roughly coherent with a fair amount of automaticity (at least of amygdala responses) but still permits higher level modulations also, leaving the debate open.

Overall, in terms of white matter regions, the amygdala has been activated and implicated in multiple studies, although challenges in interpretation remain, not least that even though I have cited numerous studies showing degrees of brain regions more preferentially recruited than others, neuroimaging may be insufficient to determine whether activation in these regions is necessary for social judgments, or merely a downstream consequence of judgments computed in other regions (Poldrack, 2006). Supplementary to this, it is not clear under what conditions in the social judgments that I have examined whether the amygdala's response is linear or non-linear and for what type of judgments. For example, amygdala activations have also been observed to the valence of person names, where the response was sensitive to the current goals of the subject (Cunningham, Van Bavel, & Johnsen, 2008a). Additionally, outside of the amygdala, there is surprisingly little overlap across other studies in activated regions for facial social judgments (it may be challenging to interpret the attentional modulation of a social judgment region or network of regions).

At a minimum, even accepting the role of the amygdala in the role of emotional and social judgments, it is important to bear in mind the nature of the social judgments that the amygdala activates in response to. This section (**1.3**) has looked at a number of studies involving diverse facial stimuli, ranging from threatening to trustworthy. As I have already asserted, the boundary between social judgment on such stimuli as trustworthiness and emotional ones such as threat is obscure, and thus it is possible that the patterns of activation evidenced in these studies could be construed as in response to face valence or some other general face quality rather than to a specific trait, emotion or expression attribute (Todorov et al., 2008a). Indeed some support for this perspective is provided by the high correlation between trustworthiness judgments and general valence evaluation of faces. This may mean that it is possible that the amygdala is more sensitive to face valence say, rather than a social judgment such as trustworthiness (e.g. the greater the valence content of a dimension, the stronger the engagement of the amygdala (Todorov et al., 2008b)).

Another point to bear in mind, is that if all facial stimuli can in theory be accommodated in a 2-dimensional face-space according to the model Oosterhof et al proposes (Todorov et al., 2008a) – (see section **2.5** Dimensional face spaces), it is feasible that the amygdala could also be engaged in dominance evaluations (the face space can be construed as comprised of two dimensions; trustworthiness and dominance) when this dimension is motivationally significant.

Looking forward and following on from the disparate results presented so far, there is still a clear need to clarify the role of attentional modulation in expression processing (and by implicature, uncover any putative behaviour of its cousin of automaticity). This is particularly pertinent, as how this modulation affects more nuanced social judgments such as trust as opposed to anger for example, has not been addressed at all. One way of achieving this, is by systematically examining the effects of attentional modulation on some social judgment dimension (such as trustworthiness) and exploring the consequences on face judgments (the perceptual load manipulation offers an idealized tool for investigating such effects). Additionally, to cohere with prior work on social judgments and the importance of valence in expression processing, it would also be constructive to integrate the possibility of valence evaluations in this process. Fortuitously, employing a standardized face space (which integrates valence) in researching these domains would be an avenue to allow a simultaneous examination of both the role of emotional/valenced facial components and neutral facial processing under attentional constraints; potentially addressing some of the conflicting results that we have reviewed.

1.4 Conclusion: Facial Social Judgments; Pay Attention Please!

One of the implications throughout this preliminary review is that any attempt at a complete appraisal of this multi-disciplinary research is both daunting and challenging. Whether (emotional) facial stimuli are processed in an automatic manner nature and how attention and facial processing interact is still currently a highly debated issue in the literature (Okon-Singer, Lichtenstein-Vidne, & Cohen, 2013; Pourtois, Schettino, & Vuilleumier, 2012).

In addition, it is perplexing to determine precedence for the variety of concepts we are examining; particularly as within the literature on both trait and emotional facial perception and judgment (whether with attentional restrictions or otherwise), different authors, signify different things by automaticity and the role of attention in face perception and its modulation. Ranging from attentional control (selectivity), that relate to task goals (intentionality), to conscious awareness (reportability)(Palermo & Rhodes, 2007; Jung, Ruthruff, Tybur, Gaspelin, & Miller, 2011). So what can we conclude from our foray into this multi-faced literature? Taken together, the diverse results reported within this review are not antagonistic to supporting some degree of "automaticity" in the processing of facial expressions and their consequent social judgments (in that distinctive trait features can be extracted, rapidly and on occasion unconsciously), perhaps through specialized cortical or subcortical structures of which the amygdala appears prevalent. Nonetheless, the role of the experimental task, particularly some form of load, seems a thorn in any definitive and conclusive statement on the issue and indeed may be a crucial component modulating facial social judgment processing.

I use the term "degree" above, as the requirement for attention could perhaps be thought of as occupying a continuum with very little or sparse "quantities" of attentional input more suggestive of automaticity. Although in point of fact, what is considered automatic could be relative to the conditions under which it is measured. For example, plateaus in performance on some task that is not impaired (or no longer impaired) by attentional interference does not necessarily mean that no further cognitive change would occur. There may be temporary asymptotes in performance, or, as we have seen, insufficient demands on attention on a specific stimuli class to observe impeded performance. Many discussions have treated automaticity as an all-or-none phenomenon usually with immunity from interference as a requirement and defined as processing without attention (e.g. (Posner & Snyder, 1975)). However, the notion of a continuum of automaticity is consistent with the view that attention is most certainly implemented as a graded modulatory influence on processing (Cohen, Servan-Schreiber, & McClelland, 1992), so that the more automatic a process is, the less it will rely on attention, rather than gated in an absolute all or nothing manner.

The conceptual closeness of attention and automaticity may mean that future research will seek to unify the two models, capturing all of the aspects of attention and automaticity within a single model that encompasses all their characteristics with regard to face processing. Indeed some theorists suggest that rather than being polar opposites the differences between these two concepts may be illusionary

(Logan & Compton, 1998), and suggest that the concept of graded automaticity is useful, as it provides a reference point for researchers to show contrasts against more stimulus driven cognition if attention can oppose its automatic processing.

Facial judgments and automaticity

As I have already alluded to in this Chapter, the debate within the facial automaticity literature is of course pertinent to that of the literature on social judgment attributions from facial appearance (the most systematically studied domain of which is arguably that of attractiveness) even though these domains are often studied in parallel and separately. The link is arguably evident by both the emergence of certain aesthetic preferences early in development and cross-cultural agreement in facial assessments, both pose a challenge for the view that our preferences reflect arbitrary cultural standards (Rhodes, 2006). As I have discussed earlier, facial judgments on features such as attractiveness can be incredibly fast. For example, research by Olson and Marshuetz has shown that very rapid (a staggering 13 ms) exposures to faces were sufficient for subjects to discriminate between different levels of facial attractiveness, potentially signifying that attractiveness is a type of facial social judgment that is derived in some manner automatically from facial appearance (Olson & Marshuetz, 2005). The result that attractiveness can be perceived after extremely brief exposures to faces has provided inspiration to test for a host of other social judgments, ranging from likeability, trustworthiness, competence, and aggressiveness (Rule et al., 2010). Testing on a plethora of social judgments has indicated the efficacy of facial processing and its corresponding ability to rapidly extract social information. This is evidenced by the fact that judgments made after 100 ms exposure to faces are highly correlated with judgments made in the absence of time constraints. In fact, additional facial time exposure did not improve these correlations (in actuality the opposite occurs, increased exposure time, resulted in judgments on different traits becoming less mutually correlated (Willis & Todorov, 2006)), showing that more time permits higher level inferences and judgments and hence may be less beholden to any putative automaticity, if speed of processing is indicative of this.

We can conclude from the aforementioned that minimal exposure time is sufficient for most people to make very specific trait inferences and judgments; indeed this time limit can be pushed to at least 50 ms exposure for judgments such as trustworthiness (Todorov, Pakrashi, & Oosterhof, 2009) - and perhaps even shorter for emotional assessments (Bar et al., 2006). The effect of supplementary exposure time seems to be in simply adding increased confidence in judgments, allowing for more differentiated trait evaluations, however, the judgments appear to have been already predicated on the initial inference (Willis et al., 2006). That is, social judgment attributions from facial appearance can be made very rapidly and with arguably little conscious effort, highly suggestive of being immune to attentional constraints and falling within the purview of automaticity (Moors et al., 2006). Nevertheless, rapidity does not necessarily mean, immunity from top-down control and resource limitations, particularly of the attentional type evidenced in perceptual load manipulations and thus this is something still to be clarified. The influence of attention on social fail judgments is in fact little studied outside of attractiveness research (e.g. (Sui et al., 2009)) and needs to be explored with arguably more complex facial evaluations such as trustworthiness.

Facial judgments and neuroanatomical correlates

Within this review, anatomically, I have focused primarily on the amygdala as an important functional component in social judgments absent from and with various levels of attention; however this emphasis does not seek to imply that there are no other important regions that can aid in reveal the underlying processes involved in facial social judgments. For example, a recent meta-analysis of functional neuroimaging studies of social processing in Autism Spectrum Disorders (ASD) demonstrated that the right insula (amongst various other social processing regions), consistently activated in this group (Di Martino et al., 2009). Furthermore, it is probably redundant to highlight that there are several brain regions that are involved in face processing, including fusiform cortex, posterior cingulate gyrus, and the amygdala, notwithstanding “downstream” regions such as caudate and anterior cingulate cortex (concerned with reward and motivational), regions which are also activated and can be modulated by social context (Vrticka, Andersson, Sander, & Vuilleumier, 2009). For instance, Vrticka and colleagues demonstrated that these very regions were differentially modulated as a function of a previous encounter, and generally more activated when faces were perceived as foes as opposed to friends (Vrticka et al., 2009). Hence past impressions may lead to long-lasting effects on memory for faces and thus influence facial social judgments during subsequent encounters, despite being in a different (neutral) context. Indeed, to complicate the issue and to indicate the deep multivariate nature of even the simplest of facial social communications, even social interactions in economic games may affect subsequent facial social judgments (Singer, Kiebel, Winston, Dolan, & Frith, 2004).

With regard to the structural components of face processing, as we have described in the prior sections, neuroimaging research has delineated distributed brain networks selectively recruited during such tasks, demonstrating (although somewhat contradictory) differential responses to diverse conditions of both attention and task. The undertaking in front of us then, is to further examine to what degree these responses can be construed as automatic and whether they are sustainable during conditions of increased attention (a tool for which perceptual load is well suited). Additionally, although research on social judgments such as trust and attractiveness indicate that facial affective features, aside from emotional expressions can be evaluated rapidly, suggestive of a type of automaticity, the relationship between emotional facial processing and social judgment processing and how or to what extent they sub-serve each other is unclear (Forgas, 1994). In fact the gradations and borders between facial emotion and facial social judgments are fuzzy at best (for this reason I have not made any sharp demarcation between them, although how attention interacts with facial trait judgments such as trustworthiness is generally unknown).

Facial judgments - concluding remarks

To conclude, although the research presented here argues for some degree of automaticity in processing facial appearance and its consequent social judgments (implying that certain facial expression characteristics may be processed rapidly and perhaps even involuntarily), the nature and extent of the automaticity that materializes within this contentious topic is far from resolved. In this review, I have examined evidence from behavioural, neuropsychological and neuroimaging studies to explore whether aspects of facial social judgments are “automatic”, principally focusing on the capacity-free definition of the term and whether such limited-capacity selective attention mechanisms are bypassed by social emotional facial trait stimuli. The later body of work that I have reviewed is broad and diverse (see (Palermo et al., 2007) for another review) and still elicits debate regarding the extent and even to which, if any, facial expressions parameters can be processed automatically. Moreover, it also unclear whether even apparent automaticity implies an attention-free process, independent from top-down control. Furthermore, even though in some instances, automatic processing can persist, regardless of factors such as those related to explicit task demands or voluntary attention, the fact that such processing is still amenable to modulations such as the state of the observer and social context is still suggestive of some form of top down control and hence the possibility of attentional constraints.

The fact that in many of the studies that I have cited, diverse and varied stimuli have been employed may be an important methodological issue facing this research. It is possible that these diverse results (arguing for or against some form of automaticity), may partially reflect the nature of this diverse stimuli. Arguably, therefore, the introduction of a standardized face space may aid in clarifying the disparate results that have been hitherto observed. Faces likely differ in terms of their typicality (the rated typicality of faces is considered to be the most reliable predictor of how well observers recognize them (Tanaka & Corneille, 2007), with typical faces being less well recognized than atypical or unusual ones); this is a pertinent concern in many of the studies examined, as potentially face typicality (e.g. extremely attractive faces are less typical, although not necessarily less average (Halberstadt & Rhodes, 2000)) may partially account for the amygdala's and indeed other white matter areas response to the valence of face stimuli (Said, Dotsch, & Todorov, 2010b). This leads to the allied concern or possibility that different types of face stimuli (with and without attentional constraints) may lead to different patterns of neural responses (Mende-Siedlecki, Said, & Todorov, 2012) – again suggesting that a constructed and “uniform” face space may be beneficial as an appropriate diagnostic baseline for this research area.

The neurobiological evidence appears to indicate that this processing is achieved through specialized pathways and nuclei, prominent amongst them the amygdala. However, due to the multiple methodologies, tasks and approaches taken in this complex interdisciplinary literature, definite statements are elusive as to how modulators such as attention affect these specialized pathways. Drawing on the research presented here, the aims of this thesis are twofold; firstly to seek to clarify the role of attention in face perception, and secondly to examine the role of facial trait judgments such as those of trustworthiness in capturing attention, as opposed to the earlier work that we have seen that has concentrated primarily on emotional facial signals.

Based on the evidence reviewed in this Chapter, we propose two avenues which may help clarify the diverse results that we have reviewed examining the relationship between the processing of facial stimuli, task demands and attention.

Firstly, employing a standardized social judgment face space (Todorov et al., 2008a) reducing variability in image statistics. Multiple features are extracted during facial processing, for instance amygdala responses to facial emotion have been shown to be driven by elementary facial features such as wide-open eyes and pupil size (Demos, Kelley, Ryan, Davis, & Whalen, 2008), meaning that structures such as the amygdala may be engaged in very subtle facial signal computations. For example, pupil dilation is a facial signal indicating heightened vigilance on the part of conspecifics (see (Applegate, Kapp, Underwood, & McNall, 1983)). The latter example is indicative of the difficulties in modulating and tracking the foundational drivers of facial social judgments, although these may be easier to discover with a face space that is fully parameterised.

Secondly, having a standardized attentional task which is validated in multiple domains and modulates attention (by load for example), rather than changing its focus or orientation, could also aid in addressing some of the inconstancies in this field. The latter can be achieved by the perceptual load framework (Lavie, 1995), which at the very least would permit a characterization of the effects of perceptual load on social facial judgment (which as previously discussed is still unresolved), but could also permit extensions to the broader debate as to whether social or trait expression perception proceeds automatically or under the control of selective attention.

1.5 Structure of Thesis

In this thesis I investigate social judgments from facial appearance under an attentional or perceptual load, investigating a range of social judgments and their degree of automaticity or immunity to attentional constraints. As the prior literature review intimates, the research presented in this thesis focuses on the role of attentional effects on facial social judgment and whether the predictions of perceptual load theory extend to the object class of faces. If they do, this could imply that facial processing may depend on the level and type of load involved. To observe whether this is the case, it is necessary to directly assess awareness of facial stimuli while manipulating load in a concurrent task.

This can be accomplished by manipulating perceptual load with regard to one set of stimuli, and measuring awareness of, or, better said, social category accuracy of some form of facial stimuli.

Ultimately, by developing a fuller understanding of the situational factors and internal evaluations that are involved in social judgments from facial appearance, we can gain greater insight into the empirical study of this domain. Such an understanding has applications in a diverse range of decision scenarios, from eye witness testimony to social interactions and provides information regarding the theoretical underpinnings of the mechanisms involved in attention, emotional and trait facial judgments.

To begin, Chapter 2 explores some general methods employed in this thesis. In Chapter 3, I move to investigating how attentional factors modulate social judgments and present a series of experiments focusing on whether perceptual load affects the accuracy of judgments of social facial characteristics. These experiments are the first to investigate whether perceptual load can alter social trait judgments of facial visual experience. The effects of trustworthy social judgments were contrasted against two other baseline conditions of threat and dominance. Attention (the level of perceptual load) in a visual letter search task was modulated by varying the number of non-target items in a search array (one item in low load vs. six items in high load) while simultaneously viewing trait face stimuli. The aim is to determine whether the effects of load on the perception of social judgments of faces are different when standardized faces are employed, morphed on a particular social judgment dimension. In this Chapter (and the following) I investigate the role of perceptual load in the conscious detection of facial stimuli. In a series of experiments, I investigate whether performing a task under high perceptual load makes observers less accurate at social discrimination than they are under low load. The perceptual load task employed offers several advantages that make it ideally suited for the purposes of investigating the role of attention and automaticity of facial social judgments. First, this paradigm has been broadly used in the literature for investigating attentional load effects on a variety of objects (see section **1.3.3** in Chapter 1 and Section **2.2** on perceptual load in the following Chapter 2). Secondly, this task arguably resembles in a very abstract way the multiple demands that facial judgments occur under. In day to day life, we endeavour to attend to the primary social signal - the face, but there are often conflicting attentional and perceptual constraints in the environment. However, perhaps the main benefit of this paradigm is that it involves both moderately minimal cognitive maintenance processes, in conjunction with encoding processes that are minimized by employing simple and highly differentiable stimuli (English alphabet letters which adult native speaker have acquired expertise in), thus making task performance sensitive primarily to the nature of the load task.

In Chapter 4 possible confounds and alternative explanations such as order effects, working memory and bias are investigated to ascertain the robustness of the effects of load on social judgment and a new signal detection approach is explored. This signal detection approach is again adopted in Chapter 5 to investigate the role of perceptual load in a clinical population of Parkinson's disease (PD) patients (as contrasted to age matched controls). In this chapter, the possible role of the neurotransmitter dopamine in facial trait judgment processing and its attentional modulation is explored. PD has been linked with facial expression judgment deficits, although, these deficits could be subsidiary to other cognitive processes implicated in facial evaluation, such as selective attention.

In Chapter 6, I present a functional Magnetic Resonance Imaging (fMRI) study investigating the neural correlates of social judgments. This draws on previous neuroimaging studies suggesting the amygdala will be involved in the perception of trustworthiness judgments, coupled with the results of Chapters 3 and 4 implicating attentional mechanisms in social facial judgment recognition.

The final chapter, Chapter 7, provides a brief discussion of this thesis' findings, their relationship to facial social judgment and attention research and possible avenues for future research based on the work presented here.

In summation, this thesis examines the role that higher cognitive control functions play in the selection of facial visual stimuli for social judgments concentrating on the role of attention. With respect to the latter, if visual stimuli compete for attention under perceptual load and attention acts as a top-down control function, when there is perceptual competition (theoretically reducing the visual system’s capacity to maintain a stable and coherent percept), then loading perception should have the effect of reducing the ability to perform facial social evaluation (unless perception is biased to certain salient stimuli, either positive or negative and independent from attentional constraints). It is these uncertainties that we will now explore!

2 General Methods

"It is the common wonder of all men, how among so many million of faces there should be none alike".
Sir Thomas Browne. (1605–1682) Religio Medici.

"It is of the highest importance in the art of detection to be able to recognise, out of a number of facts, which are incidental and which are vital. Otherwise your energy and attention must be dissipated instead of being concentrated" Sherlock Holmes - (The Reigate Squire in "The Memoirs of Sherlock Holmes" - Conan Doyle, 1894/2001).

Overview

This Chapter includes general information on the theoretical methods that are employed in this thesis. It begins with a general methodological approach and overview (2.1) before moving onto a deeper discussion of the study of perceptual load (2.2) and functional magnetic resonance imaging (fMRI) (2.3). A substantial part of the literature on attention and automaticity relies on neuroimaging methods and indeed fMRI is employed to study facial judgments in Chapter 6. After a brief review of signal detection theory and decision-making (2.4), a theoretical approach used in the later stages of this thesis (Chapter 4 and Chapter 5), this section concludes with a discussion of dimensional face spaces (2.5). Given the importance of dimensional face spaces and the stimuli they generate to this thesis, this subsection gives a background description of face space construction and how they can used to systematically investigate how faces are perceived and evaluated.

2.1 General Methodological Approach and Overview

This thesis incorporates an amalgamation of behavioural methods, functional brain imaging, and decision-making models, to attend to the issues and hypotheses reviewed in the preceding Chapter. In this thesis I investigate the effects of attention and automaticity on social judgments from facial appearance. The statistical methods employed, along with functional imaging and any modelling procedures specific to each experiment, will be described within the individual Chapters. In the following experiments, healthy right-handed, participants, with normal or corrected vision and no history of neurological or psychiatric disorder (except for Chapter 5 where Parkinson patients are examined) completed judgment tasks that I developed to tackle a particular research question of interest or customized from tasks used previously in the research literature. For the purpose of lucidity and clarity, these tasks, the number of participants, their mean ages and gender ratios and the specific methodological details for each experiment are provided in each experimental section separately.

Below, I present some of these methods and discuss what they add to the study of facial social judgments.

2.2 The Study of Perceptual Load

There has been a long debate as to the importance of selective mechanisms in cognitive processing and to its position (whether early or later) in the sequence of perception processing (Pashler, 1984). As mentioned in the general introduction in the last Chapter, in a series of studies, Lavie and colleagues (Lavie et al., 1994; Lavie, 1995) proposed a hybrid model, which by combining aspects of both the early and late selection viewpoints in selective attention research, aimed to clarify the contradictory results that had bedevilled the attention literature. This section will give a brief overview into the background of the theory (however for a fuller review see (Lavie, 2005; Lavie, 2010).

The Perceptual load theory of selective attention and cognitive control provides both a reinterpretation of prior research whilst simultaneously permitting empirically testable predictions. Load theory assembles the early and late selection approaches by proposing two primary postulates: The first is that the perceptual system does indeed have limited capacity (as proposed by early selection). The second, is that all stimuli, irrespective of their relevance to the task at hand, are processed automatically (as in late selection) – but only until perceptual capacity is exhausted (Lavie et al., 1994; Lavie, 1995). To expound this, an increase in perceptual load is conceived of as either (i) an increase in the number of items in a display e.g., increasing the search selection in a visual search task, or (ii) an increase in the perceptual demands of the task, while viewing the same display, e.g., responding based on a conjunction of features as opposed to a single one (Treisman, 1988; Lavie, 1995), these additional items displayed or additional operations required under high perceptual load consume capacity in the load theory framework. Mechanistically, this implies that there is a relatively passive selection system in which the level of perceptual load determines the degree to which irrelevant distractor stimuli will be perceived. When the intensity of perceptual load involved in processing task-relevant stimuli is sufficiently high to consume perceptual capacity, no capacity remains for processing of distractors, leading to their exclusion from perception. Hence, if the perceptual load imposed by the task at hand is low and does not consume capacity, any remaining capacity will 'spill over' and lead to obligatory processing of irrelevant distracters. In sum, low perceptual load will result in late selection (thus enabling distractor interference) conversely high perceptual load will yield early selection, as distractor interference will be prevented. In contrast to this predicted pattern of effects for perceptual load, load theory asserts that that as a consequence of high working memory load, (that is when subjects do a task while also actively holding in memory data related to another), the task performance will produce an increased processing of irrelevant distractors due to the reduced capability to actively hold the stimulus-processing priorities of the primary task while working memory is loaded in another task. This prediction has been established by research both in the behavioural and neural domain e.g. (Dalton, Lavie, & Spence, 2009; Lavie & de Fockert, 2005). Of particular relevance to facial judgments, in experiments using images of faces or scenes, neural responses to irrelevant distractors in visual association cortex, particularly the fusiform face area and parahippocampal place area were found to increase under high working memory load (Rissman, Gazzaley, & D'Esposito, 2009). Such neural effects are also evident for distractor competition effects in primary visual cortex using object categories (such as fruits and household items) see (Kelley & Lavie, 2011; Lavie, 2010; Lavie, 2005).

A large number of studies, using both behavioural and neuroimaging approaches have provided empirical support for load theory. Behaviourally, perceptual load has been generally investigated by employing the flanker paradigm or a variation thereof, where the level of perceptual load was modulated by altering the number of items in the attended set (Lavie, 1995; Lavie & Cox, 1997) and subsequently measuring the effect this had on processing of irrelevant distractors. I mention this paradigm as it is an ancestor of some of the experimental paradigms employed in this thesis. In these Flanker paradigms, Participants searched for a target letter at fixation, deciding whether it was an X or an N on each trial. The target could appear in one of six pre-defined locations. Under low load it could either appear alone (Lavie, 1995) or accompanied by the letter ‘O’ in all other locations (Lavie et al., 1997)). Under high load, the other five relevant locations were occupied by non-target angular letters that were dissimilar to each other. Distractor letters, which were to be ignored and could be either congruent or incongruent with the target, appeared in the periphery (see **Figure 2-1 a**). These experiments were to some extent prototypical of load theory and in accordance with its predictions. Under low perceptual load, response conflict due to distractor interference was evident. This was revealed by reaction times in trials with an incongruent distractor were significantly longer than in trials with a congruent one. Under high perceptual load, however, such differences were eliminated, indicating that distractors had not been processed (**Figure 2-1 c**), and also confirmed when distracters were presented at fixation (Beck et al., 2005).

The modulation of attention by perceptual load has been demonstrated in a number of diverse studies, whether by varying the number of items in relevant locations in the display or to varying task demands whilst maintaining identical conditions. An example of the former is the interference exerted by pictures of meaningful 3D distractor objects in a word categorization task (fruits versus musical instruments (Lavie et al., 2003). Target words appeared somewhere on the screen’s vertical meridian, either on their own (low load) or accompanied by meaningless letter strings (high load). Distractor pictures appearing in the left or right hemi-field produced interference effects only under low perceptual load.

Of particular relevance and interest to this thesis, is a perceptual load task in which the goal was to classify a famous name as either a singer or a politician, and a picture of a famous person’s face, either the same person as the target name, or someone from the other category function as the distractor. As mentioned in the last Chapter, the interference from such faces was not modulated by perceptual load. Furthermore, employing covert priming, that is more rapid identification after earlier exposure to task-irrelevant famous faces was not affected by the perceptual load of the task carried out during initial exposure to the faces (Jenkins et al., 2002). As highlighted in the general introduction, this result that famous distracter faces are processed at some level regardless of the level of the perceptual load task-relevant processing may be explained in terms of attentional priority for stimuli of high social significance. However, there is evidence that load may not be effective on the neural processing of emotional stimuli, which are also presumably stimuli of high social significance. Pessoa et al, (Pessoa et al., 2002), showed that differential amygdala responses to emotional facial expressions *can* be eliminated by high perceptual load, and thus is an area which requires greater investigation (and which this thesis undertakes).

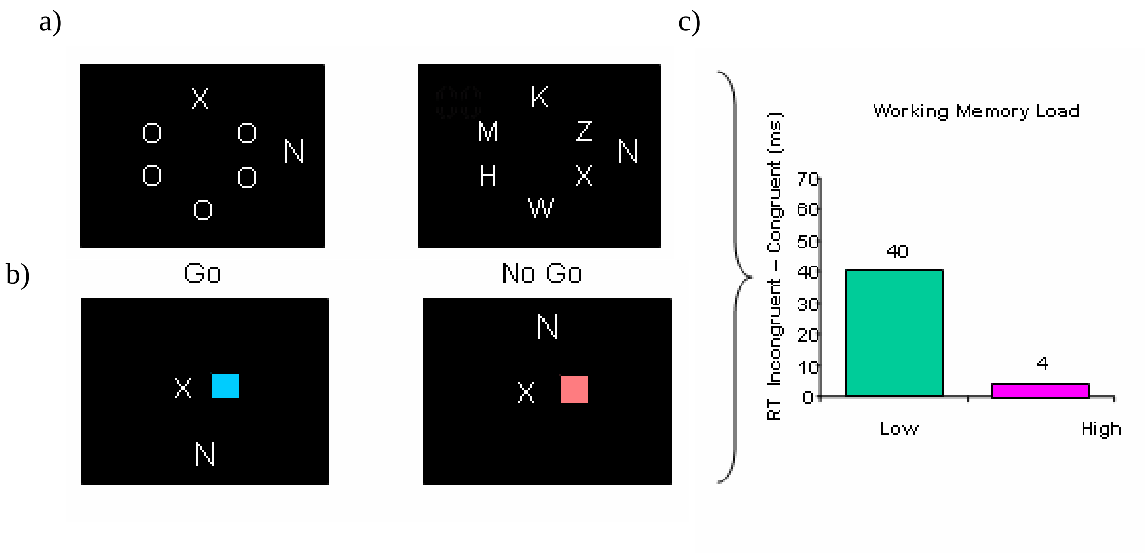


Figure 2-1 Effects on distractor processing by manipulations of perceptual load in the flanker task
In these tasks, participants make a speeded response, indicating which of two target letters (X or N) appears in one of several pre-defined locations while trying to ignore an irrelevant distractor. Distractor interference (and therefore processing) is indicated by slower responses in the presence of an incongruent compared with a congruent distractor. (a) Perceptual load is manipulated by changing the number of non-target items in relevant locations that are similar to the target (angular) and dissimilar to each other, from none under low load (left), to five under high load (right). The distractor occurs outside the circle of relevant locations (Lavie & Cox, 1997). (b) Perceptual load is engineered by increasing the processing requirements for the same displays. Under low load the presence of any blue shape designate 'go' – meaning a response to the target should be made (the other colour, red, indicates 'no go'). Under high load stimulus conjunctions (e.g., blue square or red circle) designate 'go' (Lavie, 1995). (c) Distractor interference effects (incongruent minus congruent RTs) are greater under low than under high perceptual load (adapted from Lavie, 2005).

The manipulations of perceptual load described above varied the number of items in relevant locations in the display. Perceptual load can also be manipulated by the attentional burden. For example, distractor interference effects were measured while participants performed a task in which the correct response was determined either by a single stimulus feature (low load) or a conjunction of features (high load) see **Figure 2-1 b**) (Schwartz et al., 2005). Again, results showed that distractors exerted greater interference under low (compared to high) perceptual load, moreover modulating perceptual load was also shown to affect implicit learning of the spatial configuration of irrelevant distractors (Jiang & Chun, 2001).

Encouragingly neuroimaging studies also indicate the same conclusion. Neural activity in stimulus-sensitive brain regions has been shown to decrease under high (compared to low) perceptual load, when the specific stimulus these regions respond to preferentially was task irrelevant. In one of the earliest studies on perceptual load, Rees and colleagues demonstrated that activation in area MT evoked by unattended moving stimuli was abolished when subjects performed a linguistic task of high attentional load relative to a low-load version of the task at fixation (Rees, Frith, & Lavie, 1997). Indeed, even in early visual cortex, visual cortical activity evoked by task irrelevant checkerboards can be reduced under high load (**Figure 2-2 i**). This effect was found in areas V1, V2, V3 and ventral V4, with the magnitude of the effect increasing with successive visual areas, being clearly present as early as V1 (**Figure 2-2 ii**) (Schwartz et al., 2005). In particular, perceptual load at fixation even affects the spatial tuning of population receptive fields in early visual cortex (V1–V3) (de Haas, Schwarzkopf, Anderson, & Rees, 2014).

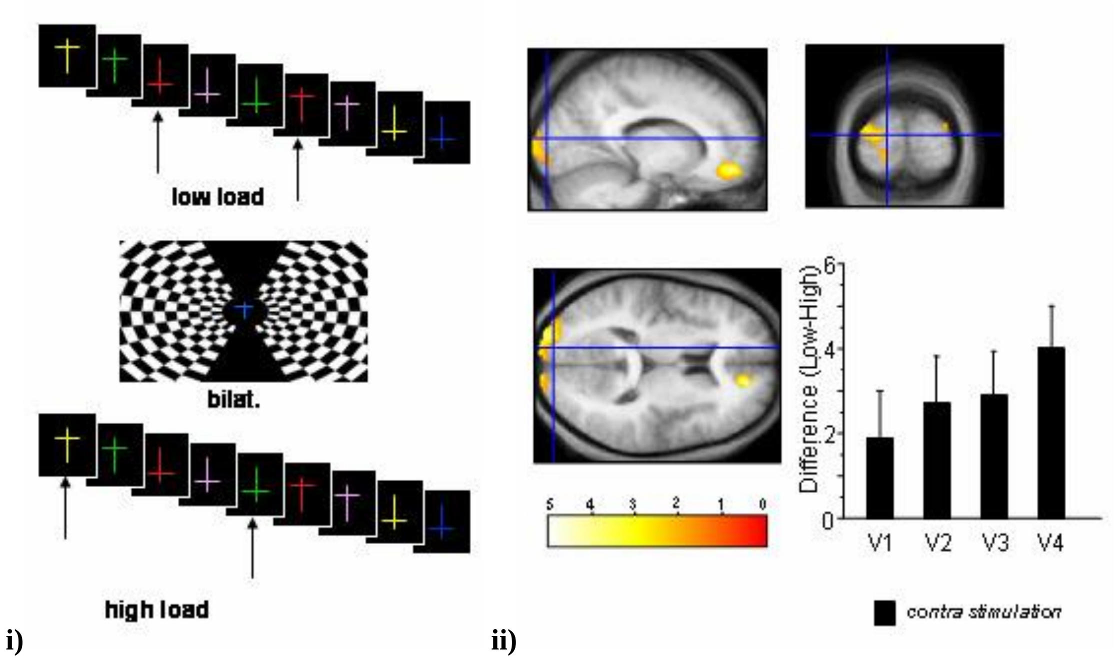


Figure 2-2 The effect of perceptual load on retinotopic visual cortex activity evoked by irrelevant stimuli. Stimuli and results in (Schwartz et al., 2005). (i) Stimuli: A rapid stream of coloured crosses was presented at fixation; participants monitored for the assigned target defined at the beginning of each stream. Under low load, targets were identified by a single feature (colour; red crosses). Under high load, targets were defined by a conjunction of features (colour and orientation; upright yellow *or* inverted green crosses). Irrelevant contrast-reversing checkerboards were presented in the periphery either bilaterally (shown), on one side or on neither side. (ii) Results: Visual cortex activity evoked by the checkerboards (pooled across unilateral and bilateral conditions, contrasted with the no-checkerboard condition) is greater under low than under high perceptual load in the central task. The bar chart shows that the difference increases monotonically from visual area V1 to V4. Adapted from (Schwartz et al., 2005)

The answer to “where” in the visual processing stream load effects are implemented is still unresolved, as is indeed is to whether there are attenuation or disattenuation effects when load effects are implemented. However, considering the above studies, it is perhaps unlikely that the exhibited reduction in distractor interference was due to an increase in distractor inhibition under high perceptual load, as the results are more consistent with an attenuation of distractor perception under high load (Lavie, 2010). Some aspects of the processing stream under load are more apparent though. For example in a nice study by Yi et al., (Yi, Woodman, Widders, Marois, & Chun, 2004) in an experiment employing a stream of faces appearing in the middle of scenes, there were results indicating that under perceptual load but not WM load, unattended distractors were suppressed at stages of visual processing before extrastriate encoding. These effects suggest that perceptual attention relies on a distinct early selection mechanism and is dissociable from working memory load.

2.3 Functional magnetic resonance imaging (fMRI)

Functional MRI affords a non-invasive method for investigating the neural mechanisms underlying behaviour and subjective experience and provides a reasonably good spatial resolution and 3D localization of brain activity, with the caveat of an inferior temporal resolution as compared with other neuroimaging modalities such as M/EEG (magnetoencephalography is mapping brain activity by recording magnetic fields, electroencephalography is the recording of electrical activity along the scalp) or single unit recording, due to the delayed and dispersed nature of the haemodynamic response function. The principle method employed for cognitive neuroimaging is the Blood-oxygenation level dependent (BOLD) contrast, which is taken as a surrogate for neural activity associated with cognitive functions. The following paragraph briefly describes the origin of this signal.

Magnetic resonance imaging (MRI) quantifies the radiofrequency energy discharged by relaxing hydrogen atoms, from a high energy induced radiofrequency pulse, to a resting state along the longitudinal axis of the scanner magnet (conventionally termed B0). This relaxation, designated as T1 relaxation amplifies the strength of the MR signal in the B0 direction, where crucially its relaxation speed changes contingent upon the tissue type (thus permitting signals from grey matter, white matter and cerebrospinal fluid (CSF) to be discriminated). Following the radiofrequency pulse, the spins of adjacent molecules are all in phase. This provides another form of hydrogen atom relaxation, termed T2. As these spins diphase (the excited protons or hydrogen atoms, initially in phase, begin to diphase between two energy states), there is a decline in the MR signal, the speed of which is also exclusive to the tissue type.

Of particular interest to the field of cognitive neuroscience, is the fact that inhomogeneities in the magnetic field prompt the T2 signal to decay more rapidly, the term for this decaying signal is T2*. As neuronal activity due to sensory, motor, or cognitive processes causes changes in metabolic demand, specifically oxygen consumption, a change in oxygen consumption will be physiologically indicated by a change in de-oxygenated haemoglobin concentration, yielding a consequent change in magnetization properties. As deoxygenated blood is paramagnetic (Pauling, 1977) the composition of blood therefore produces larger inhomogeneities in the local magnetic field, with the consequence that the T2* signal is relatively more rapid to decay in areas with a higher ratio of deoxygenated to oxygenated blood. The change in MR signal caused by this altered concentration is what is referred to as the BOLD contrast and permits us to make an inferences about an increase in the underlying neural activity of that brain region (Viswanathan & Freeman, 2007). However, while fMRI is a fantastic tool for investigating the haemodynamic dance of cognition the caveat that it is an indirect measure of neuronal activity should be borne in mind in interpreting fMRI results, from both an inferential and physiological level. Firstly, from the inferential perspective arises the challenge of reverse inference; that is concerning the role of particular brain regions in cognitive function (Russell, 2008) potential uncertainty arises when certain brain areas are assumed to single out the activation of previously labelled cognitive processes (Harrison, 2008; Poldrack, 2006). Conversely, forward inference or data-chaining, that is employing patterns of brain activation to distinguish between competing cognitive theories (not used in this thesis) is also with its attendant pitfalls (Henson, 2006). Secondly, physiologically, an increase in a particular area invokes the interpretation that this region is ‘active’ for that cognitive event, where the increase in BOLD signal is a result of an overall increased spiking rate of cells in the appropriate microcircuit. Yet , it could be for example a result of balanced, proportional increases in excitatory and inhibitory conductance, a net excitation, or even an increased inhibition (Logothetis, 2008) .

Like all research techniques, functional magnetic resonance imaging has theoretical and methodological restrictions, however, overall, neuroimaging can aid in understanding better the nature of social cognition, providing additional evidence for advancing the understanding of facial social judgments mechanisms, how they are modulated and the machinery that sub-serves this process.

Functional data is analysed in this thesis via the construction and assessment of spatially extended statistical maps to test hypotheses about functional imaging data. These ideas have been instantiated in software that takes its name from these maps, SPM. The Raw fMRI image data is often pre-processed (e.g. smoothed to boost signal detection) to arrive at a final statistical map indicating activation based on the general linear model (GLM) (for more info see (Friston, Ashburner, Kiebel, Nichols, & Penny, 2011) and see **Figure 2-2** for the SPM image processing “pipeline”).

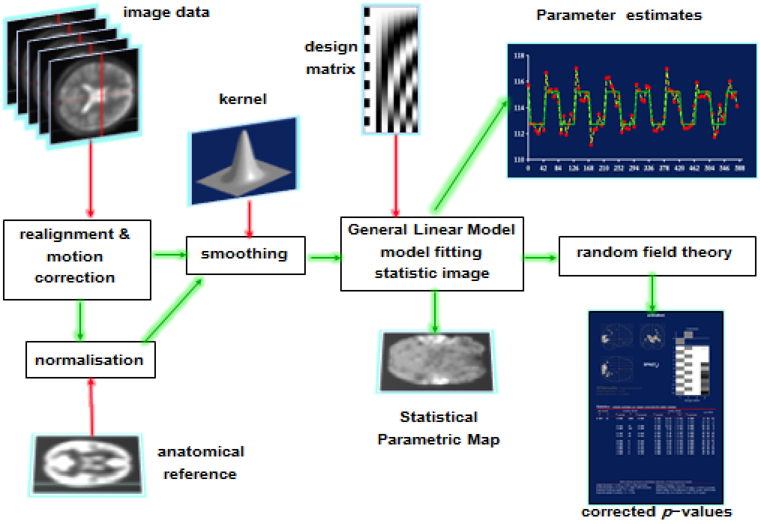


Figure 2-3 SPM processing pipeline

2.4 *Signal Detection theory and Decision-Making*

As babies, one of the earliest stimuli that we are exposed to is the human face; a stimulus that we rapidly learn to identify and discriminate from others. Over time this process ultimately yields a face discrimination capacity which is readily employed in our day to day lives. Like most cognitive processes the complexity of the underlying visual mechanisms involved in this discrimination are exposed when we attempt to computationally model this categorization. The act of simple categorization and the errors that it provides can be exceedingly useful in understating how a system works. The next section presents a relatively simple approach employing categorisation errors which can be used to probe the functioning of facial judgments - a framework that has been employed for many perceptual tasks, such as visual search (Verghese, 2001).

Signal detection theory (SDT), is a method to quantify the ability to discern between signal and noise. The theory proposes that there are a number of core elements regarding how a detecting system will perceive a signal, and where its threshold levels will lie. The theory can account for how changing the threshold will affect the ability to discern, often revealing how adapted the system is to the task or goal. SDT elucidates how performance accuracy depends on the strength of the target stimulus ("signal") compared with non- targets, while in the context of variability or noise in the signal strength (over the course of test trials).

The groundwork for the psychological side of the theory was expounded by Green and Swets (Green & Swets, 1966) criticizing the traditional methods of psychophysics for their inability to discriminate between the real sensitivity of subjects and their (potential) response biases. Their argument was that the decision maker was not a passive, but instead active receiver of information, making perceptual judgments under conditions of uncertainty.

To apply signal detection theory to a data set where stimuli are either present or absent, the observer categorizes each trial as having the stimulus present or absent, this permits the trials to be sorted into one of four categories:

	Respond "Absent"	**Respond "Present"**
Stimulus Present	Miss	Hit
Stimulus Absent	Correct Rejection	False Alarm

Figure 2-4 Signal detection framework

Performance can be analysed into two distinct elements: the degree to which the observer's responses mirror the stimuli and the degree to which they display bias. Measuring these two elements requires a theory; the most commonly employed being the normal-distribution variant of detection theory.

Two of the experiments within this thesis employ a signal detection theory model-based approach to assess detection accuracies and responses of the participants in those tasks. I employ the simplest signal detection theoretic approach - a one-interval design, in which a single image is presented on each trial (measuring the ability to distinguish between social aspects of faces in which observers can be more or less accurate). This is a correspondence experiment in which the stimulus is drawn from one of two stimulus classes and the observer endeavours to say from which class it is drawn (a correspondence experiment is one in which each possible stimulus is assigned a correct response from a finite set (of faces with respect to the experiments in this thesis)). Correspondence offers an objective standard or expectation against which to assess performance. Detection theory measures the discrepancy between the two (and may therefore be viewed as a method for understanding error also).This allows the measurement of discrimination, namely the ability to tell two stimuli apart. When one of the two stimulus classes contains only the null stimulus, that is a face with a neutral valence or emotion, such a task is termed detection, and the possible responses are essentially "present" and "absent". Measures of performance in these kinds of tasks are also called sensitivity measures: High sensitivity refers to a high-quality capacity to discriminate and conversely low sensitivity to a low quality. Experiments of this sort have been performed to compare memory for faces of different races, orientations (upright vs. inverted), and many other variables (for a review, see (Shapiro & Penrod, 1986)).

The observer's performance is evaluated in two distinct partitions: the degree to which the observer's responses parallel the stimuli and the degree to which they display bias. As all possible responses can be categorized as in **Figure 2-4**, we seek to have a measure that goes up when Hits goes up, goes down when False alarms goes up, yet simultaneously assigning equal importance to these statistics. The difference of Hits minus False alarms has in fact these very characteristics. Although in reality, the most widely used sensitivity measure of detection theory (Green et al., 1966) is called d' and is defined in terms of z, standardized scores of the normal distribution function:

$$d' = z(\text{Hits}) - z(\text{False alarms})$$

The z-transformation converts a hit or false-alarm rate to a z score (i.e., to standard deviation units). For example, a proportion of 0.5 or 50 % is converted into a z score of 0, larger proportions into positive z scores, and smaller into negative.

The second component of the decision process, also of interest, is known as the response bias. Response bias measures the participant's inclination or favouritism towards a particular response. While the sensitivity measure d' depends on stimulus parameters, but is unadulterated by response bias, correspondingly the index of response bias is unadulterated by sensitivity. As a response-bias index is intended to measure the participant's inclination to state one of the categories, it is designed both to depend systematically on both the Hit and False-alarm rates and go in the same direction (that is either increasing or decreasing in both (sensitivity measures are defined to increase with Hits and decrease with False alarms, an analogous property)). The latter implies that a response-bias index should depend on the sum of terms involving Hit and False-alarm rates, in contrast, the sensitivity statistic *d'* hinges on the difference between the Hit and False alarms values. Response-bias statistics reflect the degree to which "present" or "absent" responses are favoured. A positive bias is defined as a tendency to say "no," whereas a negative bias is a tendency to say" yes" (the rationale implicit in the formula below).

The basic bias measure, termed *C* (for Criterion), is defined as:

$$C = - (1/2) [z(\text{Hits}) + z(\text{False alarms})]$$

Employing this scheme, when the false-alarm and miss rates are equal yields *z*(False alarms) = *z*(l- Hits) and therefore *z*(False alarms) = -*z*(Hits) and thus cancel each other. Consequently, we have the desirable feature that *C* equals 0. Hence when the criterion *C* = 0, the observer is said to be ‘unbiased’. Negative values arise when the false-alarm rate exceeds the miss rate, and positive values arise when it is lower. Extreme values of *C* occur when Hit and False-alarm rates are both large or both small: If both equal .99, for example, *C* = -2.33, whereas if both equal 0. 01, *C* = +2.33. The range of C is therefore the same as that of *d'*, although 0 is at the centre rather than an endpoint.

The aforementioned summarizes the basis of SDT. In a nutshell, SDT assumes a noisy response to each stimulus and determines how criteria or decision rules classify the stimuli to make a response; it separates the true *discriminability* of target and distractor stimuli from possible shifts in the *criterion* used to make the discrimination (i.e. a mere response bias).

For a further review see (Macmillan & Creelman, 2005).

2.5 Dimensional Face Spaces

Finally, to methodically explore how faces are perceived and to perhaps to reduce some of the variance in experimental responses to faces (and in the experimental results observed in the last Chapter) it could be advantageous to restrain the image stimuli employed for research purposes. Most face data-sets attempt to reduce the intra-image variation due to diverse sources of variability, ranging from camera distance, lighting variation, etc. There is however the additional challenge of obtaining face stimuli, varying on certain social dimensions (such as trustworthiness), whilst simultaneously maintaining other dimensions constant. To achieve any exactitude in this endeavour requires the use of computational techniques for face stimuli generation; although, by using any particular face space –and the algorithmic techniques that generate it, it does not follow that there is a commitment by this thesis (and researchers in general) that the brain is actually encoding faces in that manner (or indeed that the world is presenting faces in this manner) (although see the novel approach of Gao and Wilson whom provide evidence that dimensions of a face space are encoded in the face-selective brain areas in a spatially distributed way (Gao & Wilson, 2013)). Encoding face techniques can range from norm-based coding, (faces are coded in terms of their deviations from the norm or centre of the space) (Rhodes &

Jeffery, 2006) to whether they are coded exemplar-based in terms of absolute values on the dimensions of the space (Lewis, 2004)).

Given the importance of dimensional face spaces and the stimuli they generate to this thesis, a brief (and incomplete) account and analysis of face space construction is helpful and considered here. This accounts builds up to the face space model (Oosterhof & Todorov, 2008) used to construct stimuli and applied in the experiments in this thesis to examine face processing judgments (and their modulation by attention).

One of the earliest experimental approaches exploiting computer generated face images, employed face stimuli with systematic enhanced or reduced distinctiveness (Brennan, 1985; Rhodes, Brennan, & Carey, 1987). In this early model, the face images were generated with a "caricature generator," where the principle computational step was to digitize a photograph of a specific face and situate the main face features in a two-dimensional coordinate system by inserting a multitude of key points on the face (169 specifically). This method, although painstaking, allowed researchers to morph between any two faces and to exaggerate the characteristics of any face as compared to another. The latter approach was one of the first steps toward the objective of having a fully parameterized face stimulus, although due to the model's minimalism (in the sense of it being a line-drawing model with low detail information), meant the resultant stimuli which it generated possessed low ecological validity. Even so, interesting research could be conducted with this model. For example, as a consequence of this face space, Brennan and colleagues showing that caricatures (faces with enhanced distinctiveness) were more easily recognized than the veridical faces or anti-caricatures (faces with reduced distinctiveness)(Brennan, 1985).

The legacy of the caricature generator approach was felt in the numerous extensions which followed Brennan and colleagues early model, seeking to increase the sophistication of the models, improve ecological validity and control of the stimuli. Proponents of the caricature generator took an important step forward in the 1990s by modifying the method of caricaturing faces through increasing the distance from a stimulus face to a norm, to photographs of faces (Benson & Perrett, 1991). While more ecological validity was gained with this adaption of Brennan's work (Brennan, 1985), the absence of a clearly defined theoretical model implied that this face space was perhaps more a physical one rather than a psychological facial space. Nevertheless, the key point in the caricature generator approaches and its subsequent extensions, whether by generating composite faces (Langlois & Roggman, 1990) or producing caricatures of photographs (Benson et al., 1991), was that more experimental control over the facial stimuli was provided (as every face could be described with simple more or less distinct relations with every other face).

Ultimately, all of the latter approaches implicitly relied on the concept of a face space, that is, the concept of a set within which faces reside and vary along a number of dimensions. However, it was not until Valentine's proposal of a theoretical face-space framework (Valentine, 1991) that this notion was made explicit. Within Valentines framework, each face was construed to be represented as a point in a highly dimensional space, with dimensions corresponding to features that were used to encode and discriminate between faces. An added benefit of this approach was that common notions such as distance could be employed to represent face similarity (potentially also matching up to putative psychological representations where similarity relations between faces could correspond to those distances). This construction however was agnostic on the specific nature of these dimensions. Nevertheless, the concrete example of a face space framework provided the impetus for researchers to seek to capture the implicit dimensions of facial images by principle component analysis (PCA).

Introducing PCA as methodology was a new development which permitted faces to be reconstructed on the basis of exemplar faces and provided the capacity to synthesize a wide range of novel faces by forming linear combinations of exemplar faces (although the methods still required that the faces were aligned or set in correspondence by marking a limited set of key points by hand (Hancock, Burton, & Bruce, 1996).

Subsequent models removed this handicap of requiring the manual selection of key points to create three-dimensional parametric face models where all faces were in full correspondence (e.g.(Blanz & Vetter, 1999)).

The foremost benefit of faces generated with these dimensional methods was the provision of increased experimental control over the generated stimuli (as they could now be precisely located within the face space). Once again, this increase in face space complexity and experimental control generated interesting and novel inquiries. For example, the ability to morph images permitted the investigation of whether male and female faces are discrete categories at the perceptual level (suggesting that gender information present in faces is not naturally perceived categorically) and allowed researchers to tease out the role of features such as "averageness" in the relationship between age, attractiveness and gender (Bulthoff & Newell, 2005; O'Toole et al., 1998).

Although a face space could presuppose some overlap in the features that characterize a face, our experience in the world informs us that each face is unique in its own way, meaning that varying the distinctiveness of face images results in varying identity. The distinctiveness of a face (or its atypicality) may be an important factor for face perception and recognition tasks (O'Toole et al., 1998), particularly in memory based tasks. In face recognition, the aim is to focus on the features that make a face unique, while in contrast in social categorization or facial expression analysis; one is required to focus on the characteristics that a face shares with other faces. Leaving aside temporarily the fact that social judgments may be highly inter-correlated, the contingency of distinctiveness and individual facial appearance allude to limitations for experimental research, since other relevant factors for face perception such as attractiveness or gender-typicality cannot be controlled. It is for this reason that employing dimensional face spaces are so useful in the investigation of facial social judgments. Dimensional models offer the possibility of permitting the examination of a variety of facial judgments all underpinned by fundamental structural components. For example, a recent social face space (discussed further below), showed that judgments of threat could effectively be represented as a linear combination of untrustworthiness and dominance (Oosterhof et al., 2008).

Drawing upon and inspired by the dimensional computational models of human faces discussed above (e.g. (O'Toole et al., 1998; Valentine, 1991)), Oosterhof and colleagues, performed the relatively rudimentary operation of a principal components analysis on judgments of both natural and computer generated faces (Oosterhof et al., 2008), to produce a model in which the first two components, interpreted as valence/trustworthiness and power/dominance, accounted for most of the variance in the individuals' judgments of those faces. With these two components, models representing how faces change along these dimensions (**Figure 2-5**) could be constructed.

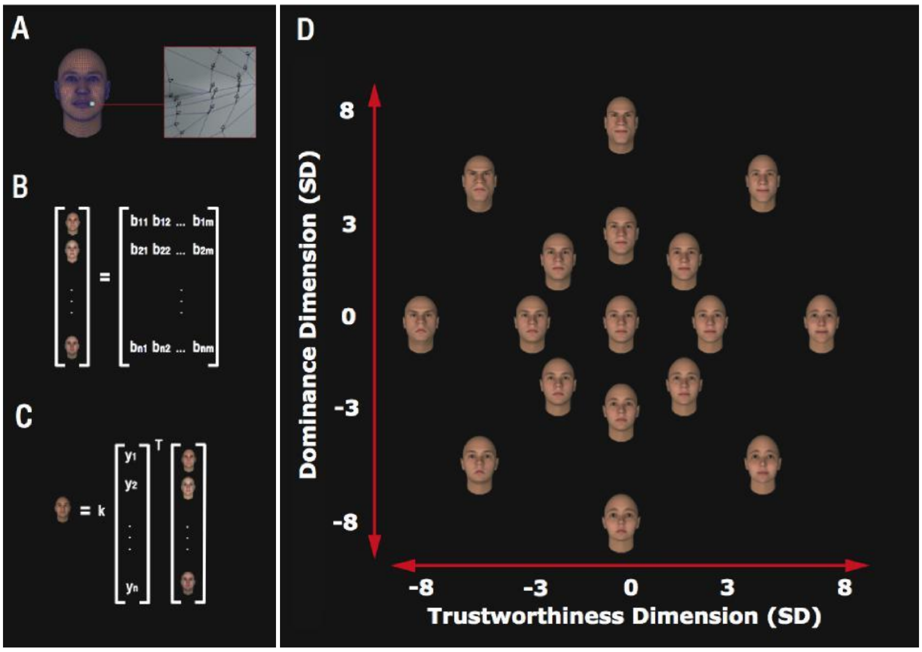


Figure 2-5 Computational stages in the modelling of social judgments of faces
A) Diagram of how the face model produces faces (with a surface mesh on the right placed on an average face). B) A set of n random faces can be obtained by linear combinations of the m shape components, and represented in an *n* by *m* matrix. These dimensions are obtained from a principal component analysis of shape variations of the vertex positions from the mesh (and may not have intrinsic psychological meaning). Each row of the matrix contains the set of *m* weighting coefficients corresponding to a particular face. C) Each of the *n* faces is rated by participants on a trait dimension and given an average score *yj*. Multiplication of the social judgments vector by the set of randomly generated faces generates a dimension that is optimal in changing faces on the trait dimension, which can be controlled with a tunable constant *k*.
The figure above shows the production of one face along the trustworthiness dimension. From the aforementioned we reach D) a two-dimensional model of evaluation of faces. Examples of a face with exaggerated features on the two orthogonal dimensions –trustworthiness plotted on the x-axis and dominance plotted on the y-axis–of face evaluation.
The changes in features were implemented in a computer model based on trustworthiness and dominance judgments of n = 300 emotionally neutral faces. The degree of face exaggeration is presented in SD units. The faces on the diagonals were attained by averaging the faces on the trustworthiness and dominance dimensions. The diagonal dimension passing from the second to the fourth quadrant was nearly identical to a dimension based on threat judgments of faces (the contrasting orthogonal dimension from the forth to the third quadrant is argued to be comparable to dimensions empirically obtained from judgments of likeability, extraversion, and competence) (Adapted and reproduced from (Oosterhof et al., 2008)).

Investigating a range of faces that varied along these trustworthiness and dominance dimensions, Oosterhof and colleagues showed that the judgments performed on faces generated from these dimensions are based on associations to facial cues that have adaptive significance (see **Figure 2-5** for an illustration of the type of faces generated). Exaggerating faces along the trustworthiness dimension resulted in faces deemed as ranging from angry faces at the negative end, to happy faces at the opposing end of the spectrum, mirroring prior social perception research implying that the valence evaluation of faces is based on cues instigating approach/avoidance behaviour (by the perceiver). In contrast, exaggerating faces along the dominance dimension resulted in faces deemed particularly mature and masculine on the dominant extreme of the scale and correspondingly in faces deemed particularly neotenous and feminine on the submissive end of the dimension. Encouragingly, this latter observation is consistent with a rich body of evidence about the importance of neotenous and sexually dimorphic features in face perception (Perrett et al., 1998).

In general, the findings suggest that inferences along the valence/trustworthiness dimension are about the intentions of the person with respect to potential harm and inferences along the power/dominance dimension are about the capacity of the person to implement these intensions (Oosterhof et al., 2008) (for convergent evidence from dynamic stimuli, also see (Oosterhof & Todorov, 2009).

In retrospect, Oosterhof and colleagues approach appears like a natural progression from the face dimensional approaches that we have discussed above, into territory seeking to capture more nuanced social judgments (such as trustworthiness). What is more, there is an appealing symmetry reflected within their face dimensional model, due to the fact that since trait judgments from faces in general are themselves highly correlated with each other (Oosterhof et al., 2008), the dimensions which they reveal in their model of facial judgments may in fact represent a fundamental dimensional structure that underlies social perceptions. Such a position is supported by the fact that this two-dimensional solution has the added advantage of external validity, corresponding to other dimensional models of social perception such as the stereotype content model (Fiske, Cuddy, & Glick, 2007; Wiggins, 1979). Similar to the approach of Oosterhof and colleagues', the stereotype content model maps out how people perceive social groups on two dimensions of social perception: warmth and competence. The warmth dimension captures traits that are related to perceived intent, including friendliness, helpfulness, sincerity or, directly relevant to Oosterhof and collegues' approach, trustworthiness (Fiske et al., 2007) . Both warmth and trustworthiness result from instantaneous judgments of faces as happy or angry (Todorov, Said, Engell, & Oosterhof, 2008c).

The second dimension, the competence dimension, reflects traits that are related to perceived ability, including intelligence, skill, creativity and efficacy (Fiske et al., 2007). Competence can also be inferred instantly from faces, based on cues to apparent physical strength, masculinity, and maturity and hence apparent dominance (Todorov et al., 2008c).

There is a clear core linkage between the two essential dimensions of person perception, warmth and competence (Fiske et al., 2007) and the related traits of trustworthiness and dominance that reflect judgments of approach-avoidance and physical strength, respectively. The overlap of these models and dimensions arguably demonstrates their evolutionary importance, however labelled, in capturing traits critical in social perception encounters with conspecifics. Social perception reflects evolutionary pressures and most likely this is reflected in the dimensions of the face spaces that we have discussed. Presumably, some form of trustworthiness and dominance trait judgments are not just psychometric statistical summations but also reflect important aspects of social perception and cognition. Given that assumption, the dimensional approach to face space stimuli generation then becomes a particularly useful tool for systematically addressing some of the issues which may cause diversity in responses in the facial social judgment literature. However, like any tool constructed for a purpose it is useful to know the limitations of the instrument so that it can better achieve its goal. The two principal limitations of the computer model used by Oosterhof and colleagues relate to the type of information it both uses and neglects in its construction.

Firstly, the computer model used by (Oosterhof et al., 2008) concentrates on shape information almost disregarding texture, which may possibly be a determinant of face perception (shape and texture may be used separately by the human face processing system (Hancock et al., 1996)). As a first approximation this is not problematic, as the research discussed in this section (2.5) indicates, models disregarding texture have been used relatively reliably for many years. However, ultimately more refined models should seek to expand the scope of face biomarkers by integrating facial skin texture and in the long run, facial dynamics (although the latter increases exponentially the complexity of a face space, they may nevertheless be important in identifying subtle facial expressions (Ambadar, Schooler, & Cohn, 2005) and as indicators of trustworthiness (Krumhuber et al., 2007)). Moreover, if we accede to the position that evolutionary processes have shaped our psychological adaptations, then it seems probable that human beings evolved mechanisms for detecting and assessing cues of mate value (Fink & Penton-Voak, 2002). As skin texture cues may be an influential component of such inferences, ranging from fertility, to health, to attractiveness (Fink, Grammer, & Thornhill, 2001), it is likely that such a cue may contribute in complicated ways to the in variability social facial judgments.

The second issue is that these models concentrate on identifying the commonalities among various judgments; however, important behavioural effects may be due to specific non-shared variance. On a related note to the communalities in face perception, is the observation that stimuli from this model do not encompass any non-facial features, whether it be hair, eye colour, or pigmentation which so often differentiate us (for example simple pigmentation differences in redness may enhance perceived aggression, dominance and attractiveness in men’s faces (Stephen, Oldham, Perrett, & Barton, 2012)). Such omissions could impact the ecological validity of the stimuli, this is notwithstanding all the other contextual cues (ignoring race and gender too) external to the face that we most likely employ in facial assessments.

Overall, we believe that the dimensional face space model of Oosterhof and colleagues provides a useful tool to explore the nature and structure of social judgments from faces. Although There are other promising approaches principal components analysis methods, they are generally used more for prediction than generation of facial images (Brahnam & Nanni, 2010).

The future for methodologies investigating the perceptual basis of face evaluation seems bright, as the brief history into faces spaces elucidated here indicates**,** data-driven and computational techniques offer promising avenues to further refine our models. For example Reverse correlation techniques provide a data-driven approach that could potentially be used in the future for the generation of facial stimuli (essentially subjects make decisions on noisy images which are then computationally classified). Such an approach has been employed for investigating the cues used for judgments ranging from the oft considered six basic facial expression signals (Smith, Cottrell, Gosselin, & Schyns, 2005) to the study of social judgment and the prototypical face representations of stigmatized out-groups (Dotsch, Wigboldus, Langner, & van Knippenberg, 2008).

Future work investigating the perceptual basis of face evaluations will no doubt draw on the expanding repertoire of computational techniques to expand our knowledge of the social categorization of faces.

3 Faces and Attention

“He who does not trust enough, will not be trusted”. Lao Tzu

“The face is a picture of the mind with the eyes as its interpreter.” Marcus Tullius Cicero

“Everyone knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration, of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others, and is a condition which has a real opposite in the confused, dazed, scatter-brained state which in French is called distraction, and Zerstreutheit in German”. The Principles of Psychology, James (1890)

Overview

The manipulations that have been established through the study of perceptual load theory can also provide a method for examining the automaticity of face processing. If processing of a certain type of stimulus remains unaffected by the level of perceptual load in an ongoing task, this might suggest that the stimulus can be processed ‘automatically’, regardless of the amount of capacity available. Alternatively, if a facial processing is shown to be effected under high (vs low) perceptual load, this can indicate that such processing does in fact depend on limited-capacity resources.

Many studies propose that emotional and facial stimuli are subject to preferential processing and may be “automatic” insofar as demanding few attentional resources, are not under voluntary control and are not subject to capacity limits (elaborated in Chapter 1). It has been argued that emotional faces are processed automatically due to their high level of sociobiological significance (Vuilleumier et al., 2003), although studies adopting perceptual load manipulations have challenged this viewpoint (Yates et al., 2010).

Famous faces have been shown to remain unaffected by the perceptual load demands of an ongoing task, suggesting that some aspects of face processing may occur automatically (Lavie, Ro, and Russell (2003). In contrast, perception of anonymous faces is significantly reduced under high perceptual load (He & Chen, 2010; Jenkins et al., 2005) suggesting that the automatic processing of famous faces could relate to their high level of familiarity, rather than reflecting prioritized processing of faces in general. These conflicting viewpoints could arise due to methodological differences between studies in this area, precluding a conclusive answer.

Drawing upon a fully parameterized face space stimuli set, constructed with two principal trait components of trustworthiness, dominance and containing the oft studied emotional threat (the latter effectively created by combining the two principle components), we can readdress the above issues within the framework of load theory to investigate people’s perceptual capacity to perform facial social judgments of trustworthiness, dominance and threat under high (vs low) perceptual load. This framework will allow us to investigate whether social facial judgments are "automatic" or contingent to some extent on attentional allocation.

3.1 Introduction - Connecting Attention and Facial Social Judgments

Facial expressions are not random configurations of skin, bone, and muscle; perceivers attribute deep meaning to expressive facial configurations and exhibit affective responses to suggest that the connotation of these configurations could be processed automatically.

From a first-person phenomenological perspective, viewing a face appears to elicit what seems like at least two automatic and rapid processes: categorization of the stimulus as a conspecific face and individual level recognition. These notions were formalized by Bruce and Young (Bruce et al., 1986) whom theorized a stepwise model, whereby categorization of faces according to their race, gender, and other social attributes occurs at an early stage of “structural encoding”, transpiring before the ‘face recognition units’ or the ‘person identity nodes’ are involved (also see **Figure 1-1**).

In the Bruce & Young framework, categorization or judgment refers to the process by which information about a stimulus is employed to connect the stimulus to classes exhibiting common traits, whereas individuation or recognition is the process by which unique traits are associated to an individual (Bruce et al., 1986). Although this thesis does not wish to digress too much upon the architecture of facial perceptual processes (focussing rather on how this system is modulated), the Bruce and Young model is important for its idea of a visually derived semantic code and its recognition of executive top-down procedures in facial expression processing – it is possible that these executive features play a critical role in modifying many facial social judgments such as trustworthiness evaluations.

Aside from what may be considered overt "structural" facial information, such as age and sex for example, we also readily grant to unfamiliar faces, attributions or judgments like honesty and intelligence; this type of information, as said above, Bruce and Young denote as a visually derived semantic code. There is also within their framework, a component which is labelled ‘directed visual processing’. The authors note that selective attention to the visual form of a face could play a central role in certain tasks, that is "as well as 'passively' recognizing expressions, identities and so forth from faces, we also encode certain kinds of information selectively and strategically" (Bruce et al., 1986). Of particular (perhaps prescient) note is the authors claim that classification of the sex and approximate age of a face for example, "may involve different processes from those involved in judging that a face appears honest" - that is to say, that social facial judgment may have different processing route.

This brief aside indicates that attention and social judgment are important mechanisms of any facial expression processing machinery, even if their underlying components are poorly understood. This is illustrated by the fact that the least defined component in the Bruce and Young model is the cognitive system which serves amongst other things to direct attention to various other components of the system such as judgments of concepts as honesty (arguably synonymous with trustworthiness). Exploratory probing of these system components could aid us in the first stages of the long endeavour to reverse-engineer the machinery that generates the complicated social judgments that we perform almost effortlessly and daily in our social environment.

Facial expressions evidently have communicative properties that bear some importance to perceivers; being both informative with respect to the future behaviour of the expressing individual and with respect to agents in the social environment (Knutson, 1996). However in a demanding and constantly changing environment with distributed attention are we receiving these vital facial signals?

To rephrase this question, what is the relationship between attention and facial perceptual awareness? Does it depend on the valence of the face or the type of judgment? For example, in Hansen and colleagues widely cited study, they reported that subjects detected angry faces faster than happy faces in an emotional visual search task (Hansen & Hansen, 1988), suggesting that an automatic pathway could process negative emotional expressions and expedite face detection. Their study insinuates a possible answer to our questions, in so far as that emotional faces may have some intimate connection with attention.

A follow-up study, inspired by the premise that an automatic pathway could process negative emotional expressions and expedite face detection, observed that threatening faces were found to be detected faster than friendly faces, although no effect was found for sad faces, suggesting that this may be a property of threat, rather than reflecting a general effect of negative emotion per se (Öhman et al., 2001). These results could perhaps indicate that threatening cues not only draw attention more strongly, but also hold attention longer than neutral information (Fox, Russo, Bowles, & Dutton, 2001). Both of these effects might be further amplified in anxious people, even below the clinical levels (Fox, Russo, & Georgiou, 2005). There results point to some role of automatic processing in facial perception, if only for certain types of negative faces, but what about other types and expressions of facial social judgment, personality ascriptions such as trustworthiness for example? Can we build upon these results which have primarily focused on the role of attention on emotional faces?

The issue of expression cues and there separation from emotional cues is somewhat complicated by their ontology. Said and colleagues provide evidence that facial social judgment trait inferences are driven in part by structural resemblance to emotional expressions (Said, Sebe, & Todorov, 2009b). In the latter study, after the authors had participants judge emotionally neutral faces on a set of trait dimensions, they were then submitted to a Bayesian network classifier trained to detect emotional expressions (Said et al., 2009b). Their results indicated that neutral faces were perceived to possess various personality traits having objective resemblance to emotional expressions. That is, a semblance to a specific emotional state may be misattributed to personality dispositions that are associated with that state (Said, Baron, & Todorov, 2009a). By and large, neutral faces that are perceived to have positive valence, resemble happiness, faces that are perceived to have negative valence, resemble disgust and fear and faces that are perceived to be threatening, resemble anger (Said et al., 2009a). These results support the idea that trait inferences are in part the result of an overgeneralization of emotion recognition systems, so that even neutral faces owing to structural variations are perceived as conveying information that resemble facial expressions and trait dimensions. Furthermore, as discussed in section 2.5 (Chapter 2), the majority of the variance in trait judgments of neural expression faces (Todorov et al., 2008a) can be collapsed into the dimensions of valence and dominance.

Clearly, however it is described, judgments based on the structural qualities of faces or their "expression" are consequential (Hassin & Trope, 2000) and as trait inferences are in part the result of an overgeneralization of emotion recognition systems, then the results that we have discussed which argue for a role for attention in emotional processing should also apply to traits and facial social judgments such as trustworthiness (although this is as yet an untested hypothesis).

The dimensional components of face spaces (reviewed in Chapter 2, section 2-5) and discussed above provide an avenue to pursue investigating social facial judgments, although there is a trade-off between experimental control and fully naturalistic stimuli, by turning to a fully parameterised face space (Todorov et al., 2008a) we are afforded more control over the face stimuli and hence any possible inferences than can be drawn from them under experimental manipulation.

In a visually noisy, demanding group environment, where social facial judgment is repeatedly required, it’s not just the facial stimuli that are important, but the agents' interest and attention also; what is the relationship between social facial judgment and attention? Are there any methodologies, techniques or breakthroughs that can be helpful in unravelling this relationship?

We know for the review in the general introduction Chapter (Chapter 1) that a possible resolution to the long standing and important debate between early (e.g. (Treisman, 1960; Broadbent, 1958)) and late (e.g. (Deutsch et al., 1963)) selection views of attention was proposed in the form of the load theory of selective attention and cognitive control (Lavie et al., 1994; Lavie, 1995). As we allude in that Chapter, this finding may be useful in elucidating the intricate relationship between facial social judgment and attention. Load theory predicts that the depletion of perceptual capacity under high load for facial stimuli will lead to lower levels of attention being deployed, resulting in reduced social judgment accuracy of facial targets. However, this prediction, as the general introduction Chapter indicated (reviewing the numerous manipulations of facial expression processing studies under attention) is not without controversy.

To this end I now investigate how facial social judgments are encoded and perceived under attentional constraints, beginning with perhaps one of the archetypes of social facial judgment research; trustworthiness.

3.1.1 Experiment 1- Whom to trust?

3.1.1.1 Introduction

Trust has multiple associations and nuances and underlies cooperation, integral to daily life (Rilling et al., 2002). It can be investigated at both the macro and micro levels, from the neurobiological, such as the investigation of the modification of trust via the application of oxytocin (Kosfeld, Heinrichs, Zak, Fischbacher, & Fehr, 2005) to the role of trust in society (Coleman, 1990), with both levels informing each other. An understanding of the micro-behavioural features of trust is important in the broader comprehension of the role of trust in social groups. This is due to the fact that the incorrect appraisal of facial trustworthiness could potentially yield negative consequences, e.g. not trusting a trustworthy individual could indicate a neglected prospect for cooperation (Cosmides et al., 2000). Moreover, correlations between facial trustworthiness and assorted other facial judgments, e.g., attractiveness, happiness (Adolphs, 2002; DeBruine, Jones, Little, & Perrett, 2008; Todorov, 2008) indicate that the social judgment of trust may encapsulate numerous derived trait inferences.

How such a "trait" judgment is related to an "emotional" one is ambiguous, although, it is improbable, that emotion alone drives the decision of trustworthiness as the latter social judgment has been shown to be partially separable from the effects of facial emotion (Adolphs, 2002; Winston, Strange, O'Doherty, & Dolan, 2002).

The relationship between trust judgments (which are to be collected here) and questions of the 'validity' of trust (i.e., do they really predict who we trust) are frequently operationalized in so called economic "trust games" (game-theoretic like tasks, in which the first move is from the second players partner, who must decide how much of their initial endowment to trust with the second player, with the expectation of receiving some of it back). Typically, the first player is encouraged to give something to the second player with an incentive that their money will be increased by a specified factor. In this manner subsequent flows of money are conceived of as a metric of the presence (or absence) of trust. There are numerous variants of this game, in one such game of particular relevance to social judgment from facial appearance, manipulation of facial resemblance in a two person sequential trust game revealed that possessing similar facial features enhanced trust (in their partner) (DeBruine, 2002). Moreover, there is some evidence suggesting that such behaviour in this game is heritable (Cesarini et al., 2008), indicating a broader avenue of relationships between judgments of trust and its mechanisms of assessment, thus if trusting behaviour does not result solely from socialization, perhaps facial assessments involved in such behaviour do not either.

Irrespective of the validity of facial trust judgments, social judgments from perceived information sources in the face are important in social outcomes which rely on kinship or community. Most likely, the relationship between facial assessments of trust and what information trustworthiness in a face can transmit are most likely complex. It is not just (facial) similarity for example that can affect trust (as in the aforementioned DeBruine, et al study); crucial social information such as trustworthy faces may tap systems involved in signalling approach/avoidance behaviours (Todorov, 2008). Furthermore, thus far, the prior discussion of facial judgments of trust has not mentioned the important presence (or absence) of cognitive constraints such as attentional resources. How and whether these judgments of trust are affected by such attentional constraints is the topic of the following study

Given the importance of the assessment of facial trustworthiness both as a potential metric for other traits/emotions and its importance in social outcomes, the purpose of Experiment 1 was to examine whether the perceptual load of a visual search task would modulate the evaluation accuracy of the trustworthiness of standardised faces.

Participants were presented with a circle of letters on each trial and were asked to search for one of the two target letters, *X* or *Z*. They were also asked to classify whether the face presented at fixation inside of the letter circle was trustworthy, by pressing a key (key 1), or untrustworthy indicated by pressing another (key 2). A short practice trial was shown at the start of the experiment. Perceptual load was manipulated by varying the number of similar non-target letters (zero in the low load, five in the high perceptual load condition; the non-target letters were *F*, *K*, *V*, *L* and *T* and in the low perceptual load condition they were all lowercase “o ” - which were smaller than the target letter) (e.g.(Lavie et al., 1997)).

In line with the general predictions of perceptual load theory we hypothesised that high perceptual load would impact the judgment accuracy of trustworthiness faces.

3.1.1.2 Method

3.1.1.2.1 Participants

Twenty one participants were recruited from University College London’s online subject pool and were paid £3 for their participation. Two males and four females’ participants were excluded because of subpar performance (as defined by the exclusion criteria elaborated below). The age range of the fifteen remaining was 18 to 43 years (*M* = 24.8, *SD* = 6.44) of which 6 were male. All of the participants in this experiment, as well as those in subsequent experiments, had normal or corrected-to-normal vision. A rigorous three level process to eliminate outliers was adopted. Firstly, as our measure of assessment accuracy was the participants’ agreement with the generated images, if they were did not concur with the faces under full time no-load ratings then we could not assess the effect of load. As a result any participant with less than 50 % accuracy on the ratings was removed from the analysis. Secondly, as we are assessing the load , we considered that the at least on the low load condition, there should be a minimal accuracy level of the extreme faces, hence again any participant who scored less than 50 % accuracy on the low load extremes was also removed. Finally, as our manipulation is based on the perceptual load of the letter task, to ensure both that participants are not trading one task for another and, to ensure that the face accuracies are based on a large enough sample (as only the search accuracy correct trials are included for the face accuracies), all participants with a search accuracy of again less than chance 50 %, were removed from any further analysis. This procedure was adopted in all subsequent experiments in this thesis.

As a result of the latter procedure, 6 participants were excluded in the following experiment (four due to less than 50 % accuracy in the low load task and two due to less than 50 % accuracy in the face rating task (no –load condition).

3.1.1.2.2 Stimuli and Procedure

24 faces identities were used that vary on 4 levels of trustworthiness yielding a total of 96 faces. The faces were generated using FaceGen Modeller 3.2 (Singular Inversions, 2007), according to the methods described in (Oosterhof et al., 2008). Of these 4 levels, two were used which were 3 and 2 standard deviations less than the neutral (i.e. less trustworthy) and two were used which were 2 and 3 standard deviations more than the neutral (i.e. more trustworthy).

Initially, the stimuli set contained six rather than four valenced items, three less than neutral (-3SD, -2SD, -1SD) and three more than neutral (+1SD, +2SD, +3SD) however after preliminary pilot testing the perceptual load set was reduced to four (-3SD, -2SD, +2SD, +3SD). This was done to increase differentiability between positive and negative valence faces, e.g. less trustworthy more trustworthy (and less dominant more dominant (see Experiment 2) and less threatening more threatening (see Experiment 3)) as some participants found it challenging to distinguish the facial images nearest to the neutral (-1SD, +1SD).

The experiment took place in a dimly-lit room. Matlab (running the cogent Toolbox) was used to program and run the experiment. All stimuli were presented on a black background, on a PC with a 15” CRT screen (80 Hz refresh rate). A chin rest was used to maintain a viewing distance of 58 cm. Each trial in the visual search task began with key press that was self-initiated, followed by a fixation point presented for 500 ms in the centre of the screen followed immediately by a 150 ms presentation of the visual search display.

The visual search display consisted of a target letter (either X or Z) and either (for the high load condition), five other non-target letters, spaced evenly around a circle (2.3° radius, closest contours 1.8°) or (for the low load condition), placeholders small ‘o’s, replaced the non-target letters appearing in place of the letters. The five other angular letters (T, F, L, V, K,) were of the same dimensions (0.4 ° by 0 .6 °), as the target letter. The target letter and the non-target letters were equally likely to appear in any of the possible combinations of positions. Centred at fixation, within the target letter circle, (4 ° by 2.3 °) was the target face stimuli (see **Figure 3-1** for an example display).

Participants were required to search the display for a target letter (either X or Z) and respond using the keyboard by pressing either of the aforementioned target letters. Following each response (within a maximum response window of 2000 ms), participants were then required to evaluate the face that was presented at fixation by pressing the keypad with a 1 (trustworthy) or 2 (not trustworthy).

Each block consisted of 24 trials, (12 trustworthy and 12 untrustworthy images, presented in random order) see **Figure 3-2** for an example time-course of the experiment.

Each face was presented once during the experiment and the assignment of positive valence faces to negative or positive blocks was randomized and counterbalanced across participants and across blocks. There were four experimental blocks (two low-load and two high-load the order of which was counterbalanced across participants). To ensure that the load manipulation was not traded off for accuracy in the other task all incorrect search trials were removed from the analysis - a procedure repeated in all experiments in this thesis).

Participants were instructed to perform as fast as possible while also being as accurate as possible and were informed that we would be recording their reaction times and accuracy scores (this was the case also for all subsequent experiments in this thesis).

Following completion of the search and judgment task, participants were asked to rate the same set of images (on trustworthiness) again randomized and with the same presentation parameters as above (essentially performing the same task but now without the search letters or dots and viewing the faces only) - see **Figure 3-3** for an example display).

As before, the face was presented in the centre of the screen (however with no rapid time window for response) and remained there until the participant had made their rating and pressed a key to progress onto the next trial (they were informed that they had an upper limit of 10 seconds within which to judge the image).

The participants' responses were scored for accuracy, as defined by agreement with the classification of the face in accordance with the dimensional face–space scheme outlined by Todorov and colleagues (Todorov et al., 2008a), this provided an "objective" measure of facial trustworthiness. This procedure was adopted in all subsequent experiments in this thesis.

Higher mean percentage face accuracy rates from participants, indicates higher agreement/accuracy (with for example the trustworthy , threating or dominance facial models as defined by Todorov and colleagues (Todorov et al., 2008a).

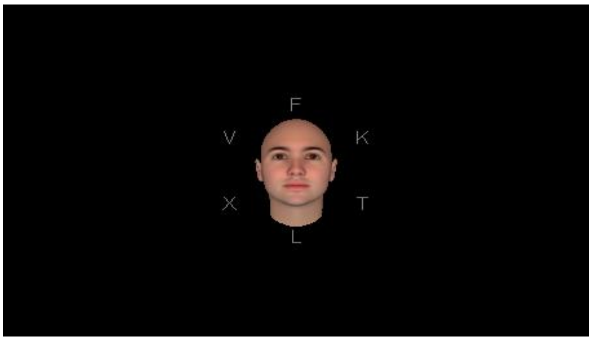


Figure 3-1 Example screen display of facial perceptual load manipulation (high load condition illustrated) The participant is required to search the display for the target letter (X or Z) amongst five other angular non-target letters (T, F, L, V, K), the correct answer being X in the above image. After the search task they would then perform a facial judgment (in this experiment whether the face was trustworthy or untrustworthy).

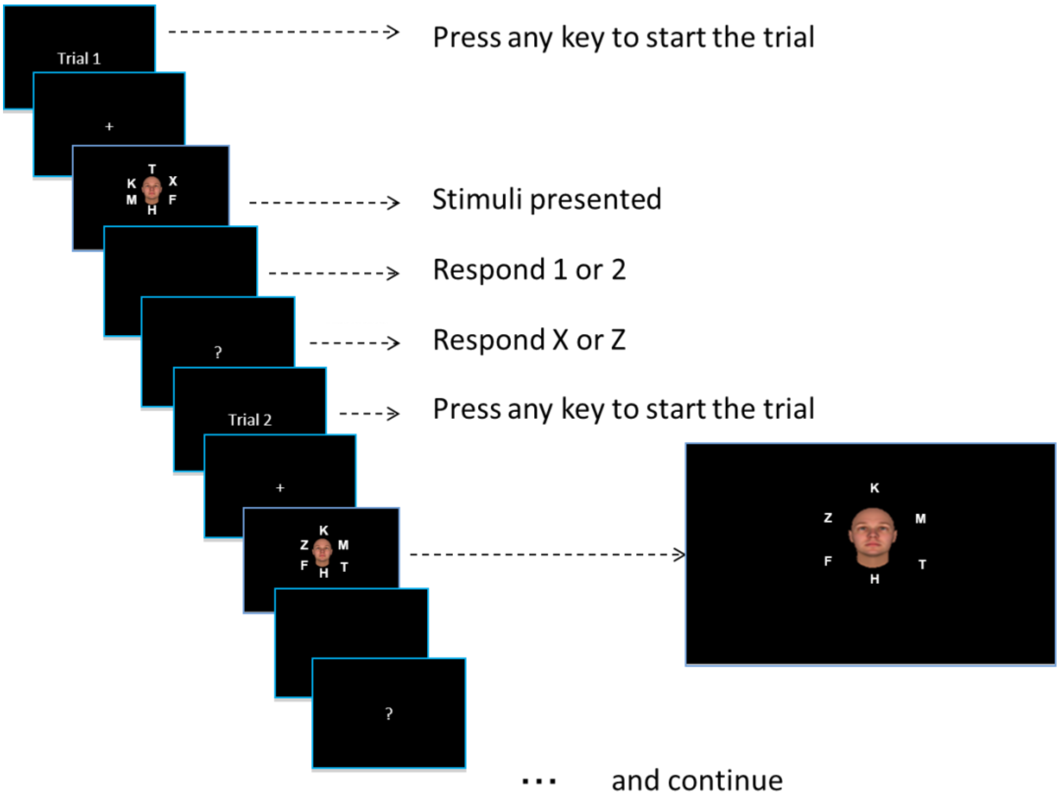


Figure 3-2 Example of the time course in the perceptual load experiments (high load illustrated) Each block consisted of 24 trials, (12 trustworthy and 12 untrustworthy images, presented in random order). Each face type was presented once during the experiment and the assignment of positive valence faces to either negative or positive blocks was randomized and counterbalanced across participants and across blocks. There were four experimental blocks (two low-load and two high-loads, the order of which was counterbalanced across participants). The above diagram illustrates the experiment beginning with a high load block; the same setup appears in the low load block, except now, the non-target letters are replaced with small 'o's placeholders.

Figure 3-3 An example trial sequence for the facial judgment rating task After the perceptual load task, participants were asked to judge the same set of images (on trustworthiness in this experiment) again randomized and with the same presentation parameters, but now without the search task (viewing the faces only and with no rapid presentation, maximum display time was 1000ms)

Finally upon completion of the experiment participants filled in a brief online personality questionnaire, using a 1 (strongly disagree) to 7 (strongly agree) scale, investigating the Big Five framework of personality traits (Openness, Conscientiousness, Extraversion, Agreeableness, Neuroticism) - (Costa & McCrae, 1992), although this data was acquired solely for exploratory purposes.

Before starting the experiment, participants completed one practice block of 12 example trials, and one practice block of ratings (different face identities were used in the practice than the experiment, and all were neutral on the respective valence scale).

3.1.1.2.3 Design

Mean percentage search accuracy rates and mean reaction times for the accurate trials (for added confirmation of the manipulation effectiveness) were the dependent variables, and were entered separately into a 2 x 4 repeated measures ANOVA. Perceptual load (Low, High) and Valence (-3, -2, +2, +3 - SD faces) were the within subject independent variables (IVs). Subsequently, the same 2 x 4 repeated measures ANOVA was used with the same within subject IVs, but with mean percentage trustworthiness accuracy rates as the dependent variable, excluding trials in which the search response was incorrect.

3.1.1.3 Results and Discussion

Search task. Mean percentage search accuracy rates in the low perceptual load condition were significantly better (M = 92 %) than in the high perceptual load condition (M =86 %), $F(1, 14) = 4.95$, $\eta^2 =.027$, $p = .043$, $\eta^2 = .261$ (two tailed, as is every statistical test in this thesis unless stated otherwise). There was no significant effect of valence $F(3, 42) =1.487$, $MSE = .012$, $p = .23$, $\eta^2 = .10$, additionally there was also no significant interaction between valence and load ($F<1$) $F(3, 42) =.38$, $MSE =.003$, $p = .77$, $\eta^2 = .026$.

Mean reaction times in the low perceptual load condition were significantly faster (M = 734 ms) than in the high perceptual load condition (M =1021), $F(1, 14) = 71.34$, $MSE = 34780.50$, $p <.001$, $\eta^2 = .836$. There was no significant effect of valence $F(3, 42) = 1.50$, $MSE = 8056.742$, $p = .229$, $\eta^2 = .097$, although there was a significant interaction between valence and load $F(3, 42) = 3.178$, $MSE = 7284.33$, $p = .034$, $\eta^2 = .185$ on reaction times (follow up pairwise comparisons between the low and high load reaction times at each valence level were all highly significant for all four pairs $P< .001$). The aforementioned confirms that the perceptual load manipulation was indeed effective (see **Table 3-1** on the following page).

	Perceptual load		
	Low	High	Differential Effect of load
Search Accuracy (%)	92(12)	86(12)	6*
Reaction Time (ms)	734(186)	1021 (208)	287*
Face Accuracy (%)	81(8)	75(11)	6*

SDs are listed in parenthesis. * = significant NS = not significant

Table 3-1 Mean search percentage accuracy rates, mean reaction time (ms) rates and mean face accuracy rates in the trustworthy task as a function of load in Experiment 1

*Face classification. M*ean percentage face accuracy rates, revealed that the accuracy rates in the low perceptual load condition were significantly higher in the low perceptual load condition (M = 81 %) than in the high perceptual load condition (M = 75 %), $F(1, 14) = 11.711$, $MSE = .009$, $p = .004$, $\eta^2 = .45$ (see **Table 3-1**). There was no significant effect of valence ($F<1$) $F(3, 42) = .345$, $MSE = .037$, $p = .793$, $\eta^2 = .026$. Additionally there was no significant interaction between valence and load $F(3, 42) = 1.178$, $MSE = .018$, $p = .330$, $\eta^2 = .078$ (see **Figure 3-4**).

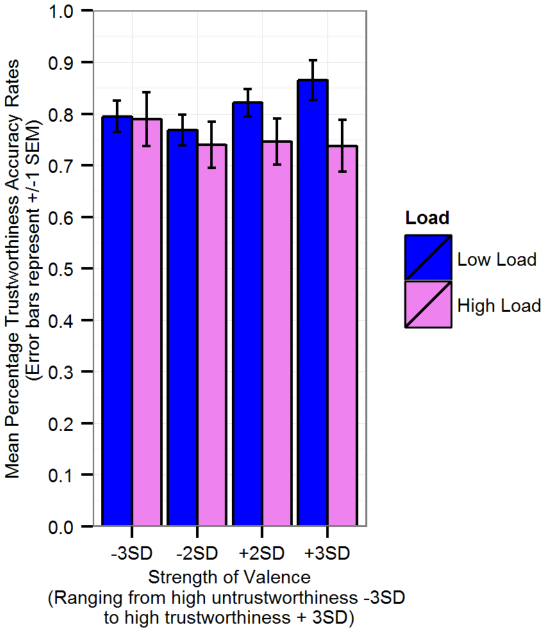


Figure 3-4 Trustworthiness mean percentage face accuracy rates for participants (valence ranges from high untrustworthy (low trust) valence -3SD on the left to high trustworthiness on the right +3SD valence)

Finally as confirmation that the low load task was not sufficiently taxing on attentional resources, the same ANOVA model was applied, but this time comparing mean percentage face accuracy rates of unrestrained time or a “no- load” (that is the rating of the images at the end of the task with no letters present) against low load.

The repeated model ANOVA on these measures revealed that the accuracy rates in the no perceptual load condition were *not* significantly higher in the no perceptual load condition (*M* = 78 %) than in the low perceptual load condition (*M* =81 %), F(1, 14) = 1.85, *MSE* = .021, *p* = 0.195 η^2 = .12, indicating the absence of an effect of perceptual load on the low load task. Additionally, there was no significant effect of valence *F*(3, 42) =1.82, *MSE* =0.017, *p* = .159, η^2 = .0.11.

There was a significant interaction between valence and load *F*(3, 42) =5.09, *MSE* =.013, *p* = .004, η^2 = 0.27.

Follow up pair-wise comparisons of the interaction indicated that it was driven by the difference of +2SD and +3SD trustworthiness full time presentations, being significantly lower than low load +2SD and +3SD trustworthiness presentations ((*M* = 70 % vs *M* = 82 % for +2SD faces) - *t*(14) = -2.23, *p*=.042 and (*M* = 76 % vs *M* = 86 % for +3SD faces) - *t*(14) = -2.35 *p* =.034) - both uncorrected for multiple comparisons). This implies that performance was actually better for the extreme trustworthy faces under *low* load with less time. This could suggest that more time in the rating task (implying more thought and cognition), reduces accuracy for the high trustworthy faces.

These initial findings provide delicate but preliminary evidence for the hypothesis that the levels of perceptual load in a task could impair whether participants can detect the trustworthiness of faces. The absence of an effect due to load between the rating condition (*M* = 78%) and the low perceptual load condition (*M* =81 %), coupled with the relatively high agreement (especially in the low load condition) between raters and the trustworthiness images defined by Todorov et al (Todorov et al., 2008a) provide some confirmation of agreement with the face trait /judgment classification scheme (defined by their dimensional face space) that the authors proposed (at least for trustworthiness).

These perceptual load results are small and subtle effects (6% in Experiment 1) but nevertheless warrant further exploration and investigation to ascertain whether this effect generalizes to other types of judgments such as dominance and threat along that amorphous boundary between emotional and trait judgments. That is the subject of the following studies.

3.1.2 Experiment 2 - Social Dominance

3.1.2.1 Introduction

In this experiment, we sought both to investigate further the structural face dimensions which define the 2D space within which specific social judgments can be represented (Oosterhof et al., 2008) and also to determine whether an alternative account for the interpretation of the results of the perceptual load from Experiment 1could be as a result of the distinctiveness of the dimension of trustworthiness (in which participants were asked to make a positive vs. negative evaluation (trustworthy or untrustworthy)) rather than a general effect of perceptual load on all facial social judgments for example. To this end the other dimension of the 2D face space, dominance, was examined under the same paradigm.

Dominance and its assessment can be highly variable depending on both the context and individuals involved. Anthropologically speaking, dominance is the state of having high social status relative to one or more other individuals, who react submissively to such "dominant" individuals, perceiving them as powerful, perhaps facially, in some form. Ethologically speaking, social rank is determined on the basis of agonistic encounters in the dominance hierarchies that characterize many nonhuman species (Trivers, 1985), although this does not necessarily apply in human encounters.

Dominance is not limited to physical conflict (although certain signals such as facial displays may indicate the possibility of it), it is stereotypically seen in individuals who control access to resources, where dominant individuals may create fear in subordinates by taking or threatening to withhold them (Cheng, Tracy, & Henrich, 2010). From the perspective of facial social judgments this may seem somewhat abstract, however inferences of dominance seemingly have a tangible social impact, predictive of military rank attainment for example (Mueller & Mazur, 1996).

A further reason for being interested in such evaluations, aside from their potential predicative value, is that according to the model that generated the facial stimuli in the last experiment (Oosterhof et al., 2008), faces are evaluated on what can be construed as two primary, independent dimensions: general valence (highly correlated with trustworthiness) and dominance. Evaluation on specific trait dimensions can be derived from the combination of these two dimensions. We have looked at trust; naturally we also wish to investigate the potential effect of perceptual load on the opposing, dominance dimension.

Dominance judgments are potentially complicated social judgments, although the importance of this dimension has been verified in alternative trait models (Wiggins & Broughton, 1991). As alluded to above in the case of military rank attainment, dominance evaluation may be grounded in facial cues signalling the physical strength of the person. These types of evaluation may correspond to inferences about harmful intentions and the ability to cause harm (Fiske et al., 2007). Of note in these facial appraisals, most of the diagnostic information for the trustworthiness dimension is asserted to be present in the internal features of the face, whereas most of the diagnostic information for the dominance dimension is asserted to be in the external (shape) features of the face (Oosterhof et al., 2008).

Given the general predictions of perceptual load theory and the results of Experiment 1,we hypothesised that high perceptual load would impact the judgment accuracy of dominance faces (although we were cognizant of the possibility that the dominance dimension faces may be more salient and thus more likely to be resistant to potential attentional constraints).

3.1.2.2 Method

3.1.2.2.1 Participants

Twenty two new participants were recruited from University College London’s online subject pool and were paid £3 for their participation. One male and four female participants were excluded due to subpar performance (four due to less than 50 % accuracy in the low load task and one due to less than 50 % accuracy in the face rating task). The age range of the 17 remaining was 18 to 34 years (*M* = 22.47, *SD* =5.24) of which 5 were male.

3.1.2.2.2 Stimuli, Procedure and Design

The apparatus, procedure, generation of stimuli and design were the same as the prior Experiment 1, except that the participants were instructed to make their response on 24 faces identities that varied on 4 levels of dominance; again two were used which were 3 and 2 standard deviations less than the neutral (i.e. less dominant) and two were used which were 2 and 3 standard deviations more than the neutral (i.e. more dominant).

3.1.2.2.3 Design

Mean percentage search accuracy rates and mean reaction times for the accurate trials, were the dependent variables, and were entered separately into a 2 x 4 repeated measures ANOVA. With perceptual load (Low, High) and Valence (-3, -2, +2, +3 - SD faces) as within subject independent variables (IVs). Subsequently mean percentage dominance accuracy rates were the dependent variable and was entered into the same 2 x 4 repeated measures ANOVA., again with perceptual load (Low, High) and Valence (-3, -2, +2, +3 - SD faces) as within IV's, excluding trials in which the search response was incorrect.

3.1.2.3 Results and Discussion

Search task. Search error rates in the low perceptual load condition (*M* = 93 %) were significantly better than in the high perceptual load condition (*M* = 82 %), *F*(1, 16) = 14.41, *MSE* =.026, *p* = .002, η^2 = .47. There was no significant effect of valence *F*(3, 48) = 1.71, *MSE* = .007, *p* = .178, η^2 = .096, additionally there was no significant interaction between valence and load *F*(3, 48) = 1.54, *MSE* =.006, *p* = .216, η^2 = .088.

Mean reaction times in the low perceptual load condition were significantly faster (*M* = 787) than in the high perceptual load condition (*M* = 1077), *F*(1, 16) = 188.75, *MSE* = 15189.26, *p* < .001, η^2 = .92. There was no significant effect of valence *F*(3, 48) = 1.33, *MSE* = 9031.75, *p* = .274, η^2 = .077 and there was no significant interaction between valence and load for mean reaction times *F*(3, 48) = .97, *MSE* = 8601.06, *p* = .412, η^2 = .057. The aforementioned once again confirms that the perceptual load manipulation was successful (see **Table 3-2**).

	Perceptual load		
	Low	High	Differential Effect of load
Search Accuracy (%)	93(9)	82(10)	11*
Reaction Time (ms)	787(161)	1077 (155)	290*
Face Accuracy (%)	74(6)	74(9)	0 NS

SDs are listed in parenthesis. * = significant NS = not significant

Table 3-2 Mean percentage search accuracy rates, mean reaction time (ms) rates and mean face accuracy rates in the dominance task as a function of load in Experiment 2

Face classification. Mean percentage face accuracy rates in the low perceptual load condition were *not* significantly higher (M = 74 %) than in the high perceptual load condition (M =74 %), (F<1) F(1, 16) = 0.019, MSE = 0.017, p = . 0.892, η^2 = 0.001, indicating the absence of the effect of perceptual load. The absence of a load effect was evident in that none of the low load vs high load pairs were significantly different (2- tailed) for any of the categories (-3, -2, +2, +3 SD faces).

There was however a significant effect of valence F(3, 48) =5.06, MSE =0.049, p = .004, η^2 = .24. Follow up bonferroni corrected pairwise comparisons revealed the dip pattern as seen in **Figure 3-5 -** namely that accuracy decreases from the low dominance faces to the high dominance faces. The overall effect of valence was driven by -3SD valence being significantly greater than -2SD and +2SD valence but not + 3SD valence, while + 2SD valence was significantly less than + 3SD valence, confirming the dip pattern and suggesting that the face space valence is difficult for the mid-range dominance faces.

Finally, there was no significant interaction between valence and load F(3, 48) =1.03, MSE =.018, p = .387 η^2 = .061.

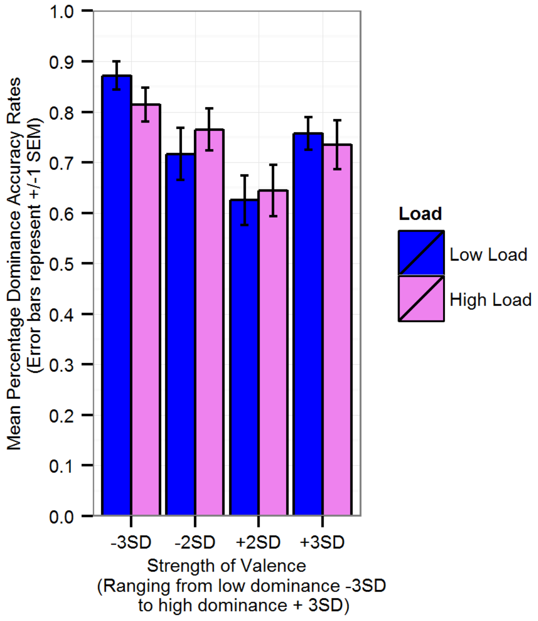


Figure 3-5 Dominance mean percentage face accuracy rates for participants (valence ranges from low dominance -3SD on the left to high dominance +3SD on the right)

To investigate (as in Experiments 2) mean percentage face accuracy rates of unrestrained time or a “no- load” (that is the rating of the images at the end of the task with no letters present) against low load, the same repeated model ANOVA was employed.

This showed that mean percentage face accuracy rates in the no-perceptual load or rating task condition (M = 84 %) were (in contrast to Experiment 1) significantly higher than in the low perceptual load condition (M = 74 %), $F(1, 16) = 33.67$, $MSE = .009$, $p < 0.001$ $\eta^2 = .68$. This was a surprising result. Follow up testing indicated that for facial judgment accuracies in most of the no load vs low load pairs, no load was significantly greater (2- tailed) for most of the categories (-2, +2, +3 SD faces), -3SD valence being the exception.

There was no significant interaction between valence and load $F(3, 48) = 3.73$, $MSE = .018$, $p = .071$, $\eta^2 = 0.19$.

There was also, unsurprisingly (given the effect of valence in the main experiment above) a significant effect of valence $F(3, 48) = 5.52$, $MSE = .038$, $p = .002$, $\eta^2 = .26$.

Follow up bonferroni corrected pairwise comparisons for the dominance no-load vs low load model revealed a similar dip pattern to that already seen in **Figure 3-5**, where overall - 3 valence was greater than -2 valence and + 2 valence faces and + 2 valence was significantly less than - 3 valence faces, again indicating a dip pattern.

In contrast to the social judgments of trust, dominance judgments were immune to the effect of high load. Another feature of these results was the dip discussed above with regard to mid-range dominance faces. This suggests that there is uncertainly in mid-range dominance judgments which implies a reduction in agreement and accuracy of ratings with the 2D face space stimuli.

The further divergence between facial judgments of dominance and trustworthiness results, is indicated by the fact that there was a significant difference between the rating condition (M = 84 %) and the low perceptual load condition (M =74 %), a difference not evident for the trustworthy faces (although encouragingly these values still indicate relatively high agreement between raters and the dominance images defined by Todorov *et al* (Todorov et al., 2008a)). This was a surprising result, it’s difficult to ascertain its significance given that we have one experiment (Experiment 1) going one way (a null effect) with regard to the difference between the ratings task and low load and another, this one, (Experiment 2) going the other (further clarification may be provide in the behaviour of participants in the following experiment when we explore threat facial judgments).

It is possible that the differing pattern of dominance results may indicate that such evaluations are processed differently than other facial judgments such as trustworthiness implying that the type of face may be important factor with regard to the effects of perceptual load, although currently this is conjecture.

The differing pattern of results between trustworthiness and dominance do not however constitute a satisfactory explanation for the absence of the expected hypothesized load effects. Whether this absence is due to the salience of dominance faces, the lack of such prominence for trustworthy faces (which make them more susceptible to load) or, the fact that that the type of face and social judgment interact with load is as yet underdetermined.

To investigate further the effects of load on this parametric face space and to ascertain the robustness of this finding, and whether it can be extended to a component comprised of the two orthogonal dimensions from the last two experiments, I turned to the effect of load on the facial judgments of threat.

3.1.3 Experiment 3- Face the threat!

3.1.3.1 Introduction

Following on from the results in the last experiment examining dominance, an associated social judgment which also may be established by aggression, intimidating displays or interchanges and again may have important role in brief social facial displays is that of threat.

It is important to establish whether our manipulation of load is specific to one social judgment domain, or whether other social judgments, such as those which arguably have more survival significance, such as threatening faces for example (Bar et al., 2006), are also modulated by perceptual load.

The importance and salience of threat from a survival point of view may lead one to the speculative conjecture that their assessment is less likely to be amenable to perceptual load effects as there is an ostensible evolutionary advantage to a species that can react swiftly to danger or a threat in the environment (be it predator or conspecific), unencumbered by attentional constraints. In the latter case, a facial expression would meet the criteria as a stimulus with the potential to signal threat, indeed merely the eye region can seemingly mediate a search advantage for threatening facial expressions (Fox & Damjanovic, 2006).

As the discussion in the introduction (particularly section 1.3) indicated, responses to threatening faces with attentional modulations have been well studied, ranging from the neurological to the behavioural. These studies, particularly those arguing for threat based processing being invariant to attentional modulations were buoyed by the discovery of a possible direct pathway from the sensory thalamus to the amygdala, which may allow automatic responses to potential threat signals (LeDoux, 1996). Moreover, patients with bilateral amygdala damage display impaired social judgment based on facial expressions, particularly those expressing threat-related emotions (Adolphs et al., 1998). However, although Ohman suggested that facial expressions rapidly access the amygdala through a “quick and dirty” analysis via a simple subcortical network rather than a complete visual analysis in the cortical network (Öhman, 2002), this does not necessarily mean that threatening faces cannot be influenced by some form of attentional or perceptual load. On the contrary, there is evidence that threatening facial expressions can modulate attention even when the face is presented outside awareness (Mogg & Bradley, 1999). In fact, amygdala activity may be influenced by the type of threat transmitted by different categories of facial expressions and this modulation may diverge for individuals with high as compared to low anxiety traits (Ewbank et al., 2009). And to complicate matters, the amygdala activates to fearful faces both when attended and unattended, but is increased in individuals with higher anxiety in unattended conditions. This observation is supported by studies where overlapping activation in certain regions indicated increased responses to angry faces and increased effects of high anxiety only when faces are attended (Bishop, Duncan, & Lawrence, 2004). This possible dissociation may signal a differential biological implication for these categories of stimuli, in relation to undetermined signals of danger within the environment (fear) as opposed to a more direct form of threat (anger), consistent with the amygdala being part of a warning system that detects danger and prompts adaptive alert responses.

An alternative, however to the view that evolutionary the human brain is specialized to preferentially attend to threat-related stimuli, is to assume that some (perhaps all) classes of stimuli that have high biological significance may be (partly) prioritized by the attention system, rather than threat or negative valence faces per se. If this is the case, and following from the divergent literature and the results in the last two experiments (where presumably trustworthiness and dominance are also of high biological significance, although only the former was affected by load) we might expect and hypothesise that threat processing (or the ability to detect or judge a threatening face) could also be modulated by perceptual load.

The power of a face space comes to the fore here, as Oosterhof *et al's* model can potentially represent any social judgment from its two dimensions, indeed from the dimensional face space perspective; threatening faces (indeed any facial expression) contains components of both trustworthiness and dominance (see section 2.4 for more details). To construct threatening faces, the model essentially assigns equal weights to the trustworthiness and dominance dimensions. This accords with the intuition that threatening faces should be both untrustworthy, signalling that the person may have harmful intentions, and dominant, signalling that the person is capable of causing harm.

Once again we asked in Experiment 3 whether perceptual load effects would modulate the ability to perform facial judgments, this time however, for threatening faces.

3.1.3.2 Method

3.1.3.2.1 Participants

Twenty three new participants were recruited at University College London (UCL) and were paid £3 for their participation. Seven participants, (two male and five female) were excluded due to their poor performance (four due to less than 50 % accuracy in the low load task and three due to less than 50 % accuracy in the face rating task). The age range of the 17 remaining was 19 to 34 years (M = 24.88, SD =5.81) of which 9 were male.

3.1.3.2.2 Stimuli, Procedure and Design

The apparatus, procedure, generation of stimuli and design were the same as the prior two experiments, except that the participants were instructed in this instance to make their response on 24 faces identities that vary on 4 levels of threat. As before, two were used which were 3 and 2 standard deviations less than the neutral (i.e. less threatening) and two were used which were 2 and 3 standard deviations more than the neutral (i.e. more threatening).

3.1.3.3 Results and Discussion

Search task. Search accuracy rates in the low perceptual load condition were significantly better (*M* = 95 %) than in the high perceptual load condition (*M* =81 %), *F*(1, 16) = 39.50, *MSE* =.016, *p* < .001, η^2 = .71. There was no significant effect of valence (*F*<1) *F*(3, 48) = .90, *MSE* = .10, *p* = .448, η^2 = .053. Additionally there was no significant interaction between valence and load (*F*<1), *F*(3, 48) =.178, *MSE* =.009, *p* = .911, η^2 = .011.

Mean reaction times in the low perceptual load condition were significantly faster (*M* = 849) than in the high perceptual load condition (*M* =1132), *F*(1, 16) = 62.82, *MSE* = 43506.332, *p* < .001, η^2 = .80. There was no significant effect of valence *F*(3, 48) =1.04, *MSE* =14138.05, *p* = .381, η^2 = .061, although there was a significant interaction between valence and load *F*(3, 48) = 2.98, *MSE* = 9032.19, *p* = .041, η^2 = .16.

Follow up pair wise comparisons between the low load reaction time and high load reaction time at each valence were all highly significant for all four pairs *P* < .001 as in the case of the reaction times for trust in Experiment 1. The aforementioned confirms that the perceptual load manipulation was effective (see **Table 3-3**).

	Perceptual load		
	Low	High	Differential Effect of load
Search Accuracy (%)	95(7)	81(12)	14*
Reaction Time (ms)	849(272)	1132 (252)	290*
Face Accuracy (%)	79(9)	72(10)	7*

SDs are listed in parenthesis. * = significant NS = not significant

Table 3-3 Mean percentage search accuracy rates, mean reaction time (ms) rates and mean face accuracy rates in the threat task as a function of load in Experiment 3

Face classification. Mean percentage face accuracy rates in the low perceptual load condition were significantly higher (*M* = 79 %) than in the high perceptual load condition (*M* =72 %), *F*(1, 16) = 5.80, *MSE* = .029, *p* = .039, η^2 = .24, indicating the effect of perceptual load. There was no significant interaction between valence with and load (*F<1*), *F*(3, 48) = .048, *MSE* =.027, *p* = .986, η^2 = .003.

There was a significant effect of valence however, *F*(3, 48) = 12.58, *MSE* = .038, *p* < .001 η^2 = .440. Follow up bonferroni corrected pairwise comparisons revealed the dip pattern as seen in **Figure**

3-6 (and similar to that seen for dominance faces in **Figure 3-5)**. Specifically, accuracy decreased from the low threat faces to the high threat faces (combined valence accuracy means: -3SD =.879, -2SD = .801, +2SD = .599, and +3SD = .734, respectively).The overall effect of valence was driven by -3SD valence being significantly greater than +2SD and + 3SD valence, - 2SD valence being significantly greater than +2SD, which in turn was significantly less than + 3SD valence, confirming the dip pattern and suggesting, as in the case of the dominance stimuli, that face space valence judgments are troublesome for the mid-range threat faces also.

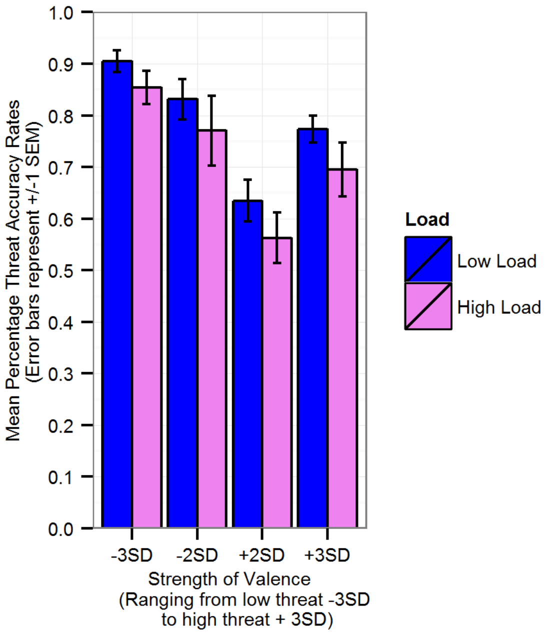


Figure 3-6 Threat mean percentage face accuracy rates for participants (valence ranges from low threat -3SD on the left to high threat +3SD valence on the right)

As in the prior two experiments, confirmation was sought that the low load task was not sufficiently taxing on attentional resources, using the same ANOVA model and comparing mean percentage face accuracy rates of unrestrained time or a “no- load” (the rating task with no letters present) against low load. This revealed that importantly the accuracy rates were not significantly higher in the no perceptual load condition (*M* = 83 %) than in the low perceptual load condition (*M* =79 %), *F*(1, 16) = 3.73, *MSE* = .018, *p* = 0.071 η^2 = .19, again indicating the absence of effect of perceptual load on the low load task.

There was no significant interaction between valence and load (*F*<1) *F*(3, 48) = .93, *MSE* =.014, *p* = .437, η^2 = .055.

There was however a significant effect of valence *F*(3, 48) =13.35, *MSE* = .026, *p* < 001, η^2 = .45. Follow up Bonferroni corrected pairwise comparisons revealed s similar dip pattern as exposed for the load conditions of the main threat experiment above (combined valence accuracy means: -3SD =. 90, -2SD = .86, +2SD = .67, and +3SD = .80, respectively). Where -3SD valence was significantly greater than +2SD and +3SD valence, -2SD valence was significantly greater than +2SD valence and +2SD valence was significantly less than + 3SD valence.

These findings extend the scope of perceptual load to modify negative and arguably evolutionary adaptive facial signals and confirm our predictions that these threat images (containing components of the trust space) are also amenable to the effects of load.

As in the case of trustworthiness (Experiment 1), the differential effect size of load of 7% (as opposed to 6% for trustworthiness) is subtle; although it is encouraging that at every valence category (see Figure 3-6) the face percentage accuracy scores are reduced under high perceptual load.

The significant effect of valence and the “dip” in the classification accuracy for the mid-range threatening faces, particularly +2SD threat, suggests two related possibilities. Either that the standard deviation gradations of the face space are not uniformly perceived as such by the participants, thus while there is strong agreement between the extremes of the threatening face set stimuli (and participants social judgments), this decrease in concordance in the middle is due to either the inability (or uncertainty) of the raters to make such fine grained distinctions, or alternatively a misconception in the linearity of the face transformation progressions of threat in the generating face space.

Lastly, again the absence of an effect due to load between the rating condition (*M* = 83 %) and the low perceptual load condition (*M* =79 %) - (also seem in Experiment 1 for trustworthiness faces) is reassuring, indicating the absence of an effect of perceptual load on the low load task (suggesting that there is not something anomalous about the dual task nature of this experiment evident in low load) and indicative of relatively high agreement between raters and the threat images defined by Todorov et al (Todorov et al., 2008a).

I have examined three distinct types of social facial judgment now, under the same conditions. To see if there was a specific effect of experiment on the social facial judgments results that may account for dominance's immunity to perceptual load for example, all three experiments were entered into a full conjoint full.

(Note, dominance and threat effectively range from low but relatively positive valence to high negative valence, that is, low dominance and low threat to high dominance and high threat respectively. This range of valence is reversed however for trustworthiness in Experiment 1, ranging from negative valence (low trust) to high positive valence (high trust).

To ensure that all social judgment categories run along the same continuum of valence for a full-model comparison, the results of the valence ranges of trustworthiness were reversed so that they also ranged from low (positive) valence (high trust) to high negative valence (high untrustworthiness).

3.1.3.4 Full model

As to be expected from our prior results above there was a main effect of Load, Low load (78 %) against high load (74 %) $F(1, 46) = 9.46$, $MSE = .019$, $p = .004$, $\eta^2 = .17$ and an expected effect of

Valence (due to the dip patterns over valence evident in Experiments 2 and 3 (see Figure 3-5 and 3-6)), $F(3, 138) = 12.86$, $MSE = .041$, $p < .001$, $\eta^2 = .22$.

There was no main effect of experiment $F(2, 46) = 1.20$, $MSE = .049$, $p = .312$, $\eta^2 = .049$, suggesting that the dominance evaluations were not significantly different from either of the other experiments. Additionally, none of the two way or three way interactions were significant.

These results are subtle, with a small differential effect size, they weakly indicate that that the level of perceptual load at relatively rapid visual presentations (150 ms) can influence subjective facial judgments, although dominance evaluations appear to be somewhat anomalous in their results profile.

3.2 General discussion

While the effects of perceptual load have been illustrated on multiple stimulus detection measures, ranging from reaction times to stimulus-evoked neural activity (Beck, Rees, Frith, & Lavie, 2001; Yi et al., 2004), the role of perceptual load and attention on faces is unclear. The results obtained here, provide tentative support to indicate that trait (trustworthiness) and emotional (threat) facial judgment capability, are to some capacity, susceptible to some degree of perceptual load effects - although (as discussed in the introduction chapter) the difference between these two conceptual categories of trait and emotion is blurred at best.

Lamentably, the factors that influence facial judgments under attention are most likely complex and multifactorial and perhaps this accounts for the disparity of results in the field (Jenkins, Lavie, & Driver, 2005; Lavie, Ro, & Russell, 2003; Vuilleumier, Armony, & Dolan, 2003; Yates, Ashwin, & Fox, 2010). However, these results cautiously suggest that even though faces may enjoy a privileged status in our visual processing, perhaps due to the social signals they convey, that status is not completely immune to attentional or specifically perceptual load modulations, however small that effect may be.

In a series of experiments that applied load theory, employing a combined visual search and face judgment task, where the level of attentional load in the search task was manipulated (by varying the search set size of similar non-target letters - zero in the low load, five in the high perceptual load condition)), the results indicated reduced accuracy for trustworthy and threat judgments, while in contrast, dominance judgments were resistant to attentional load effects.

It is challenging to assess the generalizability of perceptual load effects on facial judgments due to the somewhat anomalous results profile of dominance evaluations. Although there was no main effect of experiment between the categories of trustworthiness, threat and dominance, the absence of an effect of load for dominance judgments (where follow up testing revealed that none of the low load vs. high load pairs were significantly different for any of the categories (-3, -2, +2, +3 SD faces)) indicated that dominance judgments may interact differentially with attention. Furthermore, the fact that, as opposed to the other trustworthy and threat judgments where low load is numerically greater than high load at all valences, this was not the case for the mid-range dominance faces (see **Figure 3-5**), suggest that such mixed results for dominance may indicate something unique regarding that principal component.

A notable feature of particularly the dominance and threat judgments results was a dip in the overall accuracy rates for the mid-range faces. This may be as a result of some facet of the face space e.g. that the -2SD and +2SD are particularly harder to discriminate as compared to -3SD and +3SD valence, irrespective of the attempted parametric linearization of the face space (in which the extent of face exaggeration is presented in SD units). Although alternatively it is possible that how such categories such as dominance and threat are finally perceived and judgments performed does not reflect the linear construction of the face space but rather the perceptual capacities of the participants (namely that more extreme facial signal criterions are needed to make successful classifications). Irrespective of the cause of this dip, its presence was evident in the results for threat judgments. Threat is assembled combinatorially from trustworthiness and dominance and its pattern of results reflect this dual parentage. There was an effect of load (as in the trustworthy judgments) but also a similar dip pattern as evidenced in the dominance evaluations.

The prior experiments are on a somewhat complicated data-set and these results are not unquestionably unambiguous, there was in an effect of load but the role of the dip in the face space, particularly for threat and dominance merits further investigation. Most likely there is simply more uncertainty in the middle areas of any faces space purporting to structurally classify features to traits and social judgments. If this is the case, teasing out effects of attentional modulation on face processing may better served with faces that are more emphatic and exemplary of the judgment that they seek to evoke, namely +/- 3SD faces in the current face dimension space employed in this thesis (an idea that we will return to in the next Chapter, section 4.4).

Although it has been previously suggested ((e.g.(Lavie et al., 2003)) that distractor faces for example may require mandatory processing, providing an exception to perceptual load theory (Lavie & Tsal, 1994; Lavie, 1995), the findings described here suggest that the processing of valenced faces is not necessarily automatic and may be sensitively modified by top-down goals.

These results suggest that social trait judgments are not wholly automatic, but instead are influenced by the deployment of attentional resources. The subtle effects of perceptual load demonstrated here indicate that participants were less likely to be aware of certain types of social characteristics of a face when performing a search task of high perceptual load.

Even though the prominence of the facial and social expression judgment is seemingly underscored by a body of research that indicates its privileged position within human visual processing (Calder et al., 2005) these results support the view that this privileged position is very much likely to be subject to constraints, at least for certain classes of facial stimuli e.g. trustworthiness, although perhaps not others e.g. dominance. This may be due to the relevance of the facial signal to an organism's survival.

There is ample evidence to indicate that some form of preferential processing is involved in a comprehensive range of facial stimuli (e.g. (Gliga & haene-Lambertz, 2005; Sagiv & Bentin, 2001; Kanwisher & Yovel, 2006), even when the face stimulus is simplified into line drawings (e.g.(Öhman et al., 2001)) or highly schematic (e.g. (Eastwood, Smilek, & Merikle, 2001)). What the results presented here cause us to question however, is the extent and malleability of this face prioritization mechanism and whether this prioritization is intimated in the different valence accuracies that were observed (higher general accuracies for "nicer" or positively valenced faces, e.g. high trust, low threat and low dominance).

If any prioritization mechanism is malleable or adaptive, then it will require the capacity to distinguish between these qualitatively (or quantitatively in the face space that we employed) differing social signals. It is for this reason that the perceptual load methodology is particularly suited to evaluating the differential ability of valenced stimuli to guide or attract attention (Eastwood et al., 2001). Rather than an investigating an absolute capacity, as is the case of detecting different valenced targets embedded amongst others, using a perceptually demanding search task as we have done here enables the influence of attentional constraints to be relatively examined on social facial judgments.

Given the prior discussion and due to the differential results of perceptual load on threat, trust and dominance facial judgments, in a further attempt to elucidate the role of valence in the results observed in this Chapter, pair wise post- hoc comparisons were performed on all the valences (-3, -2, +2, +3 SD faces) under high and low load.

Under such testing, only the judgments of high trustworthy faces in Experiment 1 (+3 SD valenced faces) were affected by load (*t* (14) = 2.26, *p* =.04 (low load *M* = 86.5 % vs. high load *M* = 74 %)) and +2 SD valenced faces reaching near significance (*t* (14) =2.00, *p* =.065 - two- tailed test (low load *M* = 82 % vs. high load *M* =75 %)), although, arguably significant one-tailed, given our clear predications about the direction of perceptual load effects (with no significant pairwise comparisons in Experiment 2 or 3 (dominance and threat judgments respectively). This suggests an important role for valenced stimuli in perceptual load modulations

Currently, it is uncertain whether this effect is driven by low or high level cues. Investigating performance on rotated faces may help to ascertain whether the effects are more likely to be driven by the effect of low-level or high-level facial features on attention (Frischen et al., 2008). As in the Thatcher effect (the phenomenon where it becomes difficult to detect local feature changes in an upside down face, despite identical changes being obvious in an upright face) - (Thompson, 1980) rotation would help to see how emotion cues interact with attention and whether they facilitate attention by enhancing specific (local or global) cues.

In general terms, any emotionally valenced stimuli appears difficult to ignore (e.g. Stenberg et al., 1998) and even resistant to suppression (e.g. (Lavie et al., 2003)). Much of the previous research on valenced faces has focused on the ability of negative valenced stimuli (particularly faces) to efficiently attract attention to themselves within the visual search paradigm (e.g. Hansen & Hansen, 1988; Eastwood et al., 2001).

There is some evidence that negative valenced faces, such as expressions that signal potential threat to an individual (i.e. expressions of anger, fear or distress), seem to be processed faster and take longer to ignore than either emotionally neutral faces or those displaying positive affect (e.g.(Eastwood et al., 2001)). This line of reasoning seems to initially support the fact that untrustworthy faces in the post-hoc comparison were not affected by load, however we need to be cautious in our interpretation as under low load, participants performed better for trustworthy faces than for untrustworthy faces (and participants performed better for positive valenced faces under low load for dominance (-3 SD) and threatening faces (-3 SD); low threat and low dominance respectively). However, employing richer, more lifelike stimuli from a dimensional face space and the type of judgment (e.g. untrustworthiness evaluations, although negative valenced may be processed differentially to expressions of anger, fear or distress for example) may produce results which diverge from prior findings and intuitions.

Whether there is indeed an adaptive advantage to the efficient detection of negative valenced stimuli, particularly those that signal threat (where participants performed better for all valenced faces under low load in contrast to the mixed results of dominance) under perceptual load is unclear. It is possible that the type of face and social judgment may interact with the effects of load. Moreover, it is less apparent why negatively valenced stimuli would continue to dominate selective attention if further processing indicates that they are irrelevant to the current goals of the observer, or, of particular relevance to most experimental set-ups, currently pose no realistic threat to the participant (which may be accentuated in dual tasks where there may be an implicit recognition that the negative valenced aspect such as threat is contextualized with another task).

This latter facet may explain the positive valence advantage that we found with threat and dominance (where the mean rating accuracy was non-significantly higher for the less dominant less and threatening faces -3SD), and moreover the fact that threat was not immune to load effects, despite the alleged negative affect superiority found using a range of paradigms ranging from cueing (Georgiou et al., 2005), flanker (Fenske & Eastwood, 2003) to shapes (Vuilleumier et al., 2001b).

This issue is likely to be complex, particularly as much of the evidence for example, in flanker tasks (Fenske et al., 2003) uses very simple, schematic faces as opposed to the more lifelike stimuli we have employed and hence whether the same type of facial processing mechanism is invoked is uncertain. This complexity comes to the fore with the dominance results. The absence of a main effect and the mixed valence results under load, could indicate something about the role of the type and valence of the face under perceptual load, alternatively it could indicate that participants used a proxy feature, perhaps masculinity (which may be clearer at the extremes (e.g. -3SD and +3SD valence) but less so nearer the neutral (e.g. -2SD and +2SD Valence).

Overall, the attentional capture and engagement properties of negatively valenced stimuli were not apparent in Experiments 1-3, to the extent that accuracy was higher for more positive lower valenced faces. These results could reflect a facet of the more ecological stimuli, or even indeed a specific property of the face-space employed. It would be interesting to investigate these questions with a parametrical time presentation approach, and also to corroborate these conjectures with other facial social judgments. More research is needed to disentangle the role of valence, social judgment and perceptual load.

While the findings presented here are subtle, they nevertheless support demonstrations of increased attentional load to partly alter facial processing capability, although it is also worth considering some stipulations regarding these results, the possibility of pre-attentive features in the dimensional images and the dual task nature of the task particularly merit a brief mention.

It is generally assumed that certain image characteristics may be so elementary to the visual system that they require no attentional resources to be perceived. Such pre-attentive features are commonly identified by visual search performance, where the reaction time for detecting a feature difference against a set of distractor items should not increase with the number of distractors. Whether there are such facial pre-attentive features in the dimensional face space we have employed here, perhaps allocated deferentially between the dominance and trustworthiness components is unknown, although presumably the capacity for elementary characteristics requiring no attentional resources to be perceived would not be unlimited. For non-facial attributes, the detection of differences in a simple feature such as orientation is worsened by additionally imposing an attentional demanding rapid serial visual presentation task involving letter identification. The same visual stimuli exhibit non-increasing reaction time versus set-size functions. These results demonstrate that attention can be critical, even for the detection of so-called pre-attentive features (Joseph, Chun, & Nakayama, 1997), whether a similar process occurs for complex stimuli such as faces is of course unclear.

Ultimately a better understanding of the feature components of the highly multidimensional faces that we have used in the latter experiments would help in discerning how load interrelates with the valence and type of a face in utilizing attentional capacity.

A possible concern in the interpretation of our results, is that when two visual discrimination tasks are performed concurrently, it is conceivable that performance on one task comes at the expense of performance on the other (although we are somewhat protected against this criticism, as the primary interest is the relative change of performance from high low to high load). This concern is somewhat mitigated by the observation that people may possess a significant visual awareness of poorly attended stimuli, especially when these are salient and pop out from the scene such as faces. Some authors have proposed the term "ambient vision" to describe this visual performance with respect to poorly attended but salient stimuli (Braun, Koch, Lee, & Itti, 2001). This concern can be allayed somewhat further by the finding that when one of the tasks involves simple detection, as in the letter search task (and even arguably in the case of social facial judgment for those who argue in the pervasiveness of trait/emotion facial processing capacities) there is no such decline in performance (Braun et al., 2001). Although task requirements may be an important factor in influencing the distribution of attention (Bonnel, Stein, & Bertucci, 1992), the tasks employed here comprise relatively distinct processes, e.g. semantic (character recognition) and facial judgment (face processing) and thus the dual task nature should not undermine our inferences regarding attention. Such a position is supported by the absence of interactions between valence and load in Experiments 1-3 either for the search array results or reaction times, suggesting that the load task was not subject to interference by the facial judgments tasks.

Overall, the inferences from this study are restricted to the comparison of accuracy performance in dual-task conditions which differ only in the level of load on attention; although these inferences may be open to other alternative accounts in terms of potential effects of load on response bias or memory.

The experimental task employed permits relative comparisons between high and low load (in that the task remains the same in all respects other than the perceptual load of the search task). The results obtained are unlikely to be an effect of task difficulty, given the high accuracy in the low load and no load search task, or goal neglect (due to performing two tasks simultaneously) as only accurate search trails are included. However, the load comparison may be confounded by non-attentional processes such as memory (due to the delay or order caused by making one task response after the other), or response bias. To investigate these facets we will have to turn to the next Chapter.

It is also worth mentioning (as may be apparent from the discussion in the first Chapter) that amongst the multivariate way attention has been manipulated, as a first approximation, studies demarcate between attended/unattended, or in the case of perceptual load high or lower perceptual resources in their manipulation of attention. Arguably, the perceptual load approach is superior, as it is often highly debated as to whether a stimulus can ever be completely unattended (Braun, 2001), especially when it involves a sudden visual onset, is anticipated by the observer, or is the target of an observer response (Braun, 2001).

There are important subtle questions regarding the role of attention and how it is manipulated, the perceptual load approach fortunately circumvent some of them, as in our manipulation we seek to adopt only a qualitative as opposed to quantitative difference of attention with the load manipulation (that is we are interested in the differences rather than the absolute quantities of attention, if such a s thing can be measured), without getting drawn, (on the admittedly important issue) of the ontological nature of attention.

To summarize, these results, although complex, provide subtle but provisional support for the claim that the level of perceptual load in a task can sway the extent to which certain facial stimuli are perceived. Social facial judgment can be modulated by attentional perceptual resources.

Relating these results to the issue of automaticity in facial processing is complex, notwithstanding simply the polyvalent nature of the term “automaticity”. From these preliminary findings, it is not possible to adjudicate with certainly that there is not some form of automaticity in facial processing, especially vis-à-vis the outcome of the dominance results. However, presumably this automaticity takes time, and at least for social judgments such as trustworthiness and threat, it may be modifiable by attentional load. This finding is thus intertwined with one of the central creeds of load theory and has importance for the early and late selection debate as to where facial processing and social judgments are affected by perceptual resources. Although, there are still issues to be addressed, these results endorse a role for attention as a component in the gateway of facial social judgments.

4 *Facial Social Judgment and perceptual Load: Questions, and Criticisms*

“There are mystically in our faces certain characters which carry in them the motto of our souls, wherein he that cannot read A, B, C may read our natures” Religio Medici - Sir Thomas Browne (1643)

"A man finds room in the few square inches of his face for the traits of all his ancestors; for the expression of all his history, and his wants". Ralph Waldo Emerson, Conduct of Life

Overview

The perceptual load studies of the prior Chapter by manipulating the number of items in the search display explored a range of social judgment dimensions; namely trustworthiness, dominance and threat. This chapter seeks to rule out alternative accounts to explain the preliminary results presented in that chapter. Alternative accounts such as the order of the task effects (countered by reversing the order of the experiment), specificity to perceptual load (implying that a working memory load task that doesn’t exhaust perceptual capacity of a similar difficulty to the perceptual load task, should not affect social judgment perception), or simply some form of bias under the demanding effects of load (investigated by modifying the experimental paradigm with a signal detection framework).

The results add cautious but convergent support to the observations presented in Chapter 3. The evidence indicates that facial judgments under perceptual load may be contingent on both the type of judgment and valence of a face, discounting alternative descriptions as explanations for the data. The pattern of results for dominance facial judgments once again evidenced atypical responses to load effects in comparison to trustworthiness and threat evaluations.

4.1 Chapter Introduction

In the preceding series of experiments in the last Chapter, the capacity for facial social judgment perception at fixation was impaired under high perceptual load for certain types of judgments. While this provides support for some level of efficacy of perceptual load on facial judgments, there are some valid criticisms to any inferences from these experiments which need to be addressed. For example, participants in these experiments made the letter search response before the social judgment response. This helps to show that the perceptual load manipulation was effective (leading to reduced search accuracies under high (as compared to low) load). However, it is feasible that the effect of perceptual load on the social judgment perceptions was due to the delayed reaction for the facial stimuli, that is, as the facial judgment was reported after the letter task, conceivably the longer time it took participants to report the target letter under high load may have led to a weaker memory imprint for the facial stimuli. Another possibility is that high perceptual load may have led to goal neglect or reduced prioritization of the second response on each trial, potentially influencing the observed results in Chapter 3.

Another criticism refers to the nature or specificity of the effects. If the attentional constraint effects on social judgment accuracy are specific to *perceptual* load, that should imply that a working memory load task (that doesn’t exhaust perceptual capacity) of a similar difficulty to the perceptual load task, should not affect valence or social judgment perception in the manner intimated in the prior Chapter.

Finally, although the issue did not arise in the experiments in the last Chapter, it is also of concern that it is not facial detection capacity that is in actuality affected (and thus causing the findings presented in Experiments 1-3) but rather some form of bias under the demanding effects of load that is the important concern.

It is the resolution of these matters that I shall explore in this Chapter.

4.2 Role Reversal

4.2.1 Experiment 4

4.2.1.1 Introduction

As I mentioned in this Chapter’s introduction, it is possible that the effect of perceptual load on the social judgment perceptions in the prior Chapter were due either to the delayed response or attenuated short term memory imprint for the facial stimuli. To address these issues, in the present study, we set out to examine the effects of perceptual load on the detection of trustworthiness subjective judgment faces with a slightly modified paradigm (where participants performed the facial social judgment task *before* the perceptual load search task).

As Experiment 4 was a follow-up to that of Experiment 1, we hypothesised that the reversal in participants' response order would not prohibit high perceptual load from impacting the judgment accuracy of trustworthiness faces and therefore predicted that facial judgment accuracies would be reduced under high perceptual load.

4.2.1.2 Method

4.2.1.2.1 Participants

13 new participants were included in Experiment 4, Mean Age = 21.69, SD 2.72 (range 18 - 26) (6 males) (3 outliers removed). All of the participants in this experiment had normal or corrected-to-normal vision, as in the prior experiment, any subject with less than 50 % accuracy on the Low Load face or search tasks was classified as an outlier and removed from the subsequent analyses, participants participated for course credit or were paid £3 pounds.

4.2.1.2.2 Stimuli and procedure

The apparatus and procedure were the same as experiments 1-3 except that the participants were instructed to make their response on the faces identities *before* that of the search stimuli (the perceptual load manipulation). For brevity, no face rating task was performed at the end in this series of corollary experiments (and nor were reaction times recorded as they were contaminated by order effects as the load task was now performed after the face judgment.

As before, the faces were generated using FaceGen Modeller 3.2 (Singular Inversions, 2007), according to the methods described in (Oosterhof et al., 2008). Mirroring Experiment 1, in Experiment 4 participants were instructed in this instance to make their response on 24 faces identities that vary on 4 levels of trustworthiness. Also as before, in advance of starting the experiment, participants completed one practice block of 12 example trials to familiarise themselves with the keys.

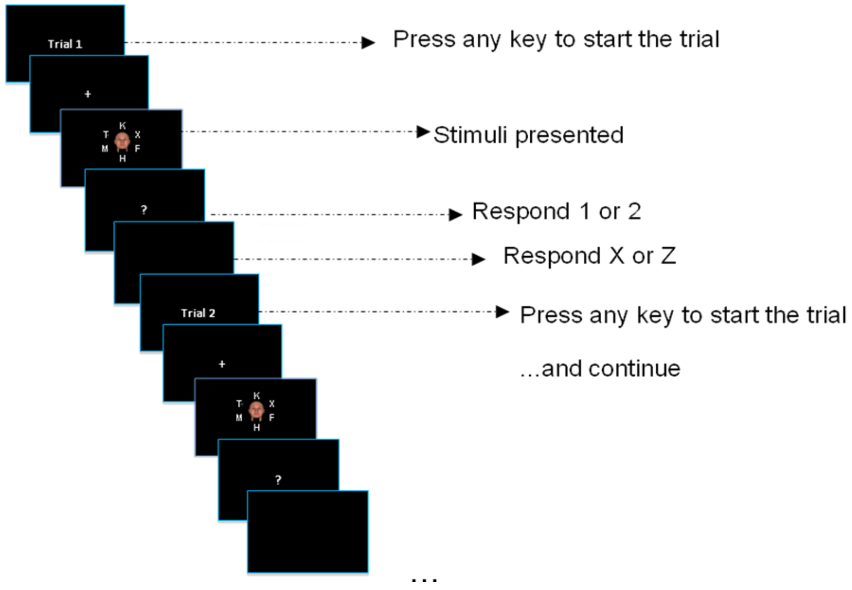


Figure 4-1 Example screen display of Perceptual Load – "Role Reversal" manipulation (high load condition illustrated)

4.2.1.2.3 Design

The Design was very similar to Experiment 1. Mean percentage search accuracy rates were the dependent variable and were entered into a 2 x 4 repeated measures ANOVA, with perceptual load (Low, High) and Valence (-3, -2, +2, +3 - SD faces) as within subject independent variables (IVs).

Subsequently the mean percentage trustworthiness accuracy rates were treated as the dependent variable and entered into the same 2 x 4 repeated measures ANOVA, again with perceptual load (Low, High) and Valence (-3, -2, +2, +3 - SD faces) as within IV's, excluding trials in which the search response was incorrect.

This same design was employed for Experiment 5 (using dominance faces) and Experiment 6 (using threatening faces).

4.2.1.3 Results and Discussion

Search task Mean percentage search accuracy rates were significantly better in the low perceptual load condition (M = 96 %) than in the high perceptual load condition (M =92 %), $F(1, 12)$ = 8.08, MSE =.005, p = .013, η^2 = .41. There was no significant effect of valence (F<1) $F(3, 36)$ =0.19,

MSE = .003, p = 0.96, η^2 =.002. Additionally there was also no significant interaction between valence and load (F<1) F(3, 36) =.25, MSE =.004, p = .86, η^2 =.02, this confirms again that the perceptual load manipulation was effective (see **Table 4-1**).

	Perceptual load		
	Low	High	Differential Effect of load
Search Accuracy (%)	96(4)	92(5)	4*
Face Accuracy (%)	83(6)	80(6)	3*

SDs are listed in parenthesis. * = significant NS = not significant

Table 4-1 Mean percentage search accuracy rates and mean face accuracy rates in the reversed trustworthiness task as a function of load in Experiment 4

Face classification. Mean percentage trustworthy face accuracy rates were weakly but significantly higher in the low perceptual load condition (M = 83 %) compared to the high perceptual load condition (M =80 %), F(1, 12) = 3.58, MSE = .09, p = .041(*one-tailed*), η^2 = .23, indicating a moderate effect of perceptual load. There was a significant effect of valence F(3, 36) =17.90, MSE = .014, p < .001, η^2 = .60, specifically, accuracy decreased from the high untrustworthy faces to the high trustworthy faces. As **Figure 4-2** illustrates (and confirmed by post –hoc testing), the overall effect of valence was driven by -3SD valence being significantly greater than all the other valences, - 2SD valence being significantly greater than +2SD and less then -3SD valence, and +2SD being less than +3SD valence.

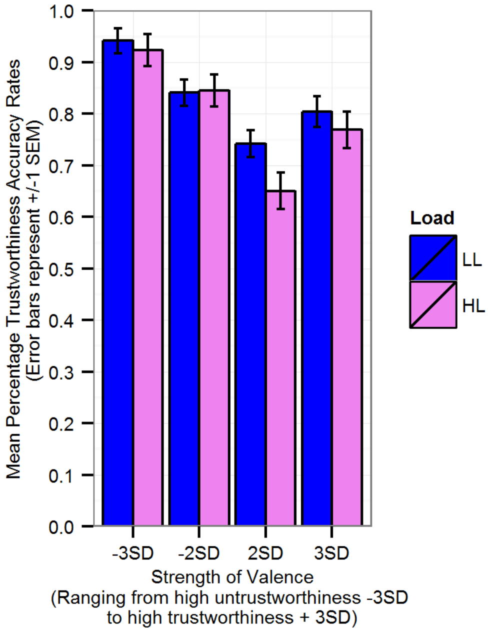


Figure 4-2 Trustworthiness mean percentage face accuracy rates in the task reversed assignment (valence ranges from high untrustworthy valence -3SD on the left to high trustworthy +3SD on the right)

Finally, there was no significant interaction between valence and load *F*(3, 36) = 1.07, *MSE* =.01, *p* = .374, η^2 = .082.

This result seems tentatively encouraging in that, we have a weak main effect of load (one-tailed given our predications about the direction of perceptual load), with a similar pattern to that of Experiment 1 (see **Figure 3-4)** with a dip in the mid-range valence faces (Figure 4-2 above). However in contrast to Experiment 1 there are higher overall accuracies for the untrustworthy valenced faces as opposed to untrustworthy ones here. This suggests that the button order may slightly impact the participants' evaluations. Additionally, all the low load accuracies are numerically greater than the high load accuracies except for the mid-range valence -2SD category, where high load is very slightly (although non-significantly) greater than low-load.

Overall, however, in both instances, Experiments 1 and 4, it seems the effect of load is being driven by trustworthy faces, which follow-up testing revealed to be borne by +2SD valence faces being lower under high load (*t*(12) = 2.38, *p* = .035) here, rather than +3SD valence faces as in Experiment 1.

To ascertain if the patterns that we observed in the last Chapter are reflected in the other facial judgment domains, we return to facial dominance evaluations in the next experiment.

4.2.2 Experiment 5

4.2.2.1 Introduction

The aim of Experiment 5 was identical to Experiment 4, to examine the effects of perceptual load on facial judgment detection accuracies, however in this instance, to provide a contrast to the trustworthy evaluations there, we investigate the orthogonal dimension of dominance facial judgments.

In line with the experimental results of Experiment 2, where the dimension of dominance judgments were resistant to perceptual load effects, we hypothesised a similar pattern here, suggestive of something uncharacteristic either regarding perceptual load for dominance evaluations or yielded by some property of the face space that we are employing.

4.2.2.2 Method

4.2.2.2.1 Participants

12 new participants were included in Experiment 5, (2 males) Mean Age = 19.47, SD 1.64 (11 females) (range 18 - 29) (0 outliers removed). All of the participants in this experiment had normal or corrected-to-normal vision, as in the prior experiment, any subject with less than 50 % accuracy on the Low Load face or search tasks was classified as an outlier and removed from the subsequent analyses, participants participated for course credit or were paid £3 pounds.

4.2.2.2.2 Stimuli, Procedure and Design

The apparatus and procedure and design were identical as experiments 4, except that the participants were instructed in this instance to make their response on 24 faces identities that vary on 4 levels of dominance.

4.2.2.3 Results and Discussion

Search task Mean percentage search accuracy rates were significantly better in the low perceptual load condition (M = 82 %) than in the high perceptual load condition (M =68 %), $F(1, 11)$ = 17.58, MSE =.026, $p < .005$, η^2 = .61. There was no significant effect of valence (F<1) $F(3, 33)$ = .57, MSE = .021, p = .638, η^2 = .049. Additionally there was also no significant interaction between valence and load (F<1) $F(3, 33)$ =.428, MSE =.014, p = .735, η^2 = .037. These results confirmed the effectiveness of the perceptual load manipulation was effective (see **Table 4-2**).

	Perceptual load		
	Low	High	Differential Effect of load
Search Accuracy (%)	82(14)	68(12)	14*
Face Accuracy (%)	76(9)	76(10)	0 NS

SDs are listed in parenthesis. * = significant NS = not significant

Table 4-2 Mean percentage search accuracy rates and mean face accuracy rates in the reversed dominance task as a function of load in Experiment 5

Face classification. Mean percentage dominance face accuracy rates were the same in the low and high perceptual load conditions (M = 76 %), $F(1, 11)$ =.12, MSE = .026, p = .73, η^2 = . 011, indicating again the resistance of dominance social judgments to perceptual load. There was no significant effect of valence $F(3, 33)$ = 22.39, MSE = .031, $p < .001$, η^2 = .67, or interaction between valence and load (F<1) $F(3, 43)$ = .78, MSE =.026, p = .511, η^2 = .067.

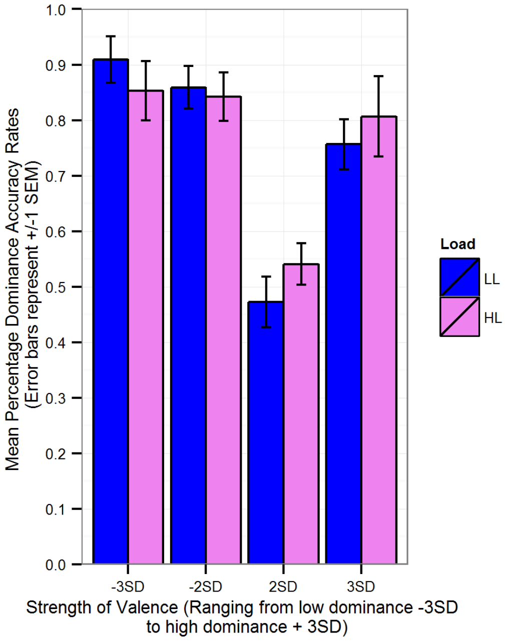


Figure 4-3 Dominance mean percentage face accuracy rates in the task reversed assignment (valence ranges low dominance valence -3SD on the left to high dominance +3SD on the right)

These findings seems cautiously reassuring in that we have replicated the absence of a main effect of load seen in Experiment 2 and the mixed response pattern across the valence range. This could suggest that that reversal of order does not impact the results seen in the prior chapter too substantively. However there some minor differences between Experiment's 2 and 5, although there was similar dip pattern in the mid-range valence faces to that of Experiment 2 (see **Figure 3-5)** (the brunt of which is borne on both cases by + 2SD valence faces), here numerically-2SD and +3 SD valence are less under low load as compared to high load and (the opposite of which was evident in Experiment 2). Importantly however, follow up testing revealed as in Experiment 2 that none of the low load vs. high load pairs were significantly different for any of the categories (-3, -2, +2, +3 SD faces) and thus overall the pattern seen here for dominance in the task reversed assignment coheres relatively well with that for dominance seen in the prior chapter.

4.2.3 Experiment 6

4.2.3.1 Introduction

The aim of Experiment 6 was identical to Experiment 4 and 5; to examine the effects of perceptual load on facial judgment detection accuracies; although like Experiment 3 we employ the arguably more emotional stimuli of threatening faces to examine and contrast the effects of perceptual load on facial judgment detection accuracies with the prior results (where participants performed the facial social judgment task *before* the perceptual load search task).

Once again, given that our prediction is that any impairment in facial social judgments is specific to perceptual load (Lavie et al., 2004) we do not expect that the order of tasks should drastically impact the pattern of results and thus hypothesize a similar pattern observed for threat in Experiment 3, that is, threat judgment accuracies will be reduced under high load.

4.2.3.2 Method

4.2.3.2.1 Participants

15 participants were included in Experiment 6; Mean Age 19.47, SD 1.64 (4 males) (range 18 - 24) (1 outlier removed). All of the participants in this experiment had normal or corrected-to-normal vision, as in the prior experiment, any subject with less than 50 % accuracy on the Low Load face or search tasks was classified as an outlier and removed from the subsequent analyses, participants participated for course credit or were paid £3 pounds.

4.2.3.2.2 Stimuli, Procedure and Design

Once again the apparatus and procedure and design were identical as Experiments 4 and 5, except that the participants were instructed in this instance to make their response on 24 faces identities that vary on 4 levels of threat.

4.2.3.3 Results and Discussion

Search task Mean percentage search accuracy rates were significantly better in the low perceptual load condition (*M* = 90 %) than in the high perceptual load condition (*M* = 80 %), *F*(1, 14) = 13.81, *MSE* =.022, *p* < .005, η^2 = .50. There was no significant effect of valence (*F*<1) *F*(3, 42) = .63, *MSE* = .11, *p* = .597, η^2 = .043. Additionally there was no significant interaction between valence and load (*F*<1) *F*(3, 42) =.17, *MSE* =.009, *p* = .913, η^2 = .011. This again confirms that the perceptual load manipulation was effective (see **Table 4-3**).

	Perceptual load		
	Low	High	Differential Effect of load
Search Accuracy (%)	90(8)	80(13)	10*
Face Accuracy (%)	78(11)	72(11)	6*

SDs are listed in parenthesis. * = significant NS = not significant

Table 4-3 Mean percentage search accuracy rates and mean face accuracy rates in the reversed threat task as a function of load in Experiment 6

Face classification. Mean percentage threat face accuracy rates in the low perceptual load condition were significantly higher (*M* = 78 %) than in the high perceptual load condition (*M* =72 %), *F*(1, 14) = 11.20, *MSE* = .009, *p* = .005, η^2 =.44, indicating the effect of perceptual load. There was again a significant effect of valence *F*(3, 42) = 9.91, *MSE* =.044, *p* < .001, η^2 = .41 and a significant interaction between valence and load *F*(3, 42) = 4.04, *MSE* = .018, *p* = .013, η^2 = .22.

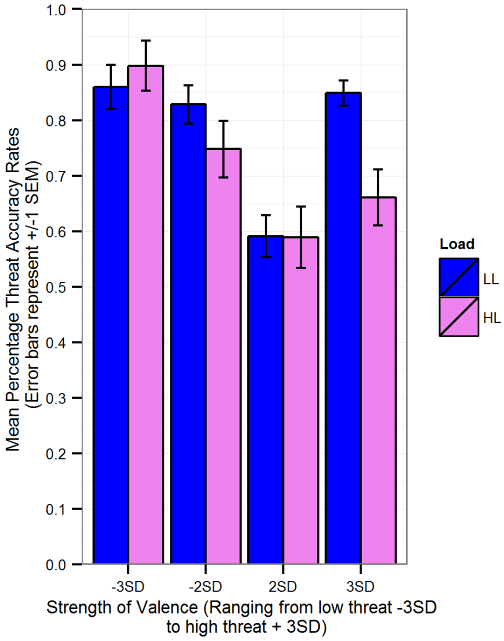


Figure 4-4 Threat mean percentage face accuracy rates in the task reversed assignment (valence ranges low threat valence -3SD on the left to high threat +3SD on the right)

This result again seem seems cautiously reassuring in that we have replicated the presence of a main effect of load seen in Experiment 3 and the response pattern seen there (**Figure 3-6**) with a significant effect across the valence range is broadly similar to the one shown above (**Figure 4-4**). Again there are minor differences between the two; such as here numerically -3SD valence mean accuracy is actually greater under high load than low load.

The significant interaction between load and valence in Experiment 6 also has to be borne in mind (an interaction not present in Experiment 3). Although follow up testing revealed that none of the low load vs. high load pairs were significantly different for any of the categories (-3, -2, +2, +3 SD faces) in Experiment 3, here, the high threat face accuracies for maximum threat +3SD valence were solidly and significantly reduced under high load (*t* (14) = 5.41, *p* <.001 (low load *M* = 85 % vs. high load *M* = 66 %)). It is this large difference which is driving the interaction between load and valence.

On the whole, the pattern seen here for threat broadly coheres in the task reversed assignment with that for threat seen in the prior chapter, although the effect of load was more formidable on high threat faces than that sees in Experiment 3 (in Experiment 3, although +3SD valence faces were the most impacted by high load with a difference of 7.5 % between low and high load, this is more than half of the observed effect here at 19 %). This could imply that for certain judgments, the slight difference in time that occurs between judging a face and then responding to load (as opposed to the contrasting order seen in Experiments 1-3) may influence the efficacy of load, although this does not contradict the general notion that perceptual load appears to have a role in impacting facial judgments for certain type of evaluations and valences.

4.2.3.4 Full model

Overall, reversing the order of responses so that the judgment responses came first did not have a significant impact on the pattern of modulation by perceptual load that we have observed in the last chapter.

A comparison of the results of experiments from the last Chapter and the reversed-order results just presented with a between experiment ANOVA revealed no main effect of experiment, for any of three groups; that is for trustworthiness $F(1, 26) =1.18$, $MSE = .047$, $p = .28$, $\eta^2 = .044$, for dominance $F(1, 27) < 1$, $MSE = .045$, $p = .62$ and for threat $F(1, 30) < 1$, $MSE = .063$, $p = .99$, $\eta^2 < 0.001$, all had no significant differences between experimental manipulations.

Additionally, none of the two or three-way interactions between experiment, load and valence were significant, except predictably (if one scrutinizes the graphs for face judgment accuracies) for a corresponding interaction for both trustworthiness and dominance between experiment and valence.

The slightly different general patterns of response for valence in trustworthiness (Experiments 1 and 4) and dominance (Experiments 2 and 5) were evident in the interaction between both of those experiments and valence.

The valences accuracies were less for the more trustworthy faces in Experiment 1 than Experiments 4. Specifically trustworthiness +2SD and +3SD valence were less in Experiment 1 (M = 75 % and M = 79 % respectively) than Experiment 4 (M = 84 % and M = 93 % respectively) - ($F(1, 26) =5.40$, $MSE = .01$, $p = .028$, $\eta^2 = .17$ and ($F(1, 26) =9.41$, $MSE = .015$, $p = .005$, $\eta^2 = .27$).

Likewise for dominance there was a slight difference of overall valence between the experimental iterations, which follow up pairwise testing revealed was driven by -2 SD valence being less in Experiment 2 (M = 74% vs M= .85) than Experiment 5 ($F(1, 26) =4.86$, $MSE = .017$, $p = .036$, $\eta^2 = .15$).

4.2.3.5 Discussion

The latter three experiments (Experiments 4-6),broadly replicates the pattern of results of perceptual load effects on facial social judgment found in Experiments 1-3, even though the order of responses was reversed so that the categorization response came after the search response. Reaction times were not analysed as they were contaminated by order effects as the load task was now performed after the face judgment – although encouragingly in all three experiments (4-6) the reaction times were significantly faster under low as opposed to high load (with no interactions or effects of valence).

As to be expected in any experimental replication, there were some differences, e.g. in Experiment 5 the high threat face accuracies for maximum threat +3SD valence were solidly and significantly reduced under high load (low load M = 85 % vs. high load M= 66 %)), as opposed to a weaker impact (but still the largest of all the valences in that experiment) in Experiment 3 (low load M = 77 % vs. high load M= 69.5 %)).

The largest disparities amongst the experimental iterations were the differences for trustworthiness evaluations in Experiment 1 and 4, where the pattern of valence accuracies were altered, being less for the more trustworthy faces in Experiment 1 than Experiments 4. Specifically trustworthiness +2SD and +3SD valence were less in Experiment 1 (*M* = 75 % and *M* = 79 % respectively) than Experiment 4 (*M* = 84 % and *M* = 93% respectively). Encouragingly, however, in both instances, the effect of load was driven by trustworthy faces (although this was borne by +2SD valence faces being lower under high load in Experiment 4, rather than +3SD valence faces as in Experiment 1) and a comparison of the results of the experiments here and from the last Chapter revealed no main effect of experiment (for any of three groups).

It is worth mentioning briefly the role of any two target cost in processing that may occur. There is some evidence to suggest that split attention leads to reduced performance when targets appear in a display simultaneously and require independent identification and a separate response (Duncan, 1980), as in the experiments reported in this thesis (where the participants are performing both a search task and a facial judgment task, based on a single stimulus presentation). Since however, we are primarily interested in the relative difference between low and high load, the potential effects of any two target response do not impact our conclusions as it is the application of load which is critical for our inferences.

Furthermore, the high overall accuracies as observed in the experiments thus far, indicate that the consequences of any possible two-target cost if indeed present, are not substantive.

Where it is possible that any putative two target cost may be relevant, is with regards to the order of task e.g. whether the facial judgment or search task is performed first.

By and large, the similar pattern of results with both key press orders (the effects of load are present irrespective of the order of stimuli response (i.e. search and facial social judgments being reversed) in Experiments 1-3, and Experiments 4-6 do not appear to support this possibility. Although, perhaps some of the slight differences in the trustworthy results of Experiments 1 and 4 for example, may by as a result of slightly different consequences of split attention. Of course this is speculative, as it is possible that there may be slight memory cost instead. Indeed, the nature of a two target cost for experiments such as in this thesis, is itself debated, with some authors suggesting that in fact in dual type tasks, attending to the first stimulus may increase or boost performance in the second task – an attentional boost effect (Swallow & Jiang, 2010). The idea being that the target detection opens an attentional gate that briefly enhances the perceptual processing of coinciding information (Swallow & Jiang, 2014). Although, as I said earlier within this section, this does not impact our conclusions, or the assumption that perceptual processes are limited.

Perceptual load is the working hypothesis that we are employing, accounting for how attention influences which information is processed, where all available perceptual resources are used even if it results in poorer performance (Lavie, 1995). This assertion entails that increasing the perceptual load of the target implies a reduction in resources available for encoding the concurrent image. It is possible that the effect of image encoding may be somewhat offset by modest deviations or some form of interference due to alerting and arousal by the need to respond to two tasks (Posner & Boies, 1971). Reassuringly, however in the experiments is this section (Experiments 4-6) there were no main effects or interactions between valence and load (or indeed in Experiments 1-3) either for the search array results or reaction times (in Experiment 1-3) for the search task, suggesting that the load task was not subject to interference by the facial judgments tasks. Even so, it will be important for future research, given the conflicted findings in the face and attention literature, and the modest effects that we have demonstrated so far, to determine any possible effects of a dual-task interaction and whether this applies to tasks comprised of distinct processes such as semantic (character recognition) and facial judgment (face processing) as employed here.

Overall, reversing the order of responses so that the judgment responses came first did not have a significant impact on the pattern of modulation by perceptual load that we have observed in the last chapter. This suggests that the button order, if at all, only slightly impacted the participants' evaluations (arguably more so for trustworthiness judgments). This may indicate something specific about that trustworthy judgments, sampling variability or some subtle participant bias preferences, an issue we will return to and focus on in Experiment 10.

Taken as a whole, these results and the fact that in these experiments, participants did not have to pause their judgment response until after they had made the search response, weakens alternative accounts of the results being in terms of a perceptual load effect on working memory say, rather than on perceptual categorization sensitivity. This result provides some evidence to counter the criticism that it is not the perceptual aspects of the facial stimuli which are affected by increasing load but rather the fact that participants have to hold in memory their response which is then what is actually affected by perceptual load.

This adds further support to the hypothesis that the level of perceptual load in a task has a role in influencing facial social judgment perception.

4.3 A Good Memory for Faces

Chapter 3 and the latter experiments of this chapter have put forward a role for perceptual load in visual alertness in social facial judgments. In this section I turn to examine the role of executive processes in stimulus judgments. If working memory is required to act as a top-down control mechanism, then loading working memory should reduce the visual system’s ability to perform facial social evaluations, implying that the observed effects in the last Chapter and in the prior experiments are not specific to perceptual load.

On the other hand, if the latter proposition is not the case, then this suggests that a working memory load task (which doesn't exhaust perceptual capacity) of a similar difficulty to the perceptual load task employed in Experiments 1-6, should not affect valence perception. Explicitly, we hypothesize, in contrast to the prior set of experiments (Experiments 1-6) that high perceptual load will *not* significantly impact face judgment accuracies. It is precisely this hypothesis that the next group of experiments, Experiment 7-9 will investigate.

4.3.1 Experiment 7

4.3.1.1 Introduction

In order to further explore whether the moderately reduced trustworthiness facial judgment accuracies of Experiments 1 and 4 under high perceptual could be accounted for by some facet of working memory we turn to the next experiment.

Explicitly, we hypothesized that in contrast to the already observed effects of perceptual load on trustworthiness facial judgments; such judgments under working memory load will *not* significantly differ between the low and high working memory load conditions.

4.3.1.2 Method

4.3.1.2.1 Participants

11 new participants were included in Experiment 7, (5 males) (Mean age = 22.54, SD 3.24 (10 females) (range 18 – 27) (2 outliers removed). All of the participants in this experiment, had normal or corrected-to-normal vision, as in the prior experiment, any subject with less than 50 % accuracy on the Low Load face or search tasks was classified as an outlier and removed from the subsequent analyses, participants participated for course credit or were paid £3 pounds.

4.3.1.2.2 Stimuli and procedure

The apparatus and stimuli generation were identical to Experiments 4, 5 and 6, however as this was an experiment on working memory there were some modifications.

The flow of the experiment is illustrated below in **Figure 4-5**. Participants were provided with a written explanation and told that their task was to mentally verbally rehearse each number presented on each trial. As in the experiment in the last Chapter, each trial in the visual search task began with key press that was self-initiated. This was followed by a fixation point presented for 500 ms in the centre of the screen, followed immediately by a presentation of a single number in the low load condition (of 500 ms duration) and a six number string for the high load (of 1500 duration); the target numbers were equally likely to appear in any of the possible combinations of positions. Following this number, a fixation cross would appear on the screen; followed by a face. The face, centred at fixation was displayed with a 150 ms presentation time. The participants' first response would be to indicate whether the face shown (within a response window of 2000 ms) was trustworthy or untrustworthy (for Experiment 7 the same procedure was employed but the participants were asked to indicate dominant or not dominant and for Experiment 9, threatening or not threatening).

The presentation of the face was then followed by a mask of 500ms. To maintain comparability with the prior experiments in Chapter 3, the number keypad values 1 and 2 were used for social facial evaluations. Following the response to the face a "probe" number would appear (with a total delay duration between face onset of 3000ms) – whereupon the participant was instructed to indicate, using the keyboard whether the probe number that they were mentally verbally rehearsing appeared at the beginning of the trial: indicating "X" for present or "Z" for absent, (within a response window of 4000 ms). As aligned with the prior experiments, there was a total of 4 blocks, 2 high and 2 low (randomized across participants). Each block consisted of 24 trials, (12 trustworthy and 12 untrustworthy images, presented in random order). Each face was presented once during the experiment and the assignment of positive valence faces to negative or positive blocks was randomized and counterbalanced across participants and across blocks. Before starting the experiment, participants completed one practice block of 12 example trials to familiarise themselves with the keys.

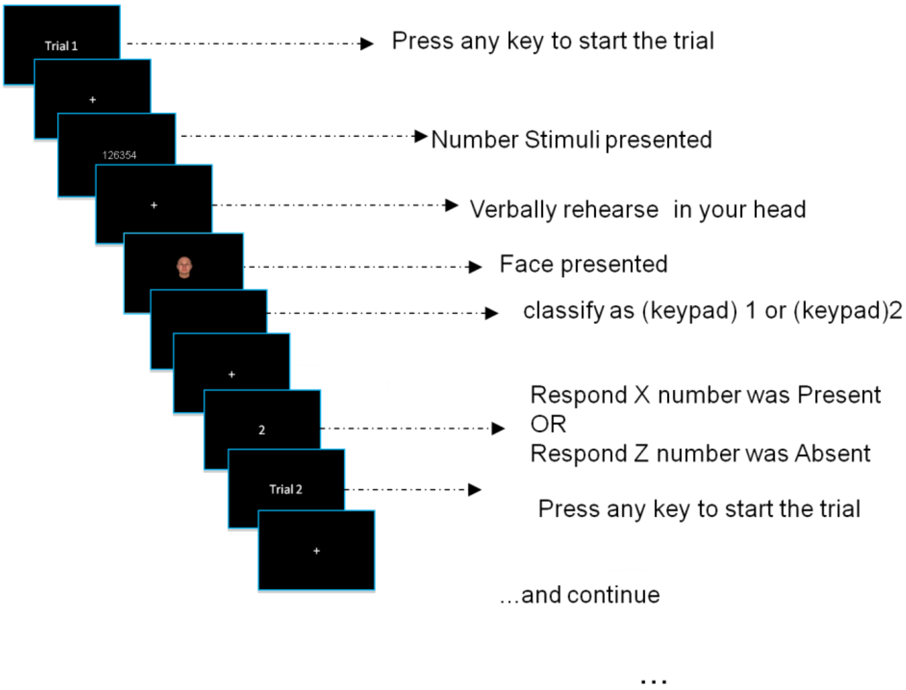


Figure 4-5 Example screen display of Working Memory load manipulation (high load condition illustrated) The flow of the experiment is illustrated above for the "6 numerals" or "high load" condition in which participants endeavoured to remember a six digit number. As in the prior experiments, there were total of 4 blocks, 2 blocks of high load and two of low load; 96 Trials in total – 24 unique identities 4 levels of emotion/valence. In the high load a number sting is displayed e.g. 126353 as shown above, at probe, e.g. the number 2 as above, a correct response would be for the participant to say that this number was indeed present. An instance of a low load would be a single number between 1 and 9

4.3.1.2.3 Design

The design employed here was almost identical to that employed in the prior experiments (Experiments 1-6), only slightly differing on the dependent variables (and restated here for clarity).

Mean percentage search accuracy rates and mean reaction times for the working memory response were the dependent variables, and were entered separately into a 2 x 4 repeated measures ANOVA. With perceptual load (Low, High) and Valence (-3, -2, +2, +3 - SD faces) as within subject independent variables (IVs).

Note, the mean reaction times for the working memory response is a relatively uncontaminated measure, as it does not measure from the time of the memory number stimuli which would then include processing of the face viewing, but measures instead probe response time minus onset of memory probe. This measurement should give some indication of the comparative difficulty between the levels of working memory load.

Next mean percentage trustworthiness accuracy rates were the dependent variable and was entered into the same 2 x 4 repeated measures ANOVA., again with perceptual load (Low, High) and Valence (-3, -2, +2, +3 - SD faces) as within IV's, excluding trials in which the search response was incorrect.

This same design was employed for the following two experiments, Experiment 8, for dominance faces and Experiment 9 for threatening faces.

4.3.1.3 Results and Discussion

Memory task The mean correct memory-probe identification rates were significantly better for trustworthiness in the low working memory load condition (*M* = 97 %) than in the high working load condition (*M* =91 %), $F(1, 10) = 18.80$, $MSE = .005$, $p = .001$, $\eta^2 = .65$. There was no significant effect of valence $F(3, 30) = 1.55$, $MSE = .005$, $p = .222$, $\eta^2 = .13$. Additionally there was also no significant interaction between valence and load *(F<1)*, $F(3, 30) = .89$, $MSE = .006$, $p = .456$, $\eta^2 = .082$.

Mean reaction times in the low working load condition were significantly faster (*M* = 770) than in the high working load condition (*M* =1126), $F(1, 10) = 43.27$, $MSE = 64525.32$, $p < 0.001$, $\eta^2 = .81$. There was no significant effect of valence *(F<1)*, $F(3, 30) = .87$, $MSE = 11215.86$, $p = .468$, $\eta^2 = .080$. Furthermore, there was no significant interaction between valence and load for mean reaction times *(F<1)*, $F(3, 30) = .49$, $MSE = 18377.37$ $p = .694$, $\eta^2 = .046$.

These results endorse the claim that the working load condition manipulation was indeed more demanding in the low load condition as in contrast to the high load condition for trustworthiness judgments (see **Table 4-4**).

Perceptual load			
	Low	High	Differential Effect of load
Search Accuracy (%)	97(3)	91(5)	6*
Reaction Time (ms)	770(268)	1126 (336)	356*
Face Accuracy (%)	87(7)	85(5)	2 NS

SDs are listed in parenthesis. * = significant NS = not significant

Table 4-4 Mean percentage search accuracy rates, mean reaction time (ms) rates and mean face accuracy rates in the working memory trustworthy task as a function of load in Experiment 7

Face classification. Mean percentage face accuracy trustworthiness rates in the low working memory load condition were *not* significantly better (M = 87 %) than in the high working memory load condition (M =85 %), $F(1, 10) = 1.69$, $MSE = .006$, $p = .222$, $\eta^2 = .145$. There was however both a significant effect of valence $F(3, 30) =5.79$, $MSE = .026$, $p <.005$, $\eta^2 = .367$, and a significant interaction $F(3, 30) = 4.073$, $MSE =.004$, $p = .015$, $\eta^2 =.289$.

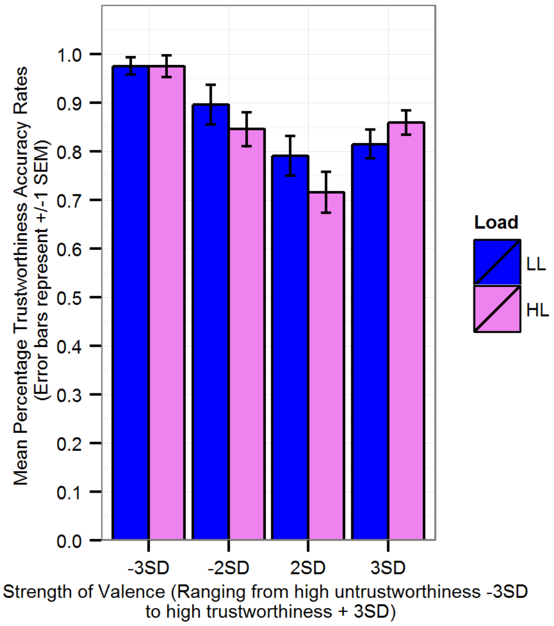


Figure 4-6 Trustworthiness mean percentage face accuracy rates in the working memory task (valence ranges from high untrustworthy valence -3SD on the left to high trustworthy +3SD on the right)

This pattern of results somewhat resembles those seen for trustworthiness judgments in Experiment 4, with higher accuracies for untrustworthy faces (+3SD valence). Furthermore, low load accuracies are numerically higher for all valences, as seen in the prior trustworthiness experiments (Experiments 1 and 4), except for the maximum trustworthy faces where this order is reversed. As evidenced by the main effect of valence, the mid-range faces, particularly +2SD valence, are more challenging to discriminate than the extremes of trustworthiness. To investigate the significant interaction, follow up uncorrected pairwise comparisons revealed that none of the contrasts between low load and high load accuracies were significantly different, except for -2SD valence (low load *M* = 89.5 % vs. high load *M*= 84.5 % , *t*(10) =2.38 *p* = .04).

The results of Experiment 7 broadly support our prediction that the level of working memory load in a comparable task to that of perceptual load (seen in Experiments 1-6) would not impact facial judgment accuracies, and thus that the already observed effects are more likely to be specific to perceptual load than an influence upon working memory. Although follow up testing revealed a small effect for -2SD valence, it is possible that the smaller sample size employed here contributes to this. Reassuringly the more distinct valence faces -3SD and +3SD valence were not impacted by load.

The last two trustworthiness experiments (Experiments 4 and 7) both have similar results profiles (see **Figure 4-2** and **Figure 4-6**) and of particular note, have reduced accuracies in the mid-range valences (-2SD valence and particularly +2SD valence). These valences may be more ambiguous for participants to evaluate and thus may potentially obfuscate inferences on the role of attention in trustworthiness facial judgments. Future experiments may be better served by using the maximum valence -3SD and +3SD (an approach which we will adopt in Experiment 10).

4.3.2 Experiment 8

4.3.2.1 Introduction

Once again, to provide a contrast to the trustworthy evaluations in the last experiment (Experiment 7) under working memory load, we investigate the orthogonal dimension of dominance facial judgments.

The dominance category provides an intriguing case, in that, although in general dominance facial judgments have been relatively resistant to the effects of load (Experiment 2 and Experiment 5) generating a null effect, that is nevertheless what we still expect here. Given that our prediction is that any deficit in facial social judgments is specific to perceptual load (Lavie et al., 2004), we hypothesize the same null pattern will once more be evident as we do not expect a working memory load task to considerably impact facial social judgment. Thus we hypothesize that dominance judgment accuracies will *not* significantly be altered under high working memory load.

4.3.2.2 Method

4.3.2.2.1 Participants

11 new participants were included in Experiment 7, Mean Age = 21.91, SD 3.56 (7 females) (range 18 - 28) (2 outliers removed). All of the participants (recruited from University College London (UCL)), had normal or corrected-to-normal vision, as in the prior experiment, any subject with less than 50 % accuracy on the Low Load face or search tasks was classified as an outlier and removed from the subsequent analyses, participants participated for course credit or were paid £3 pounds.

4.3.2.2.2 Stimuli and procedure and Design

The apparatus and stimuli generation were identical to Experiment 7 although the stimuli that participants were asked to judge were faces ranging along the dominance spectrum.

4.3.2.2.3 Results and Discussion

Memory task For the group performing dominance judgments; the correct memory-probe identification rates were significantly better in the low working load condition (*M* = 97 %) than in the high working load condition (*M* =89 %), *F*(1, 10) = 13.16, *MSE* =.011, *p* = .005, η^2 = .57. There was no significant effect of valence (*F*<1), F(3,30) =.67 , *MSE* = .006, *p* = .576, η^2 = .063, or significant interaction between valence and load *F*(3, 30) = 2.50, *MSE* =.005, *p* = .078, η^2 = .20.

Mean reaction times in the low working load condition were significantly faster (*M* = 736) than in the high working load condition (*M* =1133), *F*(1, 10) = 164.15, *MSE* = 21138.83, *p* < .001, η^2 = .94. There was no significant effect of valence *F*(3, 30) =.94, *MSE* = 15214.18, *p* = .433, η^2 = .086, or significant interaction between valence and load *F*(3, 30) =2.66, *MSE* =96998.53, *p* = 0.066, η^2 = 0.21, for mean reaction times.

This analysis once more confirms that the working load condition manipulation was more demanding in the low load condition as in contrast to the high load condition (see **Table 4-5**).

	Perceptual load		
	Low	High	Differential Effect of load
Search Accuracy (%)	97(2)	89(7)	8*
Reaction Time (ms)	736(119)	1133 (179)	397*
Face Accuracy (%)	85(6)	84(9)	1 NS

SDs are listed in parenthesis. * = significant NS = not significant

Table 4-5 Mean percentage search accuracy rates, mean reaction time (ms) rates and mean face accuracy rates in the working memory dominance task as a function of load in Experiment 8

Face classification. For the dominant faces mean percentage face accuracy rates in the low working memory condition (*M* = 85 %) were not significantly better compared to the high working memory load condition (*M* =84 %), (*F*<1) *F*(1, 10) =.21, *MSE* = .011, *p* = .658, η^2 = .02. There was no significant effect of valence *F*(3, 30) =1.67, *MSE* =0.033, *p* = 0.194, η^2 = 0.14, or significant interaction between valence and load (*F*<1) *F*(3, 30) = .33, *MSE* = .021, *p* = .806, η^2 = .032.

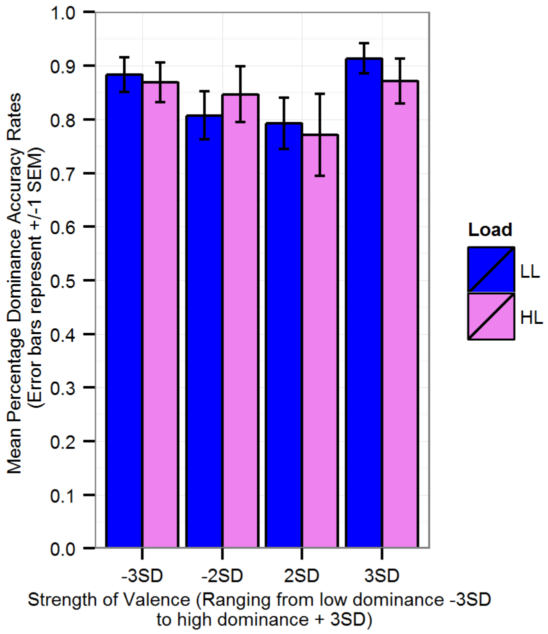


Figure 4-7 Dominance mean percentage face accuracy rates in the working memory task (valence ranges from high untrustworthy valence -3SD on the left to high trustworthy +3SD on the right)

As hypothesized, there was no effect of working memory load on facial judgment accuracies. The patterns of results in general in these experimental iterations are relatively consistent. As in the case of trustworthiness (Experiment 1, 4 and 6) where the patterns of results were broadly similar, that is also the case here with the prior dominance experiments (Experiments 2 and 5) and working memory load (Experiment 7). As in the other dominance experiments, a similar assortment of some low load valence accuracies being numerically less than high load and others being greater is also observed here (**Figure 4-7**), although importantly follow up (uncorrected) pairwise comparisons revealed that none of the contrasts between low load and high load accuracies were significantly different, cementing the absence of effect of working memory load.

Additionally, a similar, though somewhat less pronounced mid- range dip for the valences (-2SD valence and +2SD valence) was again evident as seen on the last two dominance experiments result's profiles (see **Figure 3-5** and particularly **Figure 4-3**).

Overall, the flat pattern of valence accuracies, allied with the relatively high mean accuracies across all valences (combined valence accuracies ranging from 78 % to 89 %) indicate that the high load working memory task did not impact facial judgment capacity.

4.3.3 Experiment 9

4.3.3.1 Introduction

We have observed two experiments (Experiments 7 and 8) that broadly support the view that facial judgments under working memory load are *not* significantly reduced under high working memory load conditions. Once again we return to the arguably more emotional stimuli of threatening faces to confirm this pattern, retaining the same hypothesis that threat judgments under working memory load will *not* significantly differ between the low and high working memory load conditions.

4.3.3.2 Method

4.3.3.2.1 Participants

10 new participants were included in Experiment 9, Mean Age =20.02, SD 4.44 (8 females) (range 18 - 32) (2 outliers removed). All of the participants (recruited from University College London (UCL)), had normal or corrected-to-normal vision, as in the prior experiment, any subject with less than 50 % accuracy on the Low Load face or search tasks was classified as an outlier and removed from the subsequent analyses, participants participated for course credit or were paid £3 pounds.

4.3.3.2.2 Stimuli and procedure

Once more the apparatus and stimuli generation were identical to Experiments 7 and 8 although here threatening faces were employed for Experiment 9.

4.3.3.3 Results and Discussion

Memory task Finally for the group performing threat judgments, the correct memory probe identification rates were significantly better in the low working load condition (M = 98 %) compared to the high working load condition (M =89 %), $F(1, 9) = 6.25$, MSE =.024, $p < .05$, $\eta^2 = .36$. There was no significant effect of valence $F(3, 27) = 1.91$, $MSE = .01$, $p = .147$, $\eta^2 = .15$, additionally there was also no significant interaction between valence and load $F(3, 27) = 1.45$, MSE =.008, $p = .250$, $\eta^2 = .11$.

Mean reaction times in the low working load condition were significantly faster (M = 774) than in the high working load condition (M =1233), $F(1, 9) = 45.97$, $MSE = 91631.61$, $p < 0.001$, $\eta^2 = .84$. Interestingly there was a significant effect of valence $F(3, 27) = 13.96$, $MSE = 3460.15$, $p < .001$, $\eta^2 = .61$, but there was no significant interaction between valence and load $F(3, 27) =2.23$, MSE =10692.45, $p = 0.107$, $\eta^2 = 0.20$, for mean reaction times.

As in the case of Experiment 7 and 8, these results confirm that the working load condition manipulation was more demanding in the low load condition as in contrast to the high load condition (see **Table 4-6**).

Perceptual load			
	Low	High	Differential Effect of load
Search Accuracy (%)	98(2)	89(6)	9*
Reaction Time (ms)	774(184)	1233 (326)	459*
Face Accuracy (%)	86(5)	86(8)	0 NS

SDs are listed in parenthesis. * = significant NS = not significant

Table 4-6 Mean percentage search accuracy rates, mean reaction time (ms) rates and mean face accuracy rates in the working memory threat task as a function of load in Experiment 9

Face classification. Mean percentage threat face accuracy rates were the same in the low and high working memory conditions (*M* =86 %), (*F*<1) F(1, 9) = .077, *MSE* = .013, *p* = .787, η^2 = .009. Once again there was no significant interaction between valence and load (*F*<1) *F*(3, 27) =0.034, *MSE* =.012, *p* = .991, η^2 = .004.

As also observed for threat in Experiments 3 and 6, there was a significant effect of valence *F*(3, 27) = 13.018, *MSE* = .018, *p* < .001, η^2 = .591. Follow up (bonferroni corrected pairwise) comparisons once again established the dip pattern as seen in **Figure 4-8** below (and similar to that seen for threat faces in **Figure 3-6** and **Figure 4-4)**.The overall effect of valence was driven by -3SD threat valence being significantly greater than all the other valences, while - 2SD and + 2SD threat valences were significantly less than their + 3SD valence counterpart.

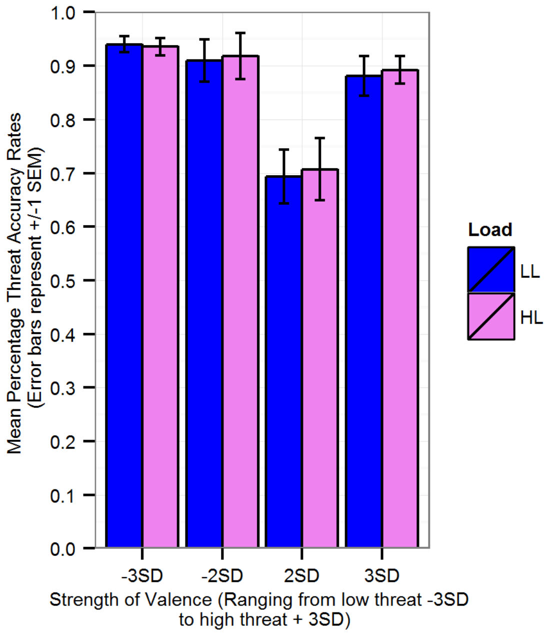


Figure 4-8 Threat mean percentage face accuracy rates in the working memory task (valence ranges from high untrustworthy valence -3SD on the left to high trustworthy +3SD on the right)

Experiment 9 substantiates the specificity of the effect of perceptual load on facial judgments that we have explored (Experiment 1-6), distinguishing it from the effect of working memory load. In this experiment, as hypothesized, there was no effect of working memory load on threat facial judgment accuracies (and once more follow-up testing revealed that none of the contrasts between low and high load accuracies were significantly different, bolstering the claim of an absent effect of working memory load).

The patterns of results here in Experiment 9 coheres with the prior threat experiments (Experiments 3 and 6), with a significant effect of valence, driven primarily in all three experiments by the low mean accuracy scores of the mid-range facial threat valence +2SD. This dip pattern and the associated low accuracies for +2SD valence (which have been a relatively consistent feature in all the threat experiments) indicates the participants' difficulty and or uncertainty in categorising this valence. Whether this is due to an intrinsic property of the face space (insofar as participants have difficulty assigning threat to the visual image characteristics) or simply a property of threating mid-range faces themselves being difficult to classify (in that the judgment of threat is less applicable to mildly threatening faces) is underdetermined. However, future experiments on facial social judgment (as I have already suggested) may be better served by employing the less ambiguous extremes of the facial space when seeking to clarify the role of attention.

4.3.3.4 Discussion

Experiments 7-9 provided support for the specificity of the effect of perceptual load on facial social judgment. While tasks with a greater demand on attention (high load tasks) reduced the ability to judge, possibly even to perceive the valence or emotion of a face in Experiments 1-6; the latter results from Experiments 7-9 are suggestive that this is not just an effect of task difficulty, as the same effect was not observed in an arguably equally difficult working memory task.

Increasing the working memory load during performance of the facial classification task in Experiments 7-9 did not have an effect on accuracy rates. This finding weakens support for the claim of an account of the effects of perceptual load as solely conditional on an increase in the demand of general cognitive capacity resources.

The results of Experiments 7-9 also perhaps hint at the conclusion that if the facial trait judgment does not visually compete with other distractors for selection, then this will not involve executive control of selective attention by working memory. That is the executive control function role of working memory (rather than the aspect that is implicated in maintenance of a target template) biasing perception in facial social judgments situations where there is conflict between stimuli (as opposed to merely many stimuli in the visual field) will not be involved (Lavie et al., 2005).

To rephrase, if by loading working memory executive control is occupied for the task, this will not necessarily affect or modulate the capacity for social facial judgment if there is no visual conflict between stimuli.

It can be tricky, due to experimental and task differences, to compare the results of of Experiments 7-9 to similar experiments in the literature. However, some slender support for the outcomes in Experiments 7-9 can be found in fairly comparable experiments which have focused on distractor processing (de Fockert et al., 2001). For instance, De Fockert and colleagues demonstrated that there was increased processing of faces, specifically higher memory load resulted in greater interference effects on behavioural performance from the distractor faces (and increased face-related activity in the visual cortex). Although their face stimuli were task-irrelevant (and famous), whereas here the experiments mandated a response, there are some parallels between the results if one construes increased experiment mean judgment accuracies (using the grand mean as a proxy) of possibly being indicative of increased processing. For instance, the overall mean for Experiments 7-9 for the various facial judgment categories was higher (Trustworthiness *M* = 86 %, dominance *M* = 84.5 %, Threat *M* = 86 %) than in the perceptual load experimental versions. This overall mean was somewhat reduced in Experiments 1-3 (Trustworthiness *M* = 78 %, dominance *M* = 74.5 %, Threat *M* = 75 %) and in Experiments 4-6 (Trustworthiness *M* = 81.5 %, dominance *M* = 75.5 %, Threat *M* = 75 %). Overall however, while the results from Experiments 7-9 are coherent with our predictions of the specificity of the effect of perceptual load on facial social judgment, they are not completely satisfactory. This is simply due to the challenges in interpreting a null effect, where the failure to reject the null hypothesis is not evidence for it. Ultimately, rather than relying on convergent evidence and null effects, having complementary measures of face processing (such as tracking brain activity by detecting associated changes in blood flow) may be more advantageous in conforming the specificity of facial load judgments such as trustworthiness (an issue which we will return in Chapter 6).

As a final point, potentially the results of Experiments 7-9 may have relevance for the debate on the efficacy of working memory (e.g. (Yi et al., 2004)). The positive effects of working memory load have been shown in experiments employing salient, competing distractors, while the null effects of working memory load have been demonstrated in experiments in which the task-irrelevant stimuli did not compete with the target for selection (Yi et al., 2004). A crucial factor regarding the role of working memory load may simply be what working memory is actually operating, its category or its intrinsic salience. Future experiments could investigate (perhaps parametrically) a more difficult working memory task to see how this interacts with the proposed saliency of face stimuli to ascertain whether resistance to working memory load effects is still maintained in these circumstances.

4.4 Responding to the Response Bias

4.4.1 Experiment 10

4.4.1.1 Introduction

I have examined considerable evidence for the role of attentional effects on social judgments (where a large part of that evidence refers to expressions which are often labelled as emotional) however for more complex social facial judgments (often labelled as traits) such as trustworthiness the role of attention upon them has not been studied. To this end, this thesis, has explored perhaps one of the most archetypal social judgments, trustworthiness in this and the last Chapter, under varying conditions and contrasting it to other judgments, such as that of threat and dominance.

The results in Experiments 1-6 offer modest yet convergent evidence for the role of perceptual load in certain types of facial judgments such as trustworthiness and threat. However, as raised in this Chapter's introduction, there is the possibility that it is not impaired facial detection capacity (under perceptual load) that is the cause of these findings but rather some form of preference or bias under the demanding effects of load. Examining facial judgment detection sensitivity independent from participants' bias may help clarify the nature of the results presented so far, particularly in relation to trustworthiness judgments. The trustworthiness results observed thus far, were slightly less coherent than those of their threat counterparts under high perceptual load. For example, there was a small effect for -2SD valence under working memory load in Experiment 7 (revealed by follow up testing), while the overall effect of load was weaker in Experiment 4 than Experiment 1 (where the effect of load was driven by +2SD valence trustworthy faces there, rather than +3SD valence faces as in Experiment 1).

Moving forward, addressing the issue of participant bias in facial social judgments affords the possibility of both modifying the experimental paradigm and potentially clarifying our results. The adoption of a signal detection theoretic approach facilitates this. Signal detection theory attributes responses to a combination of sensitivity and bias. Sensitivity to the facial judgments and valences is what we are interested in, although bias is what we have to take into account to recover sensitivity. In the prior studies, there was no way to assess detection sensitivity, as no neutral stimulus was employed.

Another factor to be addressed is that in the models of discrimination performance discussed in the prior experimental iterations (Experiments 1-9), many of the results to some degree evidenced a dip in the mid-range valence faces, particularly for the more positive +2SD valence faces. As discussed previously, whether this is due to an intrinsic property of the face space (insofar as participants have difficulty assigning valence to the visual image characteristics) or simply a property of mid-range faces themselves being difficult to classify (in that such judgments are less applicable to faces with mild trait properties) is underdetermined. However, employing the less ambiguous extremes of the facial space, by using the maximum valence -3SD and +3SD may reduce ambiguity and thus is an approach which we will adopt here.

The outcomes presented so far offer some evidence for a modest role of perceptual load in certain types of facial judgments. Given the slightly irregular results for trustworthy evaluations, allied with the non-existent work regarding such evaluations under attentional modulations (as opposed to threat for example (Bishop, 2008; Koster et al., 2005; Mogg et al., 1999; Öhman et al., 2001)), in the present study, I set out to examine the effects of perceptual load on the detection of trustworthy faces in a modified load paradigm to address the issue of detection sensitivity, independent from participants' bias. Slight modifications of the perceptual load paradigm, permits us to assess the effects of perceptual load on detection sensitivity (*d*`) and response bias (*C*).

While the findings from Experiments 1 and 4 are somewhat convergent regarding the role of the effects of perceptual load on trustworthiness facial judgments, the metrics employed in those experiments, essentially the "hit rate" (which can be construed as the proportion of correct agreements or yes responses to the faces generated according to methods described in Oosterhof et al., 2008) can be a poor guide to psychophysical sensitivity, as it confounds sensitivity (*d'*) and criterion (*C*) – (see section 2.4) (See (Azzopardi & Cowey, 1998) for a noteworthy discussion of this in relation to the clinical dissociation of 'blindsight' after damage to the visual cortex).

In line with the experimental results of the prior trustworthiness perceptual load experiments in this thesis (Experiment 1 and 4) and perceptual load theory, we hypothesized a similar pattern here. Specifically that detection sensitivity will be reduced under conditions of high perceptual load, effects which should be borne markedly on trustworthy faces.

Perceptual load theory is agnostic with regards to response bias and likewise we had no a-priori predictions regarding the expected behaviour of participants' inclination (whether conservative or liberal) to respond to the presence or absence of valence in trustworthy faces under high perceptual load.

4.4.1.2 Method

4.4.1.2.1 Participants

Twenty nine participants were recruited from University College London's online subject pool and were paid £3 for their participation nine; three male and 2 female participants were excluded (two due to missing data, the other three due to subpar performance (less than 50 % overall accuracy on the low load images).The age range of the 24 remaining was 18 to 35 years (*M* = 22.56, *SD* =4.00) of which 7 were male. All of the participants in this experiment, as well as those in subsequent experiments, had normal or corrected-to-normal vision.

4.4.1.2.2 Stimuli and Procedure

The apparatus and procedure were similar to the prior 2 experiments (and those from the last Chapter). However, the adoption of a signal detection processing framework necessitated some changes. Firstly, to avoid the ambiguities associated with the mid-range valence of the faces in the prior experiments, we decided to employ the extreme facets of trustworthiness faces only (allowing for a simpler and elegant design), that is, +/- 3 standard deviations along with the neutrals. As before, the faces were generated using FaceGen Modeller 3.2 (Singular Inversions, 2007) again according to the methods described in (Oosterhof et al., 2008). 96 faces identities were used that varied on 3 levels of trustworthiness yielding a total of 276 faces. The experiment took place in a dimly-lit room. Matlab (running the cogent Toolbox) was used to program and run the experiment. All stimuli were presented in on a black background, on a PC with a 15" CRT screen (80 Hz refresh rate). A chin rest was used to maintain a viewing distance of 58 cm. Each trial in the visual search task began with key press that was self-initiated, followed by a fixation point presented for 500 ms in the centre of the screen. This was followed immediately by the stimulus display, consisting of one, or six letters arranged to form a circle (with the radius subtending 1.6 degrees of visual angle) and a face presented in the centre, displayed for

150 ms. However, participants this time were informed that after their search letter task response, their aim was to decide whether the face had a trustworthy dimension (i.e. trustworthy or untrustworthy) or was neutral. That is, that there would be four blocks, untrustworthy vs. neutral, trustworthy vs. neutral, trustworthy vs. neutral and untrustworthy vs. neutral - this order was counterbalanced (additionally each block was of a different load condition as well. e.g. LL (untrustworthy vs neutral), HL (untrustworthy vs neutral) etc.). In the trustworthy blocks they would be presented with faces that were either trustworthy or are considered neutral and were requested to Press 1 if the face was trustworthy, or 2 if the face was neutral. Conversely in the untrustworthy blocks, they were informed that they would get faces that are either untrustworthy or are considered neutral and to Press 1 if the face was untrustworthy, or 2 if the face was neutral.

Each block consisted of 48 trials, (24 trustworthy/untrustworthy depending on the block and 24 neutral images, presented in random order). Each face was presented once during the experiment and the assignment of positive valence faces to negative or positive blocks was randomized and counterbalanced across participants and across blocks. There were four experimental blocks (two low loads and two high loads the order of which was counterbalanced across participants).

This yielded the simplest signal detection theoretic approach - a one-interval design, in which a single image is presented on each trial. This is a correspondence experiment in which the stimulus is drawn from one of two stimulus classes; trustworthy verses neutral in one condition (high load and low load) and untrustworthy verses neutral in the other (high load and low load) – (see section 2.4 Signal detection theory and decision-making).

Participants completed one practice block of 12 trials and one practice block of rating before the experiment (different face identities were used in the practice than experiment, and all were neutral on the respective valence scale).

4.4.1.2.3 Design

Mean percentage search accuracy rates and mean reaction times for the accurate search trails were the preliminary dependent variables (DVs) and were entered separately into a 2 x 2 repeated measures analysis of variance - ANOVA (a smaller modified model in comparison to experiments 1-9 where there was a 2 x 4 repeated measures design). Perceptual load (Low, High) and Valence (untrustworthy, trustworthy) were the within subject independent variables (IVs).

Next, mean percentage accuracy (hit) rates *d'* and criterion scores *C* (both for the accurate search trails) were the dependent variables. The *d'* and criterion scores *C*, calculated from the untrustworthy and trustworthy conditions (within which respectively images from each category were compared to neutral faces) were entered, again separately into a 2 (perceptual load: Low or High) x 2 (untrustworthy or trustworthy valence faces) repeated measures ANOVA.

4.4.1.3 Results and Discussion

Search task Mean percentage search accuracy rates in the low perceptual load condition were significantly better (M = 96 %) than in the high perceptual load condition (M = 88 %), $F(1, 23) = 15.80$, $MSE = .009$, $p = .001$, $\eta^2 = .41$. There was no significant effect of valence ($F<1$) $F(1, 23) = .62$, $MSE = .005$, $p = .359$, $\eta^2 = .037$, nor was there a significant interaction between valence and load ($F<1$) $F(1, 23) = .63$, $MSE =.005$, $p = .439$, $\eta^2 = .026$.

Mean Reaction times in the low perceptual load condition were significantly faster (M = 807) than in the high perceptual load condition (M =1037), $F(1, 23) = 62.72$, $MSE = 20217.69$, $p < .001$, $\eta^2 = .73$. There was no significant effect of valence $F(1, 23) = 1.88$, $MSE =8750.17$, $p = .183$, $\eta^2 = .076$. Additionally there was also no significant interaction between valence and load $F(1, 23) =1.47$, $MSE =24157.39$, $p = .237$, $\eta^2 = .060$. The aforementioned results confirm that the perceptual load manipulation was successful (see **Table 4-7**).

	Perceptual load		
	Low	High	Differential Effect of load
Search Accuracy (%)	96(4)	88(9)	8*
Reaction Time (ms)	807(189)	1037 (203)	230*
d'	1.62(.76)	1.27(.65)	.35*
C	.02(.56)	-.19(.52)	.21*

SDs are listed in parenthesis. * = significant

Table 4-7 Mean percentage search accuracy rates, mean reaction time (ms) rates, mean face sensitivity (*d'*) rates and mean face judgment bias (*C*) rates in the response bias trustworthy task as a function of load in Experiment 10

The results of Experiment 10 are summarized above (**Table 4-7**) and elaborated below in the *Face classification section*. The hit and false alarm rates (determined by is correctly/incorrectly categorizing either a neutral face or trustworthy face in the trustworthy blocks, or, correctly/incorrectly categorizing either a neutral face or untrustworthy face in the untrustworthy blocks) were used to calculate *d'* (sensitivity) and criterion (bias) scores *C*.

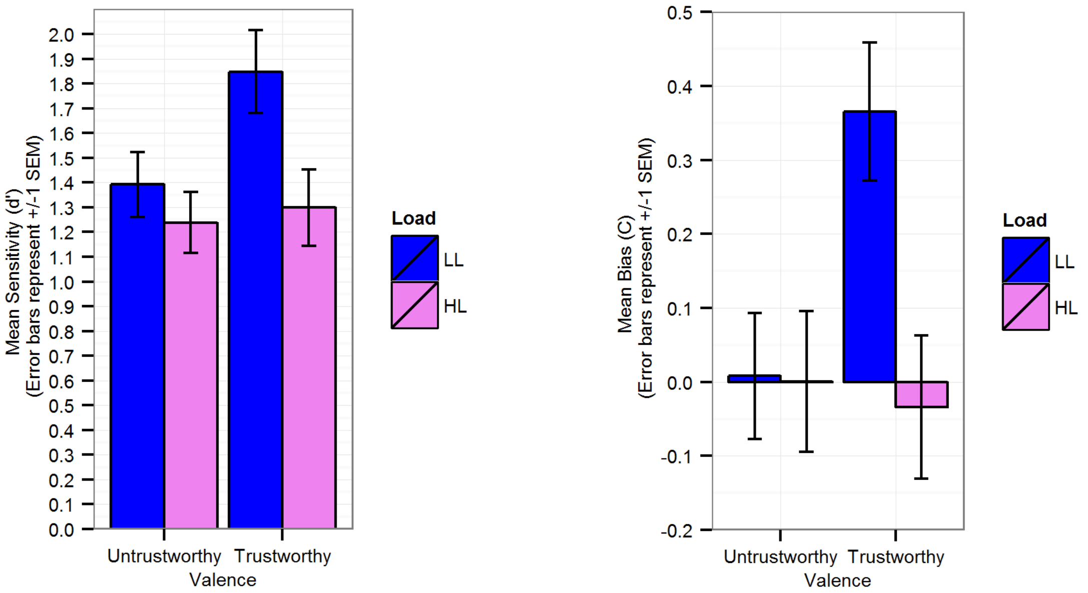
Conceptually, sensitivity as measured by *d'*, refers to how hard or easy it is to detect that a face has a trustworthy valence dimension (either -3SD or 3SD valence depending on the block) as compared to neutral face. Conversely, bias *C* is the extent to which an individuals' response of a valence dimension is more probable than another; that is, for example in the trustworthy block (where the participant is asked to evaluate whether a face is either trustworthy or neutral) a participant may be more or less likely to respond that a trustworthy dimension is present. Bias is independent of sensitivity, while in some circumstances this is important, e.g., if there is a penalty for either false alarms or misses, (which may manipulate bias), this was not the case in Experiment 10.

Face classification Both sensitivity and bias showed an effect of load. Sensitivity under low load exposure (M =1.62) was significantly better than high load (M =1.27), F (1, 23) = 8.89, MSE =0.33, p=.007, η^2 =.28. This effect was also evident for criterion scores, low load (M = 0.19) was significantly greater than high load (M = -.02), F (1, 23) = 7.75, MSE = .13, p=.011, η^2 = .25.

In contrast, the effect of valence was not significant, neither for the sensitivity scores, F (1, 23) = 3.34, MSE = .48, p= .081, η^2 = .13 nor for the criterion scores F (1, 23) = 1.94, MSE =.32, p =.177, η^2 = .078. Moreover, there were no significant interaction for d' with load; F (1, 23) = 1.34, MSE = .70, p=.258, η^2 = .055, although load did interact with C, F (1, 23) = 5.42, MSE =.17, p=.029, η^2 = .19 (see **Figure 4-9**)

Follow up testing of the interaction for C revealed no significant difference for untrustworthy valence faces under load, in contrast to that of trustworthy ones. Bias C was affected under the load manipulation for the trustworthy faces only (low load (M = .365) vs high (M = -.034)), t(23) = 3.40, p = .002. An effect not replicated for untrustworthy faces, t(23) = .068, p = .95 (M = .008 in the low perceptual load condition vs M =.0009 under high load).

Given our directional predictions that high load should reduce judgment discrimination accuracy under high load, particularly for trustworthy faces, a follow up contrast for the load effect was performed. This test revealed that the load manipulation only affected trustworthy faces under load (low perceptual load faces were discriminated better (M = 1.85) than in the high perceptual load condition (M =1.30)), t(23) = 2.30, p = .03. An effect not replicated for untrustworthy faces, t(23) = .91, p = .37 (low load M = 1.39 vs high load M =1.24).



a) **b)**

Figure 4-9 a) Detection sensitivity (*d'*) and b) bias (*C*) affects trustworthy facial judgments but not untrustworthy ones under high perceptual load

4.4.1.4 Discussion

Overall, these results replicate the results of the last Chapter in terms of detection sensitivity rather than accuracy rate. These results confirm our predictions that facial judgment detection sensitivity independent from participants' bias (in a presence/absent facial judgment task), is subject to capacity limits and therefore is influenced by the allocation of attention.

The pattern of results for detection sensitivity somewhat resembles the prior trustworthiness results in Experiment 1 (Chapter 3), where participants scored higher accuracies for trustworthy faces than for untrustworthy ones under low load. Encouragingly as in Experiment 1 also, low load accuracies were numerically higher for all valences in Experiment 10. As a first approximation, this result may seem surprising that low load, sensitivity is greater for trustworthy faces than for untrustworthy faces, given that there is some tentative evidence that negative valence faces, may have some detection advantage (e.g.(Eastwood et al., 2001)). However, whether such intuitions translate to arguably more complex trait judgments such as trustworthiness here is unclear (indeed the negative valence of trustworthiness may be distinct insofar as that it might not directly parallel threat or other negative valenced faces that signal potential harm to an individual (e.g. expressions of anger, or fear) and therefore may not thus be a beneficiary of some form of debated and presumed privileged processing under low load.

Of particular interest in Experiment 10, was the follow up contrast for the load effect that revealed that the load manipulation affected only trustworthy faces. These faces were discriminated better (M = 1.85) in the low load condition than the high perceptual load condition (M =1.30), $t(23)$ = 2.30, p = .03. A similar finding was observed in Experiment 1, converging with the results here. In that experiment it was observed that only the judgments of high trustworthy faces (+3SD, the same high trustworthy face employed in the latter experiment) were affected by load, t (14) =2.26, p =.04 (low load M = 86.5 % vs. high load M = 74 %). Taken together, these combined results provide convergent evidence for an impact on social facial judgment modulation by perceptual load. Furthermore, these results are suggestive that not only is the type of judgment, in this instance trustworthiness, relevant, for the efficacy of perceptual loads modulation but also the valence of the face may play an important role.

We were also afforded the opportunity to examine a secondary component of the decision process in Experiment 10, bias or Criterion, C. This value is not about sensitivity or discriminability but rather how more or less likely a participant is to respond that a stimulus is, or is not present.

Important in interpreting our results is understanding the implication of deviations from the neutral point (where C has a value of 0). Negative values of C indicate a bias or reflect a more relaxed criterion for saying "yes" the facial stimulus valence is present, rather than saying the stimulus has no valence (i.e. the face is neutral). Alternatively, positive values reflect a stricter criterion for saying whether the stimulus has valence or not, that is a bias towards a "no" response (i.e. the face is neutral).

As can be seen in **Figure 4-9 b)** (and revealed by the significant interaction for *C* values between load and valence), when participants are judging a face where the choice ranges between either untrustworthy valence or neutral valence, neither response is favoured and the participants are unbiased. In contrast however, when participants are judging a face where the valence choice is between either trustworthy or neutral, there is a small but significant bias under low load towards a "no" response (i.e. the face is neutral). A tendency which is abolished (or very slightly reversed) under high load (low load (*M* = .365) vs high (*M* = -.034)), *t*(23) = 3.40, *p* = .002).

We had no a-priori expectations regarding how participants' response-bias thresholds might be modulated by load and indeed in the case of untrustworthiness facial evaluations, participants were overall remarkably unbiased. The case of trustworthiness facial evaluations is particularly interesting however. High perceptual load had the effect of effectively making the participants unbiased, that is, when in doubt under low load, the participants would rather say that the face is neutral than trustworthy, whereas under the effect of high load, they are near to unbiased (negligibly reversing towards judging trustworthy).

The effect of load on both bias and valence raises some interesting questions for future research, not least regarding the stability of this threshold and whether this response criterion can be changed, either deliberately, or by altering perceived costs and utilities.

In general, the question which underlies this thesis, is the extent to whether facial detection depends on the allocation of attention or may instead be a capacity-free process that is independent of attention. As discussed in the introductory chapter (Chapter 1), the answer to this question has so far produced inconsistent results, although the results of Chapter 3 were promising, and were suggestive of a modest influence of perceptual load on certain judgments. A potential concern from those experiments (particularly the case of Experiment 1 here) was that the observed results in terms of judgment accuracy under high load may have simply reflected the adoption of a different response criterion under high load. The criticism would be, given a pressure on cognitive resources, the participants' simply prioritized trustworthiness for example as a target (i.e. a bias to low valence), which yielded the observed pattern of results. For this reason, studies that can segregate the effects on facial judgment accuracy from those on response bias, as we have done here using a signal detection approach (with two-alternative forced choices), can be more informative than simple accuracy rates and indeed affirms the results of Experiment 1.

The present paradigm employing a more objective, unbiased measure of visual facial social judgment sensitivity (devoid of bias information) once again demonstrates the effect of perceptual load on visual facial judgment capacity. High, compared with low, perceptual load in a letter search task consistently reduced participants' ability to detect the valence or trustworthiness of a face, unrelated to the search task. This effect of perceptual load was found on both sensitivity (*d*`) and also by an effect on response bias (*C*).

Overall, these results confirm that perceptual load does have a role as a modulator of social facial judgment, informing us about the function of attention in the perceptual processes involved in social facial judgment.

4.5 General discussion

As discussed in the very first Chapter, there is conflicting research into the extent to which facial emotional and trait judgments depend on the allocation of attention, or are capacity-free processes and independent of attention. The results from Chapter 3 indicated the possibility of perceptual load affecting certain types of valence and facial social judgments. To further pursue this issue, this Chapter has explored wide range of experimental iterations to explore the robustness of perceptual load effects on facial social judgments. This Chapter provides further, modest yet convergent evidence with the initial results of Chapter 3, namely that the ability to accurately perform facial social judgment can be reduced under conditions of high perceptual load, particularly of the arguably prototypical social judgment of trustworthiness; implying simple facial trait classification is subject to capacity limits and therefore depends on the allocation of attention.

The results presented here provide further modest evidence in support of the perceptual load hypothesis that certain facial social judgments depend on the allocation of limited capacity attention and that exhausting attention in a high perceptual load task can reduce the capacity for those trait judgments. The level to which this is related to conscious trait facial perception is still an open question. But the implication is that impaired ability to detect the presence of a facial trait could be suggestive of load-induced blindness.

Experiments 4-6 manipulating perceptual load, modulated visual awareness of facial social judgments, establishing that under high (compared to low) perceptual load, social judgment accuracy is impaired, showing that this is indeed due to perceptual load modulation rather than the order of key presses. In addition to principally replicating the findings from Experiment 1-3, the pattern of results in the quasi-replication Experiments 4-6 were very similar to the experiments to those from Chapter 3.

Swapping the response order, also addresses the possibility that the effects of load is a consequence of rapid forgetting of the stimulus (Wolfe, 1999). The latter is shown to be unlikely due to similar pattern of results being present irrespective of stimuli presentation order.

Although the results of Experiments 7-9 are null findings, they suggests that the observed effects in Experiments 1-6 are indeed due to a reduction in attentional capacity, rather than an effect of task difficulty, as the same effects are not observed in an equally difficult working memory task.

Experiment 10 confirmed that the effect of load on detection is not a result of response bias, by replicating the prior work for facial targets for trustworthiness, presented in a signal detection framework and converging with the results from Experiment 1 (and partially from Experiment 4, where again the more trustworthy faces, +2SD valence were impacted by load), indicating that only the facial judgments of high trustworthiness are affected by load.

These results provides convergent evidence for social judgment modulation by perceptual load, where the type of judgment (e.g. comparing the differing effects of load on the valences that were affected in the follow up tests that were performed for Experiment 4-6; modest for trustworthiness (Experiment 4), medium for threat (Experiment 6) or absent for dominance (Experiment 5)) and its valence are important determinants of its efficacy.

Taken together, this data support the view that while facial social judgment is undoubtedly a complex and intricate process, its capacity, as proposed by load theory, is still a function of available processing resources. Such a view entails the attendant implications for the automaticity of trait and emotional facial processing discussed in the prior Chapters.

As I have discussed previously, one of the most salient features of automatic processes is their resistance to suppression. That is, given the appropriate stimulus, in this instance the appropriate facial trait/emotion, an automatic process will unfold in an autonomous fashion. Attempting to curb or interrupt such processing should be unproductive in comparison to a non-automatic process. The fact that a simple binary modulation of load can modulate detection sensitivity in trustworthiness for example, suggests that processing resources can be a constraint on social facial judgment.

Analogizing the load manipulations performed here and the timeless Stroop effect (MacLeod, 1991) may be instructive. Even though subjects are aware of the perceptual conflict in the Stroop manipulation by which knowledge of the names of the words interferes in identifying the colours with which the words are displayed, the participants nevertheless have difficulty suppressing this interference. This suggests that recognizing colours is less an automatic process as compared to understanding the meaning of words (due to habitual reading). Similarly, here, subjects are aware of the increased perceptual load but cannot generate any automatic override to compensate and maintain their facial classification accuracy, suggesting that the process of facial judgment, whilst undoubtedly rapid, is not necessary automatic, in the sense that it is immune to interference from task demands.

Overall these results have replicated the prior findings of chapter 3 and established with regards to trustworthiness, a moderately robust social judgment reference point with respect to the effects of perceptual load. The effects are modest but convergent. Having established these effects, the next chapter uses the experimental framework of Experiment 10 and moves to the clinical domain to explore facial judgment processing and its possible impairment in Parkinson’s disease and the plausible role of dopamine transmission and dopamine replacement therapy in these processes.

5 Perceptual Effects of Dopamine on Trust and Attention

“The face is the soul of the body”. Ludwig Wittgenstein (1889-1951).
Culture and Value, 1932-1934 entry, eds. G.H. von Wright and Heikki Nyman (1980)

Overview

In addition to the characteristic motor signs and symptoms of Parkinson's disease (PD) accompanied by cell loss in dopaminergic neuronal populations, PD can also characterized by neuropsychological and emotional processing deficits (consistent with findings in experimental animal paradigms of the role of dopamine in modulating the response of regions such as the amygdala to sensory information).

These deficits in PD extend to impairments in face processing (Dewick, Hanley, Davies, Playfer, & Turnbull, 1991) and are suggestive of a role for dopamine in the intricate circuitry of facial judgments. For example, PD patients with acute dopaminergic blockade, display impaired recognition of anger facial expressions whilst leaving intact the recognition of other facial expressions (including fear and disgust), supporting previous findings of selectively impaired anger recognition following acute dopaminergic blockade in healthy volunteers (Lawrence, Calder, McGowan, & Grasby, 2002; Lawrence, Goerendt, & Brooks, 2007). In addition, there is evidence that PD patients have problems with ‘top-down’ attention, where it is possible that distorted regulation of dopamine function instigates a loss or inflexibility of task relevant top-down biasing signals (Sampaio et al., 2011).

Treatment with dopamine replacement therapy may disguise deficits present in PD, especially with arguably more complex facial social evaluations such as trustworthiness, whose judgments have not been examined in this group.

The effects of attention and emotion on face processing in the human brain have been well documented in non-Parkinson patients. In contrast, even though visual deficits in high level processing capacities have been reported in PD, whether the cognitive changes associated with PD, particularly attentional difficulties, can contribute to impaired facial judgment capacities has not been studied. It is undetermined whether visual attention deficits may have a role in any facial judgment capacities in PD and whether this is masked by medication.

Given both the conflicting results suggesting that abnormalities in face processing may be a feature of PD and the paucity of evidence regarding the role of attention in this processing, the objective of the present study was to contribute to the understanding of facial judgment capacities and the role of selective attention processes in Parkinson’s disease. PD has been linked with facial expression judgment impairment, although, this impairment could be subordinate to other cognitive processes enmeshed in facial evaluation, such as selective attention.

Here (contrasting medicated patients to controls), we have explicitly separated visual and attentional related patterns of performance by comparing performance under low and high perceptual load. The findings extend our previous results in an older age cohort, further suggesting a role for attention in the processing of facial expressions of trustworthiness. In addition, they reveal that selective attention could have a role in causing impaired facial processing in PD. These results suggest an avenue for investigating the role of dopamine and high level attentional mechanisms in modulating facial social judgments in PD, while advocating the usefulness of adopting a comparative perspective between clinical and non-clinical groups in trustworthiness judgments and attention research.

5.1 Experiment 11

5.1.1 Introduction

Research on Parkinson’s disease (PD) mostly concentrates on motor symptoms (and to a lesser extent cognitive deficiencies), however recently some recognition has been given to the fact that PD is not just a movement disorder and that the impaired motor/cognitive neural structures associated with PD are also implicated in attention (Dujardin et al., 2013), emotional recognition and social behaviour (Suzuki, Hoshino, Shigemasu, & Kawamura, 2006). Although, motor disturbances are perhaps the most discernible and studied facet of the Parkinson phenotype, cognitive changes and impairments in sensory system modalities such as complex visual processing and attention (Tommasi et al., 2014) can also be evident.

Given the value of facial expressions as signals (Schmidt & Cohn, 2001) and their reliance on attentional, emotional and social processing neural structures for their analysis, yields the possible implication that any impairment in their processing due to PD could add to significant consequences for Parkinson’s sufferers beyond the motor and cognitive deficiencies. Deficits in PD extending to potential impairments in face processing can have an oft overlooked impact for sufferers of Parkinson disease.

PD is estimated to affect between 100 and 180 people per 100,000 of the general population (Dodel et al., 1998) and 1-2 % of people over 65 years of age (Twelves, Perkins, & Counsell, 2003), making it one of the most common causes of neurological disability. The disease is principally a disorder of the middle-aged, particularly the elderly, in which degeneration of the extrapyramidal motor system causes significant movement difficulties. The extrapyramidal system consists of a series of functionally related nuclei such as the mid brain within which dopamine projections have complex signalling pathways. Tremor and motor impairment, has been related to the loss of dopamine-secreting neurons (Kwon et al., 2012) in this midbrain area (specifically the substantia nigra).

Neuropsychological studies have reported that deficits in emotional recognition and of certain facial expressions such as fear (Adolphs et al., 1998) are often associated with damages in identifiable subcortical structures, such as the basal ganglia and amygdala, some of the very same structures which are impaired in Parkinson's disease (Wieser et al., 2006; Péron, Dondaine, Le Jeune, Grandjean, & Verin, 2012). Moreover, the importance of dopamine on these structures, such as the amygdala, is underscored by the observation that repletion of this neurotransmitter can partially restore bilateral amygdala responses to fearful faces that are absent in PD patients during a hypo-dopaminergic state (Tessitore et al., 2002). The observation that PD patients with acute dopaminergic blockade displayed impaired recognition of anger facial expressions (whilst leaving intact the recognition of other facial expressions (including fear and disgust)) is further evidence implicating the possible role of dopamine in the processing of facial expressions. This supports previous findings of selectively impaired anger recognition following acute dopaminergic blockade in healthy volunteers (Lawrence et al., 2002; Lawrence et al., 2007).

Aversive facial expressions such as fear, are not the only types of facial judgments whose processing may be impaired in PD. General deficits in face processing have been reported in PD in comparison to matched controls (Dewick et al., 1991). In fact, there is evidence that show that patients with bilateral PD perform significantly worse (to corresponding healthy controls) in terms of emotion recognition, regardless of the modality (facial or prosodic) or the category of experimental tasks involved (identification or discrimination) (Yip, Lee, Ho, Tsang, & Li, 2003).

However, the role of PD in impaired facial judgments is not without debate. Other results have uncovered limited evidence to suggest that abnormalities in face processing are a consistent or generalized feature of medicated adults with mild-moderate PD (Pell & Leonard, 2005). It is possible therefore, that such facial processing deficits may be more consistent in un-medicated sufferers. For example, an un-medicated group were found to function worse than those who were medicated at recognising disgust from prototypical facial expressions, and at recognising anger and disgust in computer-manipulated images (Sprengelmeyer et al., 2003). Indeed both PD groups in this study displayed impairments of facial expression recognition. The worse recognition of disgust in the un-medicated group is coherent with the hypothesis from previous studies that brain regions modulated by dopaminergic neurons are involved in the recognition of disgust (Sprengelmeyer et al., 2003).

While research examining face processing in PD has tended to concentrate on negative valence judgments such as disgust and anger, any impairment in the recognition of conspecific facial expressions would have adverse effects for social functioning. For example, the expression of perhaps more nuanced social judgments such as trust are of vital importance in social signalling (King-Casas et al., 2005) and any impairment in an individual's capacity to assess it, could be useful both clinically and theoretically as an a indicator of diminished facial processing ability and as to what neural substructures may underpin it (due to the relatively established comprehension of PD pathophysiology).

There is substantive research on the processing of faces (see Chapter 1), with the dominant view in face-perception research that the recognition of facial identity and facial expression involves separable visual pathways at the functional and neural levels (Calder et al., 2005). As I have already discussed in Chapter 1, a great deal of neural resources seem to be used by the brain to understand the face and opinion is divided as to whether we genuinely develop specific competencies, have an innate capacity for understanding faces, or whether face perception is just part of a general overall proficiency. For example, Kanwisher and colleagues propose that face recognition involves processes that are face-specific, that is domain specific (Kanwisher et al., 1997; Grill-Spector, Knouf, & Kanwisher, 2004) and that are not recruited by expert discriminations in other object classes.

I have talked principally about the impairments in facial processing that may be evident in PD, however, PD is also associated with cognitive decline, and this is typically linked to deficits in working memory (D'Ardenne et al., 2012) and of particular relevance to this thesis; attention, both of which are modulated by dopamine and important for facial processing (Vuilleumier et al., 2001a; Cools & D'Esposito, 2011).

PD sufferers may have problems with ‘top-down’ attention, where it is possible that distorted regulation of dopamine functioning instigates a loss or inflexibility of task relevant top-down biasing signals (Sampaio et al., 2011). This is notwithstanding any influence of reward in modulating attentional signals. The dopaminergic nuclei in the substantia nigra, the caudate and the putamen, are essential in encoding reward signals, and may be involved in attentional tasks (Graybiel, 2005). Unfortunately these very same nuclei can also be adversely affected in PD.

It is feasible that multiple perceptual processing abnormalities may arise from dopaminergic dysregulation and the impairments associated with PD, although whether the cognitive changes associated with PD, particularly attentional difficulties, can contribute to impaired facial judgment capacities has not been studied. Taking a more system like perspective, that is examining facial judgments while concurrently modulating attention in medicated PD patients may reveal some of the subtle effects of non-movement related impairments that may occur or have been masked anteriorly in medicated patients.

The set of experiments reported thus far in this thesis are suggestive of some subtle but consistent effect of perceptual load on facial social judgments of trustworthiness, but how robust is this finding, is it also evident in the PD clinical subgroup and importantly replicated in age matched controls without dopinamenrigic dysfunction?

Given both the paucity of evidence regarding the role of attention and the conflicting results suggesting that abnormalities in face processing may be a feature of PD, the present study’s goal was to investigate face perception and attention (by perceptual load) concurrently in PD patients. This permits the possibility of clarifying the functioning of facial social judgment in PD (whilst simultaneously pointing to possible pathways underlying the processing of these functions due to the relatively developed understanding of PD pathology). PD has been linked with facial expression judgment impairment, although, this impairment could be subordinate to an alternative cognitive processes enmeshed in facial evaluation, such as selective attention.

The following study employed a sample of PD patients performing social judgments of trustworthiness compared to a level healthy volunteers group (matched by age and education level). Given the conflicting evidence that abnormalities in face processing are a stable feature in PD, a feature which may be masked by anti-Parkinsonian treatment, we choose to examine medicated patients to ascertain whether any impairments (as compared to controls) were still evident under attentional modulation. Additionally, by employing a standardised face space and signal detection framework, we can examine not only the attentional effects of perceptual load, but also determine the bias that Parkinson sufferers have for evaluating faces and determine whether this is consistent with normal non-medicated participants (while examining sensitivity to trustworthy faces for them under the same conditions).

Despite the unarguably mixed findings regarding the influence of PD in face processing, given the discussion above and the results of trustworthiness modulation in the prior Chapters, we expected that PD status would be associated with deficits in trustworthiness judgments. Specifically we hypothesised that detection accuracy would be reduced under high load. We hypothesised that PD patients would be less likely to mask any deficit in the type of task we employ (even if medicated, as the Parkinson's participants would be), when it is modulated to be more demanding (that is under high perceptual load). We also hypothesised that age matched controls would evidence impairments in detection sensitivity under high perceptual load (in alignment with the results of the prior chapters), although such a deficit would be less onerous than that of PD patients.

Finally, we hypothesized that the dual nature of the task, with a burden on both attention and face processing, could cause PD sufferers to generate inferior face judgment categorizations compared to controls (on a visual search and judgment paradigm of trustworthy judgments under low perceptual load). Naturally, only PD patients not evidencing any cognitive deficiency were selected for testing (as assessed by the Mini-Mental State Examination (MMSE), a reliable measure of cognitive impairment).

The following study contributes to the heterogeneous PD facial processing literature, in seeking to determine if patients with Parkinson's disease present a specific lack of facial expression judgment capacity and by extension emotion processing capability. Additionally, the study addresses the issue of whether this impairment could be related to selective attention functioning. The approach adopted here, also opens up a new avenue of perceptual load research into a previously untapped clinical domain.

5.1.2 Method

5.1.2.1 Participants

Twenty-one healthy individuals with a diagnosis of idiopathic PD were recruited for their participation. Patients were recruited from the movement disorders clinic at the National Hospital for Neurology and Neurosurgery in London. They met Parkinson's Disease Society Brain Bank diagnostic criteria for PD (Hughes, Daniel, Kilford, & Lees, 1992). Stage of illness was assessed using the Hoehn and Yahr scale (H&Y) (Hoehn & Yahr, 1967) and disability with the Schwab and England Activities of Daily Living scale (Schwab & England, 1969). All patients were in the mild to moderate phases of the disease as assessed using the Hoehn and Yahr scale (H&Y) - (used for describing the how the symptoms of Parkinson's disease progress, where stages of illness range from I to V, with stage zero indicating no visible symptoms of Parkinson's disease). On the Schwab and England scale, scores ranged from 5 to 9.

All patients were non-demented as demonstrated by scores >24 on the Mini-Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975). Patients were also screened for clinical depression (scores >15) on the Beck Depression Inventory-II (BDI-II), (Beck, Steer, & Brown, 1996). The Inventory has been validated as a screening tool for depression in PD (Visser, Leentjens, Marinus, Stiggelbout, & van Hilten, 2006; Schrag et al., 2007).

Three patients (one male and two females) reported moderate depression on the Beck Depression Inventory-II (scores >18) and were removed from the analysis. Additionally, 2 male participants were excluded (due to subpar performance (less than 50 % overall accuracy on the low load images)).The age range of the 16 remaining (11 male, 5 female) was between 50 and 79 years (M = 66.19, S.D. = 7.30).

Twenty-five healthy volunteers (6 male, 19 female) aged between 55 and 81 years (M = 69.40, S.D. = 7.22) took part in the study. None of the controls had any neurological disorder, psychiatric illness, head injury, or alcohol or drug abuse. All participants completed the BDI-II and the MMSE.

The study was approved by the Joint Ethics Committee of the Institute of Neurology and The National Hospital for Neurology and Neurosurgery. Informed consent was obtained prior to participation in the study from all controls and PD patients. .

Control participants were paid a fee of £10 per hour and the travelling expenses of patients were reimbursed.

Full Demographic data of participants is presented in **Table 5-1**.

Demographic characteristics of participants

	Parkinson’s Disease patients		Age Matched Controls	
	Mean	SD	Mean	SD
Age	66.19	7.30	69.4	7.22
Gender (M/F)	11/5	-	6/19	-
MMSE	29.25	1.00	29.60	.71
BDI	7.6	4.60	5.17	3.71
Hoehn & Yahr Scale	1.66	0.89	-	-
Schwab & England Scale	8.06	0.85	-	-

Table 5-1 Major characteristics of Parkinson’s disease participants and healthy controls for Experiment 10

5.1.2.2 Stimuli and Procedure

The apparatus and procedure were almost identical to Experiment 10. However, there were subtle amendments required due to dealing with both an older and clinical population. As before the experiment took place in a dimly-lit room. Matlab (running the cogent Toolbox) was used to program and run the experiment. All stimuli were presented in on a black background, on either a PC or laptop with a 15” screen. Due to the difficulty of testing for this clinical group, occasionally it was not possible to bring participants into to be tested, hence requiring the use of the laptop in the participants' homes (where an approximate viewing distance of 58 cm was maintained).

An initial pilot study was conducted to ascertain an optimal presentation time, as the display time of the prior experiment at 150 ms was found to be too rapid and frustrating for this age group of participants. For this experimental iteration, the face display time was for 350 ms, otherwise the procedure was identical to the last experiment. Each trial in the visual search task began with key press that was self-initiated, followed by a fixation point presented for 500 ms in the centre of the screen. This was followed immediately by the stimulus display, consisting of one, or six letters arranged to form a circle (with the radius subtending 1.6 degrees of visual angle) and a face presented in the centre, displayed for 350 ms. Again as before all faces and presentation blocks were fully counterbalanced. Once more as in prior experiments, participants completed one practice block of 12 trials, and one practice block of rating before the experiment (different face identities were used in the practice than experiment, and all were neutral on the respective valence scale).

5.1.2.3 Design

The design employed in Experiment 11 was identical to Experiment 10 (repeated here for clarity). Mean percentage search accuracy rates and mean reaction times for the accurate search trails were the preliminary dependent variables (DVs) and were entered separately into a 2 x 2 repeated measures analysis of variance (ANOVA), with Perceptual load (Low, High) and Valence (untrustworthy, trustworthy) as the within subject independent variables (IVs).
Next, mean percentage accuracy (hit) rates *d'* and criterion scores *C* (both for the accurate search trails) were employed as the dependent variables and were entered, again separately into the same Perceptual load (Low, High) x 2 Valence (untrustworthy, trustworthy) repeated measures ANOVA model.

5.1.3 Results

The following results for Experiment 11 are segregated into outcomes for Parkinson Disease patients and outcomes for their corresponding age matched controls, summarized below in **Table 5-2** and displayed in **Figure 5-1** (broken down by the valence and load conditions).

Parkinson's disease patients

Search task Mean reaction times in the low perceptual load condition were significantly faster (M = 1244 ms) than in the high perceptual load condition (M =1543 ms), $F(1, 15) = 16.78$, MSE = 85603.77, $p < .001$, η^2 =.528. There was no significant effect of valence $F(<1)$ $F(1, 15) = .09$, MSE =23185.34, $p = .768$, $\eta^2 = .006$, or interaction $F(1, 15) = 2.11$, MSE = 38851.27, $p = .167$, $\eta^2 = .123$.

Additionally, the search accuracy rates in the low perceptual load condition were significantly better (M = 96 %) than in the high perceptual load condition (M = 83 %), $F(1, 15) = 27.25$, MSE = .01,

$p < .001$, $\eta^2 = .64$. There was no significant effect of valence $F(<1)$ $F(1, 15) = .635$, $MSE = .003$, $p = .438$, $\eta^2 = .041$, or interaction $F(<1)$, $MSE = 008$, $p = .469$, $\eta^2 = .036$. The aforementioned results indicate that the perceptual load manipulation was successful for the Parkinson’s disease patients.

Face classification As described in the results section in Experiment 10, sensitivity as measured by d', refers to how hard or easy it is to detect that a face has a trustworthy valence dimension (either -3SD or +3SD valence depending on the block) as compared to a neutral face. Sensitivity under low load exposure ($M = .79$) was significantly better than under high load ($M = .28$), $F(1, 15) = 3.37$, $MSE = 1.24$, $p = .04$ (one-tailed), $\eta^2 = .18$. For criterion scores (measuring the extent to which an individuals’ response of a valence dimension is more probable than another); low load ($M = .67$) was not significantly more biased than high load ($M = .61$), $F(<1)$ $F(1, 15) = .11$, $MSE = .57$, $p = .745$, $\eta^2 = .007$.

The overall valence sensitivity scores of trustworthy faces ($M = .58$) faces were not significantly different than untrustworthy ones ($M = .49$), $F(1, 15) = .14$, $MSE = .89$, $p = .71$, $\eta^2 = .009$. The same pattern was observed for criterion scores, trustworthy valence faces ($M = .495$) were not significantly different than untrustworthy ones ($M = .79$) $F(1, 15) = 2.85$, $MSE = .48$, $p = .11$, $\eta^2 = .16$. Finally, there were no significant interactions with load for either d'; $(F<1)$, $F(1, 15) = .235$, $MSE = .65$, $p = .635$, $\eta^2 = .015$ or for C; $F(1, 15) = 1.06$, $MSE = 1.04$, $p = .32$, $\eta^2 = .07$.

Age matched controls

Search task Mean reaction times in the low perceptual load condition were significantly faster ($M = 1053$ ms) than in the high perceptual load condition ($M = 1355$ ms), $F(1, 24) = 55.34$, $MSE = 41256.07$, $p < .001$, $\eta^2 = .70$. There was no significant effect of valence $F(1, 24) = 1.36$, $MSE = 20350.43$, $p = .254$, $\eta^2 = .054$, and there was no significant interaction between valence and load $F(<1)$ $F(1, 24) = .60$, $MSE = 57288.31$, $p = .444$, $\eta^2 = .025$.

The search accuracy rates in the low perceptual load condition were significantly better ($M = 97$ %) compared to the high perceptual load condition ($M = 85$ %), $F(1, 24) = 84.62$, $MSE = .004$, $p < .001$, $\eta^2 = .78$. There was no significant effect of valence $F(1, 24) = 2.02$, $MSE = 007$, $p = .168$, $\eta^2 = .078$, and there was no significant interaction between valence and load $(F<1)$, $MSE =. 005$, $p = .989$, $\eta^2 < .001$. The aforementioned confirms that the perceptual load manipulation was effective for the age matched controls.

Face classification Sensitivity under low load exposure ($M = .97$) was significantly better than under high load ($M = .55$), $F(1, 24) = 7.74$, $MSE = 0.58$, $p = .010$, $\eta^2 = .24$. There was no difference however for criterion scores, C under low load ($M = .375$) compared to high load ($M = .40$), $F(1, 24) = .04$, $MSE = 0.48$, $p = .842$, $\eta^2 = .002$.

There were no significant interactions with load for either d'; F (1, 24) = .001, MSE = .65, p =.976, η^2 <.001, or for C; F(1, 24) = 3.23, MSE =0.28, p = .85, η^2 = .12.

There was an effect of valence however on both the sensitivity scores and criterion. For d', trustworthy faces (M =.57) were significantly less discriminated than untrustworthy faces (M = .95), F (1, 24) = 6.82, MSE = .55, p=.015, η^2 = .22. Additionally, there was a less strict criterion for trustworthy faces (M = -.005) than their untrustworthy valence counterparts (M = .78), F (1, 24) = 9.76, MSE = .59, p=.005, η^2 =.29 (see **Table 5-2**).

	Perceptual load		
Parkinson's patients	Low	High	Differential Effect of load
Search Accuracy (%)	96(4)	81(11)	15*
Reaction Time (ms)	1244(431)	1543 (387)	299*
d'	.79(1.03)	.28(.88)	.51*
C	.67(.68)	.61(.99)	-.06 NS
Age matched Controls			
Search Accuracy (%)	97(5)	85(7)	12*
Reaction Time (ms)	1053(305)	1355 (284)	302*
d'	.97(.82)	.55(.69)	.42*
C	.37(.70)	.40(1.02)	.03 NS

SDs are listed in parenthesis, * - significant difference between means, NS – Non-significant

Table 5-2 Mean percentage search accuracy rates, mean reaction time (ms) rates, mean face sensitivity (*d'*) rates and mean face judgment bias (*C*) rates in the response bias trustworthy task for Parkinson's disease patients and age matched controls as a function of load in Experiment 11

Finally to ascertain any possible effect of experiment, the same model design was employed for the Parkinson's disease patients and age matched controls, with the results from both being entered into a combined model. As expected sensitivity under low load exposure (M = .88) was significantly better than the high load (M =.41), F (1, 39) =8.53, MSE = .83, p = .003, η^2 = .21. None of the other effects or interactions, particularly with experiment were significant, or indeed the between factor of experiment F (1, 39) = 1.00, MSE =1.99, p=.32, η^2 = .025.

For the criterion scores, only the main effect of valence was significant. There was a less strict criterion for trustworthy valence faces (M = .245) than for untrustworthy ones (M = .785) F (1, 39) = 9.80, MSE = 1.16, p=.003, η^2 = .20. Finally, none of the other effects or interactions were significant and the same as for d', bias C, did not show any significant effect of experiment, F (1, 39) = 1.01, MSE =2.47, p=.32, η^2 = .025 between the Parkinson's patients and their age matched counterparts.

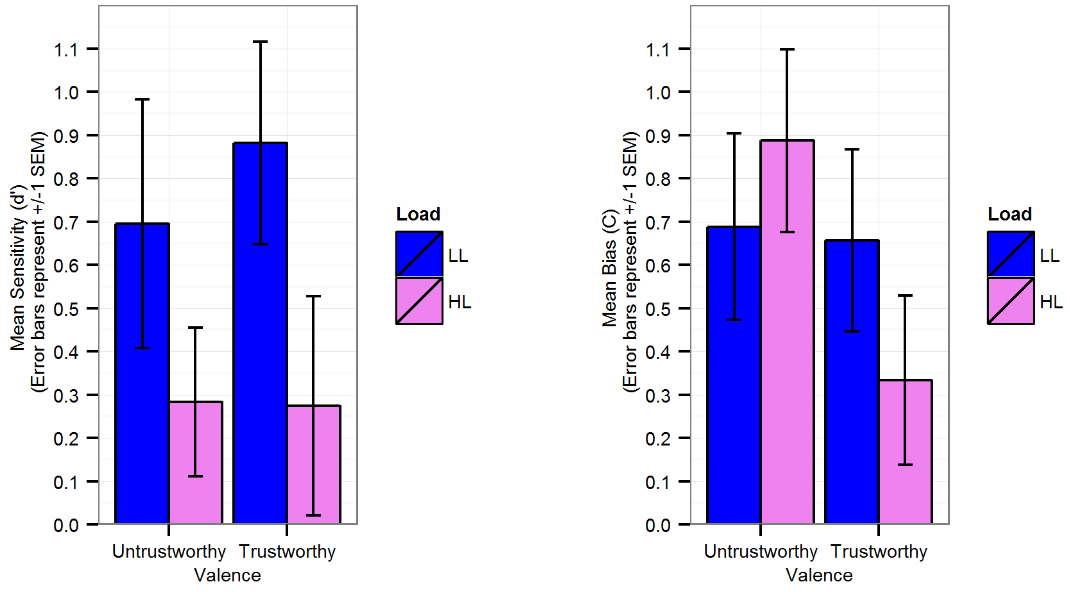
Comparison with younger cohort of Experiment 10

Lastly, to informally assess the extent to which the results of the PD patients' and their control counterparts are affected by age, we added the results of Experiment 10, where the participants performed the same task (although with slight methodological differences (the presentation time was 150 ms as opposed to 350 ms here)). This indicated that the performance pattern of results from Experiment 10 for the younger cohort was different to that of those from Experiment 11. As to be expected, given the prior pattern of results for Experiment 10 and 11 the effect of load was significant (although not on criterion scores) however now the intergroup effect of experiment was now significant for both sensitivity *F* (2, 62) = 10.24, *MSE* =1.87, $p <.001$, $\eta^2 = .25$ and bias *F* (2, 62) = 3.175, *MSE* =1.935, $p = .049$, $\eta^2 = .093$ (both sensitivity and bias had significant valence inter-experiment interactions also ($p <.05$).

Follow up testing comparing sensitivity for the Parkinson's patients and the age matched controls against the younger cohort respectively, indicated that both older groups were significantly different from the younger cohort; *F* (1, 38) = 31.86, *MSE* =1.97, $p <.001$, $\eta^2 = .30$ and *F* (1, 47) = 13.69, *MSE* =1.68, $p =.001$, $\eta^2 = .23$ in turn.

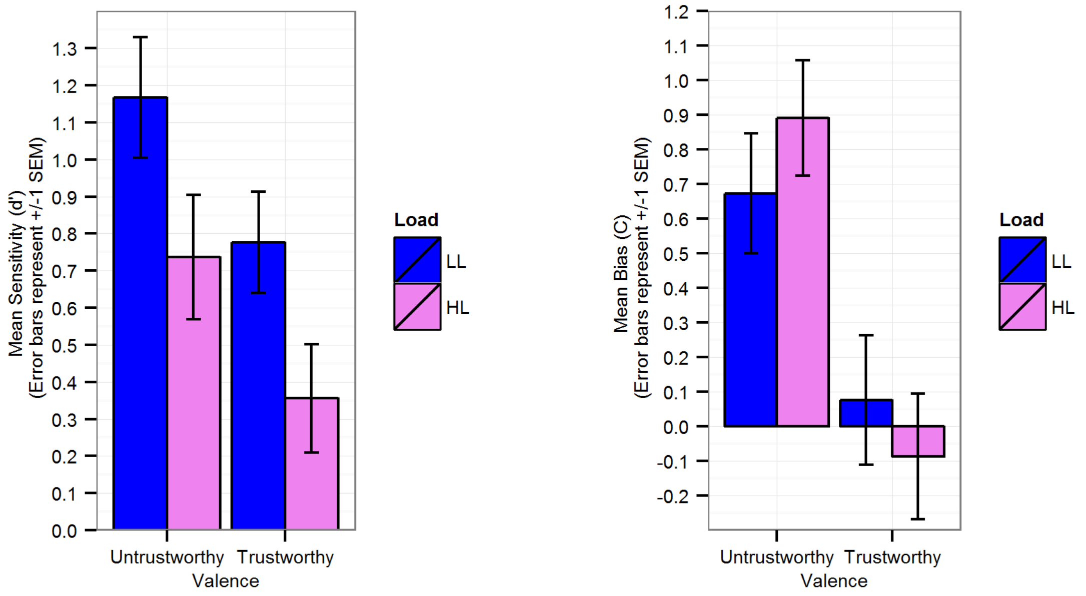
This relationship was partly observed for bias also, comparing Parkinson's patients against the younger cohort, *F* (1, 38) = 7.74, *MSE* =1.54, $p =.008$, $\eta^2 = .17$. Although there was no main effect of experiment when comparing the age matched controls and the younger cohort, *F* (1, 47) = 2.45, *MSE* = 1.81, $p =.12$, $\eta^2 = .04$ (although the absence of an effect has to be bone in mind with the significant experiment valance interaction observed for the age matched controls and the younger cohort *F* (1, 47) = 11.34, *MSE* = .97, $p =.001$, $\eta^2 = .195$).

Overall these findings indicate that (as expected given a cursory look of the results from Experiment 10, **Figure 4-9** and here Experiment 11, **Figure 5-1)** that the pattern of results somewhat differ for the younger cohort against and those presented in this Chapter, although this not so much in evidence for the comparison between Parkinson's disease patients and their age matched counterparts.



a) b)

Parkinson's patients



c) d)

Age matched controls

Figure 5-1 Detection sensitivity and bias for Parkinson's patients and Age matched controls for trustworthy and untrustworthy facial judgments

- **(a) Top left, Parkinson's patients mean trustworthiness sensitivity. Sensitivity as measured by *d'*, refers to how hard or easy it is to detect that a face has a trustworthy dimension**
- **(b) Top right, Parkinson's patients mean bias (*C*) criterion scores**
- **(c) Bottom left, Age matched controls mean trustworthiness sensitivity**
- **(d) Bottom right, Age matched controls mean bias (*C*) criterion scores**

5.1.4 Discussion

This study examined how both individuals with Parkinson's disease (PD) and age matched controls (AMC) perform social facial judgments of trustworthiness with and without attentional load. As noted earlier, there is conflicting research regarding whether PD pathology is linked with impairments in the processing of facial judgments. Moreover, it is unknown whether this impairment could be subordinate to other cognitive processes enmeshed in facial evaluation, such as selective attention.

To determine if there is a relationship between expression processing in PD and attention, and also to investigate social facial judgment in PD, the detection sensitivity scores of PD patients were compared against AGCs. The results confirmed our hypotheses that attention would impact social facial judgment, perceptual load reduced detection judgment capacity for both groups (PD and AMC) (the data also replicates the results of the last Chapter on the effects of perceptual load on trustworthiness detection sensitivity).

Our findings also indicated that the detection scores of the PD patients were quantitatively poorer in comparison to those of the AMC, confirming our expectation that PD judgment performance would be inferior as compared to AMC.

The results presented here indicate a role for attention in facial judgments with regard to detection capacity, but do not explicitly suggest that this role is necessarily exclusive to PD as compared to age matched controls. Both groups had a similar differential effect of load, a reduction of .51 standard units for the PDs compared to .42 standards units for the AMC. Moreover, a follow-test revealed no evidence of an inter-group difference between PD patients and AMC.

The results from Experiment 10 (in the last Chapter) in a younger cohort provided the opportunity to informally explore the role of age related effects the findings observed here.

Overall, the more minor load effects (a reduction in *d'* of .35) seen in the prior experiment, (Experiment 10) were not the only differences between the younger cohort and the participants of Experiment 11. Inter-experiment, the pattern of results for the younger cohort was significantly different from both the PDS and AMC in Experiment 11. These divergences could arise because of the different populations of participants and the effect of age on perceptual processing (discussed further below). However, it is possible they may also partly be due to the task disparities (e.g. the extra time increase allocated for the Parkinson and age matched control cohorts) which may have had some undetermined subtle influence on the manner of face processing employed.

Impact of PD on facial judgments

Can we detect or infer any structural facial encoding abnormalities in adults with PD from these results and what is the role of load here? The pattern of results for the PD patients was slightly different to those of the AMC (see **Figure 5-1 a)** and **c)),** with higher detections accuracies for the trustworthy faces under low load (*M* = .88) as compared to the negative valences untrustworthy faces (*M* = .695). Although, neither category, trustworthy faces, nor untrustworthy faces under high load was significantly different in comparison to low load. This pattern was reversed in AMC, where detections accuracies for the trustworthy faces under low load (*M* = .78) were numerically less than the negative valence untrustworthy faces (*M* =1.17), however they were not impacted by high load (*t* (24) = 1.75, *p* = .09). In contrast, trustworthy faces, although numerically less under low load (*M* = .78) in AMC were impacted by high load (*t* (24) = 2.15, *p* = .04). This replicates the observations of the comparable Experiment 10 in the last Chapter, where post-hoc testing revealed the effects of load only impacting trustworthy valence faces in the younger cohort. Both the PDs and AMC share features with the younger cohort in Experiment 10, but ultimately they were both impacted by load in a comparable manner, suggesting that it is not necessarily an attentional cognitive impairment which is related with the inconsistent research regarding whether PD pathology is linked with deficiencies in the processing of facial judgments.

Arguably, it is possible to infer facial structural facial encoding abnormalities in the PD group of Experiment 11 due to the discernible differences in detection accuracy, particularly between the low load categories of the PD patients and AMC (*M* = .79 vs *M* =.97 respectively). The latter findings in particular, with the weaker comparative detection of the PD patients, emphasize the difficulties for expression analysis observed in PD and reported in the literature.

An important question to pursue is whether any reduced sensitivity, not relative to load, but absolute values is in any way a consequence of some subtle impairment in motor movement while viewing faces which could account for the lower sensitivity values. Indeed whether this is a general factor of concern yielding heterogeneity in the literature in facial judgments in Parkinson’s disease?

Visual signs and symptoms of PD may include defects in eye movement, pupillary function, and in more complex visual tasks involving the ability to judge distance or the shape of an object (Armstrong, 2008). It is not clear where in the visual processing pathway or how the results that we obtained are mediated, whether by attention or by the social judgment of trustworthiness. Changes in vision in PD may introduce a cascade of potentially adverse effects, from alterations in visual acuity, contrast sensitivity, colour discrimination, pupil reactivity, eye movements, to motion perception (Diederich, Stebbins, Schiltz, & Goetz, 2014). Furthermore, slower visual processing speeds can also lead to a decline in visual perception; the longer presentation time was required to mitigate this, although this holds for the age matched controls also.

We cannot rule out a subtle effect of some form of visio-motor impairment (and the prospect that this is related to attentional mechanisms). Some aspect of the PD performance could be related to motor slowing, although we did not observe any significant differences between the reaction times for the search task (RTS) for the two groups (PD patients and AMC), this absence was not compellingly conclusive. The RTS discrepancy between groups just missed significance. The overall RTS for the PD patients (*M* = 1393 ms) just missed being significantly different (*F* (1, 39) = 3.26, *MSE* = 428186.29, *p*=.079) than for the AMC (*M* = 1204 ms). This difference, approximately 189 is nearly two-thirds the magnitude of the impact of load for both groups (approximately 300ms) (see **Table 5-2**).

This motor slowing did not seem to be related to any overt manifestation of the disease, as RTs for the PD group were not associated with the stage of illness, as indicated by adding the H&Y scores (Hoehn et al., 1967) as a covariate (or the highly correlated Schwab and England Activities of Daily Living scale (Schwab et al., 1969)) to the reaction time Anova model.

More research is need to ascertain the effects of motor deficit in judgments. For instance, it is possible that there may be a subtle facial mimicry or embodied cognition component to consider if there was any impairment in facial muscle activation (Goldman & De Vignemont, 2009) (although this did not appear to be the case in any of the participants) that could that have an effect on emoting and even understanding the facial components that signal trustworthiness.

Once again, we were also afforded the opportunity to examine an ancillary component of the decision process in Experiment 11, bias or Criterion, *C*. This value is not about sensitivity or discriminability but rather how more or less likely a participant is to respond that a stimulus is, or is not present.

Generally experimental psychology has tended to focus on *d'* as the primary measure of interest, considering criterion or bias effects almost extraneous to the research of the perceptual system. As we had no substantive predictions regarding the criterion, to some extent that convention was adopted here, nevertheless the participants' bias in both groups the PD and AMC evidenced some noteworthy behaviour.

As discussed with regards to Experiment 10, important in interpreting our results is understanding the implication of deviations from the neutral point (where *C* has a value of 0). Negative values of *C* indicate a bias or reflect a more relaxed criterion for saying "yes" the facial stimulus valence is present, rather than saying the stimulus has no valence (i.e. the face is neutral). Alternatively, positive values reflect a stricter criterion for saying whether the stimulus has valence or not, that is a bias towards a "no" response (i.e. the face is neutral).

As can be seen in **Figure 5-1 b),** although there were no significant main effects of either load, valence or an interaction on criterion scores, quantitatively, when participants are judging a face where the choice ranges between either an untrustworthy valence or neutral valence face, the PD patents have a stricter criterion (compared to trustworthy faces), under both low and high load (although slightly greater under high load). This pattern is reversed for trustworthy faces. PD patients possess a less strict criterion under high load, with a greater (and numerically similar to untrustworthy faces) bias for trustworthy faces under low load. In contrast, the bias pattern for the AMC group (**Figure 5-1 d)**) was in a fashion, similar to that of the bias for the younger cohort in Experiment 10 (**Figure 4-9 b)** although inverted. Specifically, a strict criterion for untrustworthy faces, where trustworthy faces have almost no bias irrespective of load, while untrustworthy faces engender a significantly stricter criterion (bias towards a "no" response (i.e. the face is neutral), again irrespective of load.

These different patterns of bias are challenging to interpret, particularly due to the large variability in their scores. Although the PD and AMC groups were not significantly different in terms of bias, they were in comparison to the younger cohort of Experiment 10. It is unclear to what extent the age is a determining variable in influencing any preferences associated with and in setting biases regarding how perceivers respond to the untrustworthiness or trustworthiness of a face (see below) in facial social judgment behaviour. These differing patterns of bias indicate an interesting avenue for future research to try explore the nature of these dissimilarities. It is important to emphasize that Signal detection theory (see section 2.4) makes no injunction that C is psychological phenomena rather than a sensory one. In point of fact, particularly with regard to phenomena as complicated as facial processing and particularly within the realm of facial social judgments such as trustworthiness, the role of criterion-setting processes could be an important under-examined variable. Shifts in bias could be important in elucidating changes of facial processing under attentional (and pathological) constraints (see (Bankó, 2009) for an example seeking to incorporate the criterion in studies of facial emotional expressions).

Overall, these results are encouraging in that they support the tentative results of the last chapter and in particular, Experiment 10. In spite of this, it should be borne in mind that there was a lot of variability in the data (see **Table 5-2**). Notwithstanding the high variability for both groups under high load (particularly for PD patients' sensitivity under high load), there was still substantial variance for both groups under low load (especially as compared to the variance for the younger cohort in Experiment 10). Future studies could seek to determine whether this variability is a "bug" or "feature" of PD (larger sample sizes could reduce this variance, or in contrast affirm it as facial processing impairment feature of the disease, as suggested above and in alignment with the difficulties for expression analysis for PD patients reported in the literature) and how age factors into creating this variability (see *Age related changes in capacity and attention* below).

As suggested in the prior paragraph, a larger sample size could permit stratification of face detection capacity by the stage of illness using the Hoehn and Yahr scale (H&Y) (Hoehn et al., 1967). Indeed we employed a modification of this approach, adding the H&Y scores as a covariate to the Anova model, although it did not reach significance as a predictor of detection scores ($F(1, 14) = 2.00$, $MSE = 2.85$, $p = .11$, $\eta^2 = .17$). Nevertheless, it would be a natural progression of this research to ascertain if disease progression impacts facial judgment capacity and visually-related neurobehavioral symptoms in Parkinson's disease.

Age related changes in capacity and attention

Our findings broadly establish that trustworthiness face recognition can be impaired in both PD and AMC and our current results seem to suggest that selective attention abilities (at least as indexed by perceptual load) are not globally damaged in PD. However, how can we account for the differences in detection accuracy observed here and for the younger cohort in Experiment 10?

The differing populations, particularly the difference in age between the groups in Experiment 10 and 11 could be an important factor regarding the differences between detection in these groups. For example, the spread in detection sensitivity for low load ranges from (*M* = .79) for the PD patients, through (*M* =.97) for AMC to (*M* = 1.62) for the younger cohort, is there a role of age mediated effects here?

As Parkinson's disease (PD) is a disorder of the middle-aged, the issue of age related changes in attentional capacity and distraction and their interaction with age and load effects arises inevitably arises. Theories about age-related changes to cognition commonly and unforgivingly assert that effortful cognitive abilities, indeed information processing capacities in general which mature and establish relatively late in development are the first to deteriorate in old age (for an example of the frontal hypothesis of aging and results that indicate that attention is selectively and independently influenced by age and task demands see (McLaughlin et al., 2010). This proposition when taken together with the perceptual-load model suggests the counterintuitive prediction that distractor interference may necessitate lower levels of relevant-task load in younger children and older adults, being sufficient to exhaust their more limited capacity by comparison. That is, although the stimuli are matched between Experiment 10 and 11, less perceptual load, translated as less letters; 4 rather than 6 say of relevant-search items for example, could hypothetically have improved the detection rates. This conjecture has some support experimentally as smaller increases in the number of relevant-search items were needed to reduce distractor interference in the elderly (Maylor & Lavie, 1998).

This idea of modulating the levels of load and namely the number of distractors has some additional support in an examination of the relationship between selective attention and developmental change, comparing children and adults. For example, in one study children's performance was as efficient as adults' under conditions of high but not low loads (Huang-Pollock, Carr, & Nigg, 2002). Specifically, in Huang-Pollock and colleagues’ study, children as well as adults experienced smaller interference effects moving from display load with four to display load with six letters, that is, children experienced large distracter effects from an incompatible distracter letter at low loads, although for high loads these distracter effects were considerably smaller and the resistance to distracter letters approached adult levels (Huang-Pollock et al., 2002). From this, the author’s inference is that early selection engages rapidly maturing neural systems and late selection engages later-maturing systems. This implies that overall, children initiated early selection at lower loads to compensate for immature anterior-system interference control processes.

Taken as a whole, from the above, we can conclude that maintaining effortful cognitive processes such as selective attention that consolidate later in life are more likely to regress in adulthood. This developmental proposition may contribute to the fact that under low load in Experiment 11, absolute load performance was lower for both of the older groups, and particularly the

PD group (than comparatively to the younger cohort of Experiment 10), notwithstanding any impairment generated by PD itself.

Given the possible developmental changes in selection attention, it is possible that a reduction in the search letter array size could hypothetically decrease the comparable relative reductions in detection sensitivity for PD patients and AMC (*d'* of .51 and *d'* of .42 respectively) to a similar level to that of the reduction (*d'* of .35) from experiment 10. Future research could seek to try to parametrically modulate the levels of load, namely the number of distractors, to try and confirm an optimum size search array for older age groups.

Surprisingly little is known regarding the capacity of facial trustworthiness processing across the lifespan, although the competence for accurate facial judgments may decline with age. For instance, a recent meta-analysis on facial expression recognition in aging has shown that anger, sadness and fear are less accurately recognized in elderly adults than in younger adults (Ruffman, Henry, Livingstone, & Phillips, 2008). Many studies converge on the proposition (although not without exceptions, e.g. (Mienaltowski et al., 2013)) that older individuals are less efficient in recognizing emotional expressions (Sullivan & Ruffman, 2004; Firestone, Turk-Browne, & Ryan, 2007; Calder et al., 2003). This reduced efficiency affects mainly the ability to recognize facial expressions of emotions (Keightley, Winocur, Burianova, Hongwanishkul, & Grady, 2006) as opposed to being a general deficit in social cognitive processing. Given the correlations of emotional and trait judgments, such a decline may be an important variable in explaining the reduced detection sensitivity of older adults (both PD and AMC) as compared to younger adults in their ability to perform facial judgments of trustworthiness in Experiments 10 and 11. Although older adults seem to be less efficient than younger adults in identifying emotional expressions and trustworthy judgments, it is possible they may simply have different cognitive representations of trustworthy faces than their younger counterparts, differing in the cues they use to make trait evaluations (Ethier-Majcher, Joubert, & Gosselin, 2013). For example, a number of eye tracking studies of facial perception indicate age-related changes in the allocation of attention to different parts of the face, with older adults focusing more in the mouth area and less on the eyes (Sullivan, Ruffman, & Hutton, 2007; Murphy & Isaacowitz, 2010). More work is certainly needed to elucidate the evolution of social facial judgment processing during the course of aging to disentangle impairments in PD from the evolutions in facial processing capacities across the lifespan.

Ultimately age-related changes can be considered in the context of three theoretical perspectives-positivity effects (tendencies to enhance positive and diminish negative information), general cognitive decline, and more specific neuropsychological change in the social brain. It has been proposed that age- related changes are most consistent with a neuropsychological model, stemming from changes in frontal and temporal volume, and/or changes in neurotransmitters (Ruffman et al., 2008). Understanding any structural changes due to ageing is important as changes in the volume of grey or white matter could also entail functional changes, such as in neurotransmitters concentrations, like dopamine. If we can correlate these accompanying physical changes to facial judgment ability, we may not only advance theories about their role in face processing and attention but also improve the ability for accurate diagnosis of impairment in facial evaluations, helping clinicians to design support interventions.

Conclusion

To conclude, experiment 11 has extended the effects of perceptual load modulation on facial judgments of trustworthiness to new populations, both clinical and aged, indicating once again that in many contexts such evaluations will be influenced by processing resources.

The distinguishing marks associated with older age cohorts comprise both physical and cognitive characteristics, changes which may extend to facial judgment capacity in social evaluations such as trustworthiness. Understanding how trustworthiness judgments are processed and modulated in older populations (PD being an age-related degenerative disorder is inevitably subsumed into this category) may be particularly important, as studies have shown that older adults are more vulnerable to deliberate deception (with its attendant adverse consequences) than their younger counterparts (Stanley & Blanchard-Fields, 2008). At a minimum, knowledge of any difficulty in facial social judgment capability in this group would be particularly useful in mitigating difficulties in social communication that is so reliant on facial signals, while opening the possibility to determine if there are therapeutic avenues to ameliorate them, particularly if there is indeed a deficit in the case of PD. For example, sustained attention is modulated by the neurotransmitter noradrenaline and the balance of dopamine and noradrenaline in the cortex is controlled by the DBH (Dopamine beta hydroxylase) gene. This dopamine-noradrenaline balance may be disrupted in Parkinson’s where decreases in noradrenaline may impair sustained attention, reducing the attention capacity and increasing their susceptibility to distractors (Greene, Bellgrove, Gill, & Robertson, 2009). Demonstrated linkages such as the former may in the long term open the possibility of pharmacological interventions which could rehabilitate attention and face processing capacity to some degree.

As we have stated in the introduction to this Chapter, visual dysfunction may be conspicuous in PD, numerous visual deficits, such as impaired facial processing may occur in the early stages of the disease. Not only are deficits in the primary visual pathway and the secondary ventral and dorsal pathways possible, but also dysfunction of the attentional pathways (Diederich et al., 2014). Such deficits most likely have a role in the reduced relative facial judgments accuracy of PD patients. It is challenging to synthesize how the specific impairments in the networks underpinning these functions are aberrant, however a speculative recent review by Diederich, and colleagues (Diederich et al., 2014), suggests that the perceptual deficits in PD arise from deficient processing in non-conscious visual pathways (the retino-colliculo-thalamo-amygdala and retino-geniculo-extrastriate pathways), whereas the primary visual pathway connecting retina to V1 (occipital cortex) is relatively intact. This has the consequence that patients with Parkinson’s disease have the converse of blindsight, being ‘blind to blindsight', they preserve conscious vision, but show erroneous 'guess' localization of visual stimuli. This is an early attempt to consolidate poor emotional face perception and other putative visual abnormalities into one specific syndrome but nonetheless provides a future framework to delineate the extent to which conscious and unconscious pathways contribute and interrelate in facial social judgment (in both PD and AMC). Employing patient groups may be critical in the future in teasing out nuances in the operation of selective attentional processing and aiding in unravelling the full multilevel pathways involved in facial social judgment.

It is certainly early days yet to fully understand the intricate pathways between attention, age and any possible deleterious effects of Parkinson's disease interfering on facial judgments greater than that of general cognitive decline associated with aging. Nonetheless, what we have demonstrated in this Chapter is the pervasiveness of load on the depletion of attentional resources in facial social judgment in an older and heterogeneous cohort, indicating the possible ubiquity of these effects.

This Chapter has provided some early, tentative evidence concerning the involvement of brain regions modulated by dopaminergic neurons in facial judgment and attentional processing, suggesting possible impairment for PD sufferers in face processing capacity, but not necessarily attentional capacity. Future studies will seek to build on the results here and contrasts these findings with non-medicated PD patients, to try and tease out any role of dopamine in social facial judgments, both with and without attentional constraints. Ultimately not only for a better understanding of its putative role for PD patients but also for its role in the healthy population as well.

Thus far, I have provided modest but convergent evidence for the role of some form of perceptual load in facial social judgments. The next stage, would be to "peek under the hood" to ascertain how this evidence is supported by our understanding of neurological circuitry. This Chapter has alluded to some of the biological and neurological facets of social facial judgment, particularly in the discussion of Parkinson's patients. Neural mechanisms are an important entryway into a more complete understanding of the factors which modulate social facial judgments, and it is thus these that I shall turn to in the following Chapter.

6 *Neural Responses to Trustworthy Judgments under Attention*

"Trust, but verify." Ronald Reagan "A mask tells us more than a face." Oscar Wilde

Overview

Ultimately, all of the experiments so far within this thesis have relied on participants' categorizations; verbal or explicit answers can be distorted and can be challenging to collect effectively, however functional MRI is appealing because it can be used to investigate psychological operations to which people have little or no verbal access.

The cortical effects of perceptual load described so far (predicting that high perceptual load will reduce neural responses), have been established in numerous fMRI studies and are underlined by load modulations in areas mediating sensory perception. Although the neuroimaging evidence for whether attention is specifically required for facial stimuli is mixed. In a related vein, I have discussed at length the evidence from recent neuroimaging studies on the facial evaluations of trustworthiness, studies which highlight the subcortical amygdala nuclei, as critical in processing the affective significance of facial stimuli. Consistent with the sensitivity of the amygdala to negative threat-valence stimuli, is evidence suggesting that regions in the amygdala track how untrustworthy a face appears, with amygdala activation increasing for faces appearing less trustworthy (i.e. negative-linear activation).

Given our understanding of the psychophysiological relationship of perceptual load and judgments of facial trustworthiness, combined with the results of the previous Chapters and knowledge about how specific brain regions, particularly the amygdala are implicated in the coding of facial trustworthiness signals, permits the creation of specific hypotheses. We can explore these hypotheses by amending the paradigms employed thus far in this thesis, presenting us with the opportunity to inform, compare or falsify both the observed experimental results that have been presented here and the prior results observed in the literature to date.

In the experiments reported in this chapter, we examined two principal hypotheses. Firstly we hypothesized that reduced neural (BOLD) activity would be observed under conditions of high load (although given the behavioural results presented in this thesis, we expected such effects to interact with the valence of trustworthy faces) and secondly that amygdala activation would still be responsive to both low and high trustworthiness facial signals, specifically activation would increase linearly with a decrease in facial trustworthiness.

We manipulated attentional load in a facial memory task by varying the search set size (where the task demands were not directed to trustworthiness evaluations). We found high load affects only the facial components of trustworthiness (as compared to neutral faces) in cortical areas involved in social and facial processing (but not the facial signal components of untrustworthiness as compared to their neutral counterparts). Performing region-of-interest analyses again demonstrated this same response pattern in attentional and face processing areas such as the FFA (Fusiform Face Area) and ACC (Anterior Cingulate Cortex) and also the amygdala. Finally, we found evidence of negative-linear effects in the amygdala, consistent with prior research.

These results support the idea that any automaticity of emotional and trait face processing can be disrupted by attentional modulation, although the nature of this disruption may be conditional on the type of evaluation and valence properties of the facial signals that attention acts upon. These results are suggestive of a clarification for the role of load theory and attention in the realm of facial social judgments; the efficacy of perceptual load in facial social judgments could be contingent on the valence of facial stimuli.

6.1 Experiment 12

6.1.1 Introduction

By non-invasively recording neuronal activity, functional magnetic resonance imaging (fMRI) offers the opportunity to further investigate how cognitive processes such as attention (and in contrast automaticity) interact in facial expression processing (without the requirement to resort to verbal or explicit answers). Furthermore, the diverse cortical processing pathways subsuming these cognitive and behavioural functions can also be assessed and explored with this tool. These features are useful in providing evidence for the continuing debate as to how attention influences the processing of facial stimuli, particularly as some extant research proposes that facial emotional stimuli are principally immune from attentional control and hence can activate brain regions automatically (see the introductory Chapter for an in-depth discussion of this debate).

Attention, perceptual load and facial processing

A substantial segment of the fMRI literature on face processing and attention (where task demands and stimulus visibility are manipulated), indicate that perceptual encoding of emotional face expressions in conditions where faces are seen and attended but their emotional expression is task-irrelevant can be fast, and involuntary*;* supporting the view of some type of automaticity in processing (particularly with fearful or angry expressions (Whalen et al., 1998) where significant activations to emotional versus neutral faces have been found in the amygdala, even when emotional faces are briefly presented and backward masked). It has been argued that emotional faces are processed automatically due to their high level of sociobiological significance (Vuilleumier et al., 2003), although automaticity in processing emotional facial expressions might transpire only when the attentional system is not completely occupied by the main task, so that some attentional resources may be "spared" and "spill over" to emotion processing (Pessoa et al., 2002). This is one of the principle conjectures of load theory that distractors and or stimuli are processed more at low load than at high load, and indeed is consistent with current functional magnetic resonance imaging (fMRI) studies, where for example the neural signal in both visual and auditory cortices at low relative to high perceptual load is greater, even when the distractors were not visible or in a distinct sensory modality from the targets (Schwartz et al., 2005; Rees, Frackowiak, & Frith, 1997; Klemen, Buchel, & Rose, 2009; Berman & Colby, 2002; Bahrami, Lavie, & Rees, 2007).

People exhibit fast, involuntary perhaps automatic responses to emotional stimuli, yet, as I discussed in the introductory Chapter, there appears contradictory research regarding the role of such social stimuli, or at least faces and the effects of perceptual load. For example, on one hand the result that famous distracter faces are processed at some level irrespective of the level of the perceptual load task-relevant processing (Jenkins et al., 2002; Lavie et al., 2003) may be explained in terms of the attentional priority for stimuli of high social significance. However, on the other hand, we have evidence that load may not be effective on the neural processing of emotional stimuli, which are reported to be processed automatically, namely, without attention (Vuilleumier et al., 2001b). Although this viewpoint is somewhat countered in the study of Pessoa and collegues, (Pessoa et al., 2002), where differential amygdala responses to emotional facial expressions were eliminated by high perceptual load. This latter result (discussed lengthily in the prior Chapters), is suggestive that that the neural processing of social and emotional facial stimuli may not be automatic and requires some degree of attention, similar to the processing of other stimulus categories. While I have cited extensive (although often conflicting) evidence regarding the durability of social and emotional stimuli to attentional manipulations, this resilience may be simply due to the fact attention was not sufficiently engaged in a challenging task in such studies (Pessoa et al., 2002),

The hypotheses that we sought to address in the following neuroimaging study were directly drawn from the contentious results that surround the attention and face processing debate. Attention is reported to play a critical role in the neural processing of emotional stimuli, which are often described to be processed automatically, that is not modulated by attentional input (e.g. (Rees et al., 1997) see Chapter 1 for a fuller exposition of these issues).

The amygdala in trustworthiness facial judgments

Unlike previous studies however, which have focused on principally emotional judgments when examining the role of attention on face processing, the following study concentrates on evaluations of trustworthiness, although such evaluations arguably reflect judgments related to those of a more general face valence nature (Mende-Siedlecki et al., 2012). The amygdala's activation (without the mitigating role of attention), contingent on trustworthiness, is a relatively robust finding in facial social judgment research (Winston et al., 2002; Todorov et al., 2008a; Said et al., 2009a; Engell et al., 2007).

Anatomically, the importance of the amygdala for a variety of cognitive functions ranging from facial perception, to learning is well established (Aggleton, 2000). In almost all cases, the role of the amygdala is related to the affective significance of stimuli (as reviewed in Chapter 1). It is not surprising then, that the amygdala is comprehensively implicated in research on the social judgment of faces (even though this research has produced divergent results, notwithstanding the differences between studies that may simply be attributable to diverse stimuli (Sergerie, Chochol, & Armony, 2008; Mende-Siedlecki et al., 2012)).

Preliminary fMRI results indicated that amygdala activation increases linearly with the decrease in face trustworthiness (Engell et al., 2007; Winston et al., 2002). Subsequent research indicated that the response need not in fact be linear or monotonic, but rather may be quadratic (Todorov et al., 2008a; Said et al., 2009a), with amygdala activation increasing for faces appearing either more or less trustworthy, relative to neutral (Said, Dotsch, & Todorov, 2010a; Todorov et al., 2011) (a similar profile revealed in attractiveness judgments (Winston et al., 2007)). The circumstances determining whether the relation between social judgments and the amygdala will be monotonic or non-monotonic are currently unknown, however variables such as a larger range of trustworthiness faces (Todorov et al., 2008c) and/or task demands that could be important in causing enhanced responses to positive faces creating a quadratic response pattern. A recent meta-analysis found that both linear and nonlinear responses to trustworthiness coexist in different amygdala sub-regions, it could be that regions with a linear pattern of activity are signals due to face valence (activated by arousing and threatening signals), whereas regions with quadratic patterns are coding what some researchers consider to be approximately face intensity (Mende-Siedlecki et al., 2012). The latter pattern is more consistent with the notion that the amygdala is activated by salient social cues independent from whether they have a positive or negative valence (Said et al., 2008). The quadratic pattern is also consistent with the hypothesis that faces are represented in a multidimensional space in which the origin represents the average face and more distinctive faces are represented away from the origin (Said et al., 2010; Valentine, 1991). Nevertheless, both linear and quadratic responses in the amygdala are consistent with a common attentional mechanism according to which a general attentional system causes the amygdala to bias attention towards stimuli that are of current motivational significance (Cunningham et al., 2008a; Vuilleumier, 2005).

Taken as a whole, results from neuroimaging research highlight the role of the amygdala in social judgment as a relatively reliable phenomenon in response to facial valenced stimuli. Building on these studies and that of the prior chapters provides the primary interest of the experiments conducted in this Chapter; to ascertain whether attention can modulate trustworthy facial judgments. Given that previous studies have intimated a link between the processing of the expression of a face and its valence, we also expect the amygdala to be involved in the processing of trustworthy facial expressions (although what such possible activation means with the role of attention in this processing still needs to be explored). Enquiring into this white matter area and whether it can be modulated by attention, may help as an initial step toward determining whether attention is a prerequisite for social judgments (and thus for amygdala activation).

Revealing the neural responses to trustworthy judgments under attention (Experiment 12)

Following from these outstanding inconsistencies and drawing on the series of prior behavioural studies in the preceding Chapters, we sought to investigate the neural substrates of the effect of valence under perceptual load, with the aim of employing a competing task such that it was sufficiently demanding to exhaust attentional resources. The intention was also to seek a better understanding of attention and social judgment by explicitly investigating the novel interaction of purported trustworthiness facial image properties and attention as opposed to facial image markers which are considered more emotional (e.g. threat).

The prominence of the amygdala, in both attentional and trustworthy social judgment studies as a potentially rapid, specialized detector of emotionally relevant stimuli meant that any similar research drawing on these areas would also necessitate a focus on this region. The amygdala is often considered an important biomarker in emotional and social recognition studies, even for example, when faces are masked and subjects seem to be unaware of them (Hariri, Tessitore, Mattay, Fera, & Weinberger, 2002;

Whalen et al., 1998). Hence, an additional aim of the following neuroimaging experiment was to not only specifically investigate the amygdala's response to the trustworthiness of faces (to ascertain whether this area's signal response concords with its putative coding role from earlier findings (Winston et al., 2002; Said et al., 2009a; Engell et al., 2007)) but also to investigate the novel question of how and whether this activation interacts with perceptual load constraints.

Investigating the influence of perceptual load in modulating the neural activity of facial trait processing (to ascertain if for example certain cortical structures such as the amygdala do indeed code the trustworthiness of faces and whether this activity can be modified by attention), requires a slightly different approach to that of the explicit judgments provided by participants in the experiments of the prior Chapters. Specifically, such an approach requires the use of implicit facial judgments. The principle reason for this is that if the participants did make explicit facial evaluations, such as how trustworthy a face is perceived, it would not be possible to subsequently disambiguate whether for example, general subjective face judgment processes are preferentially coded in the amygdala (or other cortical areas), as opposed to say it responding to the raw visual facial image properties.

Jettisoning the use of subjective judgments meant that participants could not be informed or requested to explicitly evaluate the facial stimuli as they have done in the previous Chapters. Any attempt to experimentally circumvent this may have induced the participants to attend to the trustworthiness properties of the faces even when instructed not to, being incapable of disengaging from this goal once presented with it (Gollwitzer & Bargh, 2005).

To summarize, in contrast to the experiments in the last two Chapters, Experiment 12's principle concern was the *implicit* judgments of trustworthiness and did not demand or comprise any form of person judgment, in fact participants were informed that the study pertained to face memory. To this end, participants were serially presented with faces (possessing visual trustworthiness features) arranged in blocks and then subsequently asked whether a presented test face was presented at the end of that group (**Figure 6-1**).

Based on the literature and the results of the previous Chapters, two primary and succinct hypotheses guided our investigations to elucidate how social facial judgments occur in the presence of constraints. Firstly, the expectation that neural processing (BOLD) activity would be relatively reduced under high load processing, although given the behavioural results presented thus far in this thesis (and the modest yet robust effects of trustworthiness valence being effected by high load demonstrated in the prior Chapters), we expected such effects to interact with the valence of trustworthy faces. Secondly, we expected that amygdala activation would still be responsive to both low and high trustworthiness facial signals. In light of the fact that we sought to maximise distinctiveness between our stimuli (as in Experiment 10 and 11) and thus employed only trustworthy, neutral and untrustworthy faces (which may have decreased sensitivity to possible amygdala nonlinear effects (Todorov, Mende-Siedlecki, & Dotsch, 2013)meant we specifically anticipated activation would increase linearly with a decrease in face trustworthiness.

Modifying the paradigms from the prior Chapters, functional magnetic resonance imaging was employed to measure activation in regions that respond differentially to faces with trustworthy (low, neutral and high) facial valence expressions. Furthermore, the modulation of these responses by attention was also assessed, using a variation of the letter search task that we have already seen employed in this thesis, with a high and low attentional load.

Any results supporting or countering our hypotheses would have useful theoretical implications with respect to the validity of the effects of facial valence processing under perceptual load and the role of attention as a modifier in facial social judgments.

6.1.2 Method

6.1.2.1 Participants

17 participated in the study; one subject was excluded due to excessive movement and difficulty in seeing the images within the scanner. Of the 16 remaining (22–40 years old, mean age =27.87), seven were women. All subjects were right-handed, had normal or corrected-to-normal vision and reported no history of neurological illnesses or abnormalities. The study was approved by the local ethics committee at University College London and each participant gave informed consent before participating in the study. Participants received monetary compensation (£16 per hour) for participating in the experiment and were fully debriefed at the completion of the experiment.

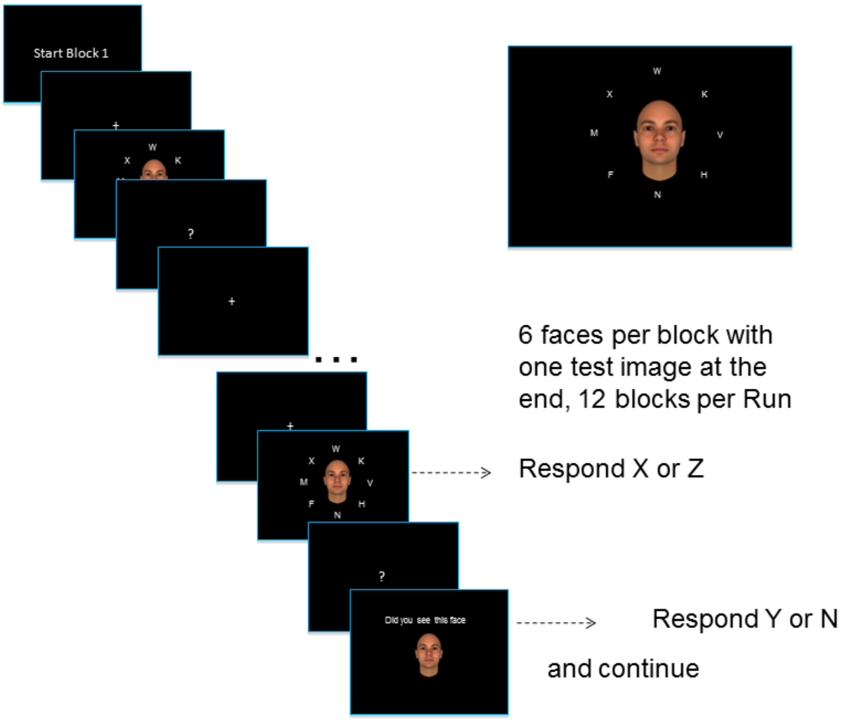
6.1.2.2 Stimuli & Procedure

The apparatus, stimuli, and procedure were similar to Experiment 1 (see **Figures 3-1** and **3-2**, Chapter 3) except that stimuli were here projected onto a screen mounted at the back of the scanner bore through an LCD projector (display resolution: 800x600). Participants viewed the stimuli through a mirror mounted on the head coil. The task is described in further detail below.

Task

Subjects were informed that they were participating in a study examining face memory. They were told that they would see a visual display of 4 blocks of face images accompanied by search target letters, where each block comprised 12 mini-blocks. A mini-block consisted of 6 face visual displays presented in random order (although the face was of a single valence type, trustworthy, untrustworthy or neutral). The assignment of valence faces to mini-blocks was randomized and counterbalanced across participants and across blocks. There were four experimental blocks (two low load and two high load, the order of which was counterbalanced across participants (although the same identities were used for the last 2 blocks)). Each mini block began with a 12 s presentation of a fixation cross; all stimuli were presented in on a black background with a fixation point presented for 500 ms in the centre of the screen followed immediately by a 150 ms presentation of the visual search display, which precluded deliberate saccades during their presentation. The visual search display consisted of a face image surrounded by a target letter (either X or Z) and 7 non target letters spaced evenly around a circle. The non-target letters were either all small ‘o’ placeholders (low load), or 7 other angular letters of the same dimensions, as the target letter (K, F, N, H, M, W, V) appearing in the position of the placeholders (small ‘o’ s). The target letter and the non-target letters were equally likely to appear in any of the possible combinations of positions. Centred at fixation, within the target letter circle, was the face stimulus. 96 faces identities were used that vary on 3 levels of trustworthiness yielding a total of 288 faces. The faces were generated using FaceGen Modeller 3.2 (Singular Inversions, 2007), according to the methods described in (Oosterhof et al., 2008)). Of these 3 levels, one was 2 standard deviations less than the neutral (i.e. untrustworthy) and one was 2 standard deviations more than the neutral (i.e. more trustworthy) (See **Figure 6-1** for an example display). Participants were required to search the display for a target letter (either X or Z) and respond using the keyboard by pressing either of the aforementioned target letters (within a response window of 2000 ms) while also paying attention to the face. Subjects were told to ‘do their best’ to remember the first 6 face images and that the 7th image would be a ‘test’ image (which was presented with a limit duration of 3000ms, where half of the time it would be selected from the prior block and half of the time would be a unique unseen image). They were instructed to indicate whether they remembered the ‘test’ image from the preceding 6 face images by pressing either a ‘yes’ or a ‘no’ button. The acquisition run began with a 12 s presentation of a fixation cross. Subsequently, each face stimulus was presented for 1 s in a jittered event-related design. The ISI was chosen randomly from a normal distribution with a target mean ISI of 3.5 s.

Subjects were scanned for a total of four runs, with a pre-practice run on a laptop to explain the experimental setup, and an additional practice run within in the scanner. Stimuli were projected onto a screen located at the rear of the bore of the magnet. Subjects were able to view these stimuli via an angled mirror fastened to the RF coil placed above their eyes.



6 faces per block with
one test image at the
end, 12 blocks per Run

Respond X or Z

Respond Y or N
and continue

Figure 6-1 fMRI trial presentation

fMRI data acquisition

Imaging data were collected at the Birkbeck-UCL Centre for NeuroImaging (BUCNI), UK. 3D T1-weighted fast-field echo structural images and multi-slice T2-weighted echo-planar volumes with blood-oxygen level dependant (BOLD) contrast (TR = 2.55 s; TE = 50 ms; TA = 2.465s, voxel size 3mm isotropic) were obtained using a 1.5 T MRI scanner (Siemens TIM Avanto, Erlangen, Germany). Functional imaging data were acquired in four scanning sessions lasting approximately 8 min 40 s each, in which approximately 170 volumes were obtained. The first 4 volumes of each session were discarded to allow for T1 equilibrium effects or for magnetic saturation effects (the time constant, T1, is a measure of the time taken for spinning protons (which ultimately underlie the MRI signal) to re-align with the external magnetic field - disregarding the first few scans allows for initial T1 equilibrium as opposed to saturation, a non-equilibrium state with no net magnetization and thus no signal).

Each functional brain volume was composed of 30 axial slices with an in-plane resolution of 3 × 3 × 3 mm, positioned to cover the whole brain. A T1 weighted anatomical image lasting 8 min 30 s was acquired after the first two functional sessions for each participant. The duration of each block was approximately 9.24 minutes and the total experiment was approximately 60 min.

Design

The design employed in Experiment 12 for the behavioural data was similar to that employed in the prior experiments in Chapters 3-5, although with slight amendments due to the modified task.

Mean percentage search accuracy rates and mean reaction times for the accurate search trails were the dependent variables (DVs) and were entered separately into a 2 x 3 repeated measures analysis of variance (ANOVA), with Perceptual load (Low, High) and Valence (untrustworthy, neutral, trustworthy) as the within subject independent variables (IVs).

Next, the mean memory task accuracy rates and their associated reaction times were the dependent variables and were separately entered into the same 2 x 3 repeated measures ANOVA, again with perceptual load (Low, High) and Valence (untrustworthy, neutral, trustworthy) as within IV's.

The data analysis procedure for the fMRI data is described below.

fMRI data preprocessing and analyses

Data analysis proceeded in two steps, firstly, fMRI image preprocessing and analyses were carried out using SPM8 (Wellcome Department of Imaging Neuroscience, London, UK), implemented in MATLAB 7.11 (Mathworks Inc., Sherborn, MA). EPI images were realigned and unwarped, to correct the images for head movement through rigid-body realignment, taking into account translation, rotation, zoom and shear. Each participant's structural image was subsequently co-registered (without reslice) to the mean of the motion-corrected functional images using a 12-parameter affine transformation, and was segmented into grey matter, white matter and CSF according to the standard procedure in SPM (Ashburner & Friston, 2005) thus removing individual differences in brain structure and placing all images onto a standardised anatomical space. To permit across-subject comparison, the co-registered EPI and T1 volumes were normalised to a standard EPI template based on the Montreal Neurological Institute (MNI) reference brain and spatially smoothed by an 8mm full-width half-maximum Gaussian kernel.

For each participant, an event-related GLM included 9 regressors of interest. These comprised six regressors for the onsets of the three types of face valences at each level of load, low load Trustworthy, neutral and untrustworthy, and the same for high load), and a further three for the onset of the probe, fixation and key response. Onsets were modelled with stick-functions (or formally known as Dirac delta functions) at the time at which participants viewed the display, convolved with a canonical HRF and its temporal and spatial derivatives. The former, together with regressors representing residual movement-related artefacts and the mean over scans, comprised the full model for each session. The data and model were high-pass filtered to a cut-off of 1/128 Hz.

Parameter estimates calculated from the least mean squares fit of the model to the data were used in contrasts, contrasting specific event related responses to baseline activity. These contrasts, (beta weights) were then entered into a 2 × 3 factorial design second-level analysis in which 'participant' was treated as a random effect to allow inferences on a population level. Main effects and the interaction between the two factors (as well as linear and quadratic effects) of attentional perceptual load (high load vs. low load) and trustworthiness (with levels trustworthy, neutral, and untrustworthy) were specified by appropriately weighted contrasts, and determined using the *t*-statistic on a voxel-by-voxel basis. Analysis was performed to investigate the effects. Data were smoothed with an isotropic 8-mm Gaussian kernel (full width at half maximum). Averaged-across-subjects parameter estimates were used to illustrate the effects of valence and attention in the amygdala.

Statistical contrasts were used to create SPM-*Z* maps thresholded at $p < 0.001$ (uncorrected, 10 or more contiguous voxels). Coordinates used for a-priori regions and region of interest (ROI) analyses were defined on the basis of independent structural maps and were defined using the Marsbar toolbox (Brett, Anton, Valabregue, & Poline, 2002). In addition, functional data for the whole brain analysis was visualized on transverse slices using the MRIcro software package (Rorden & Brett, 2000).

Cluster activations that survived family-wise error (FWE) whole brain correction at $p < 0.05$, are indicated as well as activations within the amygdala region for which we had an a-priori hypothesis and related ROI analyses of regions involved in facial and attentional processing (which survived the criterion for statistical significance $p < 0.05$).

6.1.3 Results

6.1.3.1 Behavioural Results

Note, in contrast to the experiments in Chapters 3, 4 and 5, no face is explicitly socially evaluated in this experiment, so even though for instance in the case of Experiment 7 (in Chapter 4 (section 4.1.5)) the task involved working memory, where a face was explicitly judged, that was not the case here, where we were interested in the implicit neural response to the stimuli.

Perceptual load search task

Mean percentage search accuracy rates in the low perceptual load condition were significantly better (M = 95 %) than in the high perceptual load condition (M =81 %), $F(1, 15) = 80.04$, MSE =.007, p < .001, $\eta^2 = .84$.

There was no effect of valence (M = 88 %, M = 89 %, M = 87 %, respectively for the untrustworthy, neutral and trustworthy valence conditions), $F(2, 30) = 1.05$, MSE =.002, $p = .36$, $\eta^2 =$ .065, or interaction between load and valence $F(2, 30)$ = .50,. MSE =.003, $p = .61$, $\eta^2 = .03$.

In addition, mean reaction times in the low perceptual load condition were significantly faster (M = 848 ms) than in the high perceptual load condition (M =1108 ms), $F(1, 15) = 116.00$, MSE = 14062.26, p <0.001, η^2 = . 88. Once again there was no effect of valence (M = 991 ms, M = 973 ms, M = 971 ms, respectively for the untrustworthy, neutral and trustworthy valence conditions), $F(2, 30)$ = 2.30, MSE = 1690.60, $p = .12$, $\eta^2 = .13$, or interaction between load and valence $F(2, 30)$ = 2.65,. MSE = 2612.49, $p = .09$, $\eta^2 = .15$.

The aforementioned confirmed as we have throughout the prior Chapters that the perceptual load manipulation was successful.

Facial memory task

Overall performance on the memory task was 68.20 % correct; M = 68.67% for low load vs. M = 67.72% for high load; there was no significant difference between these conditions either for accuracy $F(1, 15) = .074$, MSE =.010, p =.79, $\eta^2 = .005$, or mean reaction times for the memory probe; the low perceptual load mean reaction times were not significantly faster (M =1527 ms) than in the high perceptual load condition (M =1526 ms), $F(1, 15) = 0.002$, MSE = 8989.145, p <0.965, $\eta^2 <$ .001.

Neither of the valence main effects or interactions were significant either for the memory accuracies or memory reaction times (although as can be seen in **Figure 6-2**, there was a slight memory accuracy advantage for negative valence, untrustworthy faces (M = 74 %, M = 65 %, M = 65 %, respectively for the untrustworthy, neutral and trustworthy valence conditions), which just missed significance, $F(2, 30) = 3.26$, MSE =.025, p =.052, $\eta^2 = .179$.

Overall performance on the memory task of approximately 70 % correct, allied with the absence of a difference in reaction times between the load conditions for the memory response, indicates that the task was, as intended, a satisfactory task to ensure that participants were indeed paying attention to the face stimuli (see **Table 6-1**).

	Perceptual load		
	Low	High	Differential Effect of load
Search Accuracy (%)	95(4)	81(8)	13*
Reaction Time (ms)	848(193)	1108 (177)	259*
Memory Face Accuracy (%)	69(13)	68(12)	1 NS
Memory Reaction Time (ms)	1528 (260)	1526 (230.09)	2 NS

SDs are listed in parenthesis. * = significant NS = not significant

Table 6-1 Mean percentage search accuracy rates, mean reaction time (ms) rates and mean face accuracy rates in the fMRI memory trustworthy task as a function of load in Experiment 12

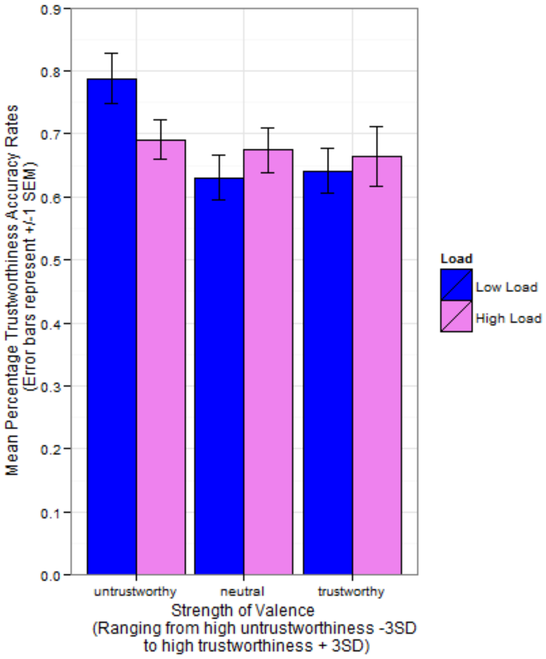


Figure 6-2 Trustworthy mean percentage face accuracy rates for participants (valence ranges from high untrustworthy -3SD on the left, neutral valence, to high trustworthy +3SD on the right)

6.1.3.2 Functional imaging results

Activated voxels meeting the FWE (family wise error) criteria were found in participants for the (positive) interaction (see **Table 6-2** and **Figure 6-3**) in a diverse array of areas associated with social processing (although no main effects of valence or load were observed individually). An interaction is observed when the model needs to take into account not just load, but also valence (that is the level of trustworthiness; trustworthy, neutral or untrustworthy), meaning the efficacy of the load (low, high) and valence factors (trustworthiness, neutral, untrustworthiness) changes in the presence of the others. Areas showing a significant positive interaction (as observed here) between variables are more active, as measured by the fMRI signal change, when valence or trust and perceptual load conditions occur simultaneously than would be predicted by the simple addition of the responses to both stimuli alone. Specifically, the positive interaction refers to the pure signal difference of the trustworthiness facial response signal as compared to a neutral face (low load trustworthiness – low load neutral) showing greater activity under low load than that of high load (high load trustworthiness – high load neutral). This is in accordance with the expectation that activity is reduced under high load compared to low load, although noteworthy that these effects do not extend to untrustworthy faces and thus here, perceptual load affects the trustworthiness component of faces (or positive valence faces) only.

The table presented below highlights the significantly activated voxels ($p < 0.05$, based on the FWE (family wise error) cluster method for multiple testing under dependent tests).

Contrast	*Region*	*L/R*	*FWE- P*	*Size*	*MNI*			*T*
					x	y	z	
Positive Interaction	**Pre-central Gyrus**	**L**	**<0.001**	**1077**	**-27**	**-19**	**67**	**4.41**
	Post Central Gyrus	**L**			**-36**	**-34**	**52**	**4.13**
	Middle Cingulate Cortex	**R**			**9**	**14**	**31**	**4.10**
	Cuneus	**R**	**0.028**	**94**	**12**	**-82**	**40**	**4 52**
	Middle Occipital Gyrus	**R**			**33**	**-76**	**34**	**3.56**
	Lingual Gyrus	**R**	**0.011**	**121**	**21**	**-52**	**-5**	**4 50**
	Lingual Gyrus	**R**			**21**	**-64**	**-2**	**4.04**
	Lingual Gyrus	**R**			**12**	**-64**	**-2**	**3.63**
	Superior temporal Gyrus	**L**	**0.004**	**153**	**-54**	**-1**	**-5**	**4.40**
	Superior Temporal Gyrus(near insula)				**-45**	**-16**	**-2**	**4.36**
	near insula				**-36**	**-19**	**-8**	**3.82**
	Middle Occipital Gyrus	**L**	**0.046**	**81**	**-27**	**-70**	**25**	**4.15**
	Cuneus	**L**			**-12**	**-79**	**34**	**3.83**
	Thalamus	**L**	**0.035**	**88**	**-3**	**-22**	**7**	**3.91**
	Thalamus	**L**			**-3**	**-10**	**13**	**3.74**
	Parahippocampal Gyrus NS	**L**	**0.067**	**72**	**-18**	**-37**	**-5**	**4.02**
	Parahippocampal Gyrus NS	**L**			**-21**	**-31**	**-14**	**3.49**

Table 6-2 MNI coordinates for the local maxima of significant clusters

MNI coordinates for the local maxima of significant clusters (FWE $p \leq 05$ at cluster level), composed of more than two contiguous significant voxels - for the cluster level: the chance (p) of finding a cluster with this or a greater size takes into account both the peak height and the spatial extent of the cluster when assessing the significance - as opposed to the voxel level which assess using height only). Size=number of contiguous significant voxels (2 x 2 x 2 mm). L=left; R=right; N/S=not significant.

The results of this contrast indicate activity in multiple regions associated with emotion, attention and visual and facial processing, all showing an interaction with perceptual load. For example, the Cuneus is known for its involvement in basic visual processing, however (pre) Cuneus activation has also been reported in previous imaging studies on ‘‘theory of mind’’ (e.g. (Farrow et al., 2001)) and particularly relevant here, facial expression processing (Kilts, Egan, Gideon, Ely, & Hoffman, 2003). The Cingulate Cortex is involved in attentional and cognitive functions (Torta & Cauda, 2011), and is often included in a salience network that facilitates the detection of important and relevant stimuli (Seeley et al., 2007).

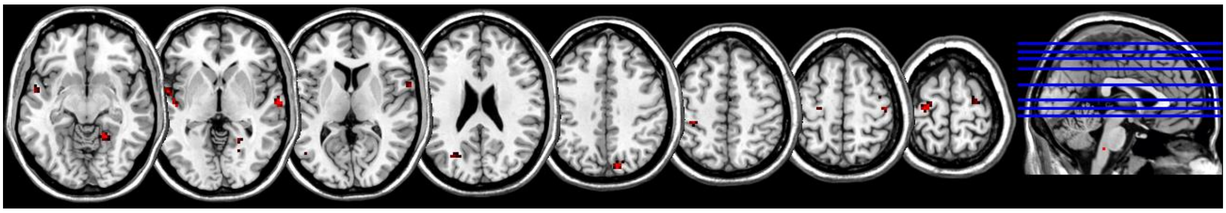


Figure 6-3 Axial slices with group significant (FWE corrected) clusters depicting the positive-interaction of trustworthiness and load categories for whole-brain volume analysis ((low load trustworthiness – low load neutral) showing greater activity than (high load trustworthiness – high load neutral)); for a more detailed description of activated brain regions, please see Table 6-2).

The Thalamus has multiple functions, inputs from the retina are sent to the lateral geniculate nucleus of the thalamus, which in turn projects to the primary visual cortex, although it is also involved in emotion an attention (Zikopoulos & Barbas, 2012). Activation in the Temporal Gyrus is also insightful. Temporal lobe regions might modulate the activity of the prefrontal cortex through extensive reciprocal connections, during facial emotion processing (Adolphs & Spezio, 2006); consequently changes in activation in this region may suggest the effects of perceptual load. Additionally the nearby Insula is thought to be involved in decoding facial emotion expressions as is also the Superior Temporal Gyrus which has been involved in the perception of emotions in facial stimuli (Radua et al., 2010).

Given the background literature and the predominance of the consistently activated amygdala within it (in contrast to other regions) and our a-priori hypotheses regarding this locality, a region of interest (ROI) based analysis of these nuclei was performed to obtain more sensitive measures of activation in these regions between load and valence (trustworthiness). Amygdala ROIs were delineated by the Marsbar atlas amygdala mask (from the anatomical automatic labelling atlas).
The region of interest analysis (Gorno-Tempini & Price, 2001), and is deemed to perform a crucial role in processing both facial emotional expressions (Gobbini et al., 2007) of the amygdala principally replicated the same pattern of response as the whole brain analysis above, with no individual main effects of load or valence present and a positive interaction (indicated by an overall interaction as well), see **Figure 6-4** and **Table 6-3** below.

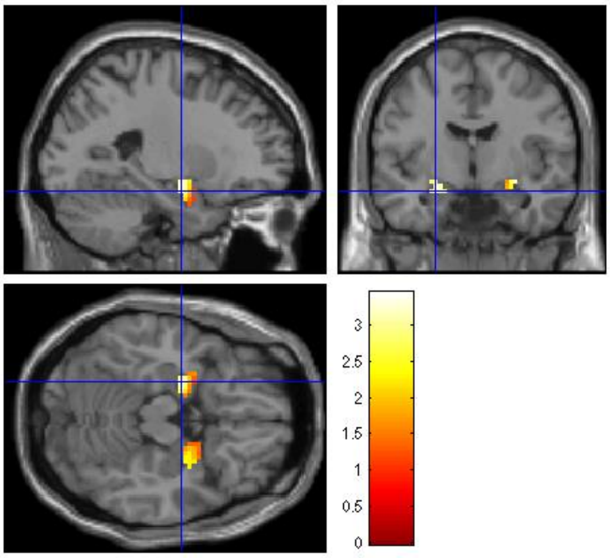


Figure 6-4 Significant positive interaction in the amygdala

Contrast name	*Region*	*L/R*	*Contrast value*	*t statistic*	*Uncorrected P*	*Corrected P*
Positive Interaction: Load x social judgment	**Amygdala**	**L**	**0.85**	**2.05**	**0.021707***	**0.042943***
		R	**0.74**	**1.99**	**0.024607***	**0.048608***
Interaction: Load x social judgment		**L**	**10.34**	**4.55**	**0.013138***	**0.026104***
		R	**4.65**	**2.54**	**0.084435**	**0.161740**
Positive linear contrast		**L**	**0.71**	**1.77**	**0.040188***	**0.078761**
		R	**0.53**	**1.48**	**0.071138**	**0.137215**

*= significant

Table 6-3 Significant contrasts in the Amygdala

Of particular interest, following from the Chapter introduction and the in-depth discussion of the role of the amygdala in Chapter 1 was whether there was an evident linear, or indeed a quadratic contrast. While there was no evidence of the latter, encouragingly, as hypothesized, we found evidence of a linear contrast; it is termed positive here as we have entered our regressors in the order of trustworthy, neutral untrustworthy. This pattern however co-aligns with the negative linear trend found in other studies, where amygdala activation tracks the valence position of the facial groups with respect to each other linearly (as the distance between measurements are equal), i.e. the amygdala becomes incrementally more responsive successively to trustworthy, neutral and untrustworthy faces.

On top of the amygdala and whole brain analyses, a number of specific brain regions involved in processing emotional and facial salient information were also investigated with exploratory random effects analyses to examine whether comparable interaction effects as found in the both the amygdala (see **Table 6-3**) and the cortical areas involved in social processing (see **Table 6-2**) were also evident.

Neuroimaging studies have pinpointed a set of brain areas responding more to faces than to other object categories in the visual extrastriate cortex of humans. This network includes the middle lateral fusiform gyrus (the fusiform face area, or FFA) as well as the inferior occipital gyrus (occipital face area, OFA). The FFA and spatially adjacent OFA have been shown to perform face computations that functionally differentiate it from other face-selective cortical regions (Pitcher, Walsh, & Duchaine, 2011; Kanwisher et al., 1997). In addition, given that our task is not only about face processing but also about its attentional modulation and given the key roles that the orbitofrontal cortex (OFC) and anterior cingulate cortex (ACC) have in processing emotion, affective value and attention meant we also sought to compare activity in these areas to trustworthy faces under perceptual load modulation. The ACC is implicated in error detection, attention and modulation of emotional responses (Bush, Luu, & Posner, 2000; Botvinick, Cohen, & Carter, 2004) while the OCC is involved in regulating the emotion attention interaction (Hartikainen, Ogawa, & Knight, 2012) and in representing the reward or affective value of primary reinforcers such as face expressions (Rolls & Grabenhorst, 2008).

Once again we conducted an ROI analysis (mitigating the multiple comparisons problem to smaller, more tractable areas and thus reducing overly stringent multiple comparisons correction thresholds), focusing explicitly on the face processing (FFA, OFA) and attentional and affective value (ACC, OFC) areas discussed above (delineated by the anatomical automatic labelling atlas). The GLM model previously employed was applied to these regions to determine more precisely how neural responses are also modulated within them as a function of face trustworthiness and load (see **Table 6-4** below).

Contrast name	*Region*	*L/R*	*Contrast value*	*t statistic*	*Uncorrected P*	*Corrected P*
Positive Interaction: Load x social judgment	**Anterior cingulate cortex**	**L**	**1.35**	**1.80**	**0.037514***	**0.073621**
		R	**1.55**	**2.35**	**0.010398***	**0.020687***
	Medial orbitofrontal cortex	**L**	**2.14**	**1.94**	**0.027587***	**0.054412**
		R	**1.43**	**1.81**	**0.036767***	**0.072183**
	Frontal Orbital Cortex (Inf Orb)	**L**	**1.07**	**1.61**	**0.055589**	**0.108087**
		R	**1.43**	**2.01**	**0.023517***	**0.046482***
	Middle fronto-orbital gyrus (Sup Orb)	**L**	**1.44**	**2.30**	**0.011762***	**0.023386***
		R	**1.22**	**1.24**	**0.108446**	**0.205131**
	Fusiform gyrus	**L**	**1.47**	**3.05**	**0.001488***	**0.002974***

	(fusiform face area, FFA)	R	1.47	3.39	0.000528*	0.001056*
	Inferior occipital gyrus(occipital face area, OFA)	L	1.26	1.53	0.064793	0.125388
		R	1.27	1.34	0.091285	0.174237
Interaction: Load x social judgment	Anterior cingulate cortex	L	11.41	1.68	0.192701	0.348268
		R	14.70	2.81	0.065445	0.126607
	Middle fronto-orbital gyrus (Sup Orb)	L	11.77	2.97	0.056192	0.109227
		R	7.57	0.77	0.464237	0.712958
	Fusiform gyrus (fusiform face area, FFA)	L	17.34	4.67	0.011774*	0.023409*
		R	19.36	6.42	0.002466*	0.004925*
Positive linear contrast	Anterior cingulate cortex	L	0.89	1.36	0.088113	0.168462
		R	0.88	1.53	0.064512	0.124862

*= significant

Table 6-4 Exploratory random-effects analyses tested for effects of trustworthiness and perceptual load within masks of decision making areas (OCC and ACC) and facial processing areas (OFA and FFA)

The sensitivity provided by the exploratory ROI analyses, confirmed the significant positive interaction found in both the cortical areas highlighted by the whole brain analysis and the amygdala (in the subsequent ROI analysis), in the specifically facial and attentional areas selected for exploratory examination. That is, the same response pattern of the pure signal difference of facial trustworthiness (low load trustworthiness – low load neutral) showing greater activity under low load than that of high load (high load trustworthiness – high load neutral) was evident. This effect was robust in both orbital frontal areas (the right fontal orbital cortex and the left middle fronto-orbital gyrus (superior orbital cortex)), the right ACC (an area anterior to the mid-cingulate cortex activated in the while brain analysis above) and in part of the face network, bilateral fusiform gyri (with the left OFA reaching near significance).

Once again, as with the amygdala ROI, none of the other main effects were significant, although there was a significant overall interaction in the fusiform gyrus, driven by the strong positive interaction (as described in the last paragraph), which also resulted in near significance in orbital frontal cortex areas (specifically the left middle fronto-orbital gyrus) and the right ACC.

Finally the ACC also tracked the affective valence of the facial images, as the amygdala did, with a significant linear contrast indicating that the ACC activation increased linearly with a decrease in facial trustworthiness.

6.1.4 Discussion

The findings in this Chapter demonstrate how the neural responsive to a face's trustworthiness characteristics interact with attentional (perceptual) load modulation, suggesting that emotional and trait perception are not immune to the effects of attention. Multiple areas involved in social processing evidenced greater activation to the pure signal difference of the trustworthiness facial image signal, as compared to a neutral face (low load trustworthiness – low load neutral) under low load than that of high load (high load trustworthiness – high load neutral).This robust positive interaction response was also evident in face processing, affective value and attention areas such as the FFA, OFC and ACC (determined by follow–up region of interest analyses (ROI)). Moreover, although the amygdala was automatically responsive to a face's trustworthiness features (insofar as the task demands were not directed to trustworthiness evaluations) and evidenced a negative linear response as seen in the prior literature, its response activity nonetheless also interacted with perceptual load demands (with the same positive interaction (and overall interaction) observed in the amygdala).

These findings point towards a resolution of the face processing and perceptual load debate that I raised in the initial Chapter. This is a debate, which in different forms appears extensively in the attention and emotional literature and as a consequence in the wider social judgment field. Our findings support the idea that any automaticity of emotional and trait face processing can be disrupted by attentional modulation and thus that perceptual load can modulate face perception. However, the nature and extent of this disruption may be conditional on the type and valence properties of the facial signals attention acts upon. Consequently, faces and valenced (emotional faces) are not a unique stimulus class immune to attentional constraints.

The amygdala hub

The finding that the orbital frontal areas and indeed the ACC and FFA were activated in response to affective facial valence stimuli is not by itself particularly surprising (Rolls et al., 2008; Bush et al., 2000; Kanwisher et al., 2006), or the activation in the multiple (social brain) areas in the whole brain analysis. What is however interesting is their interaction with the valance, or the trustworthy components of the facial images under perceptual load. These results suggest that there may be a stronger internal bias for negative valance (untrustworthy) faces than their positive counterparts, such that attentional demands can more readily interfere with the facial processing computations of positive valence faces.

Also noteworthy is that the ACC tracked the valence of the facial images (as evidence by the linear contrast), this could be because the resolution of emotional or valence conflict is associated with activation of the anterior cingulate cortex (Etkin, Egner, Peraza, Kandel, & Hirsch, 2006), but is also consistent with this idea that the (ventral) ACC (and mPFC) are engaged when subjects perform affect labelling of emotional faces (Lieberman et al., 2007), such that subjects here monitored the valences of faces during the task.

Undoubtedly the circuitry of facial valence appraisal is complex, drawing on multiple regions and involving attentional and valence appraisal areas (notwithstanding the face coding regions). Nevertheless, there has been a steady accumulation of convergent neuroimaging and behavioural data, reviewed in this thesis, which implicates specific brain systems concerned with facial, trait and emotional processing and their interaction with processes such as attention. We have once again demonstrated the amygdala as an important hub in these systems. Our results suggest that not only does it monitor the valence of facial stimuli, but as it also readily project to several other areas, sending feedback to sensory pathways (Pourtois, Schettino, & Vuilleumier, 2013), is intertwined with attention.

The amygdala has been shown to code trustworthiness faces in an attention-independent manner when faces are clearly visible (Engell et al., 2007; Todorov et al., 2011). However, how the amygdala evaluates complex social information under constricted processing is uncertain. It is also quite possible that both cortically and subcortically driven routes to the amygdala could be involved in processing trustworthiness and their nodulation by attention, exposures to facial degrees of trustworthiness is sufficient to modulate amygdala responses, however attentional resources are also implicated. For example, we would expect ventral-stream face processing pathways to be implicated in the amygdala responsivity under attention as face- processing areas (e.g., fusiform cortex) are by modulated by the trustworthiness - attention interaction (although not individually). In the present experiment, the fusiform cortex was not independently modulated by trustworthiness (consistent with some previous studies which observed robust amygdala effects of trustworthiness without significant fusiform effects (Engell et al., 2007)), but only with attention, suggesting attentional influences on ventral pathways (although is possible also that our methodological approach was simply not sensitive enough to detect independent trustworthiness effects in the facial processing areas).

Past research, and as a consequence this thesis, has focused disproportionality on the amygdala (and less on its connections). Be that as it may, the overall system for rapidly and efficiently selecting facial salient information, interwoven with attentional systems, is likely to form a more extended functional network with other brain regions, such as several prefrontal areas in orbitofrontal (OFC) and anterior cingulate cortex (ACC). These regions are usually activated during rapid processing and response to emotionally relevant stimuli in the environment (e.g. (Mobbs et al., 2009)). Future research will seek to disentangle these components and will seek to elucidate the specific pathways that underlie the amygdala's tracking of trustworthiness under attentional constraints.

In summary, we have demonstrated not only that the amygdala hub, most likely a crucial part in an extended functional network evaluating valence signals, is sensitive to variations in facial trustworthiness, supporting one of our primary hypothesis, but also provided evidence that suggests that attention can influence how high level facial information such as trustworthiness is coded.

Negative valence face advantage

Our results indicate that only positive valence faces (relative to neutral faces) are modulated by perceptual demands, echoing the results of the prior Chapters (Experiments 1, 4 and 10) where trustworthy faces as opposed to untrustworthy faces are impacted by perceptual load and suggesting a possible neural underpinning of this feature, particularly as the amygdala has stronger activation (as evidenced by the negative linear profile) for untrustworthy faces.

As I have said elsewhere in this thesis, there is evidence that negative valence faces may have some detection advantage (e.g. (Eastwood et al., 2001), negative affect superiority has been found using a range of paradigms ranging from cueing (Georgiou et al., 2005), flanker (Fenske et al., 2003) to shapes (Vuilleumier et al., 2001b). Such a detection advantage coheres with the linear profile of trustworthiness here (activation increases linearly with a decrease in facial trustworthiness) and seems emblematic of affective processing – and thus the resulting load effects here. However the interaction with attentional load also needs to be considered.

At a first glance, it seems most of the empirical evidence investigating amygdala function and indeed the interrelationship between attention and face processing seem to disproportionality focus on negative or threat-related stimuli (Vuilleumier, 2005; Compton, 2003). However, we have shown that the amygdala and associated regions interact with attention, an interaction with the relative positive valence signal of trustworthiness. Whether this is due to the possibility that positive emotions and positive valence may produce distinctive effects of attention (e.g. broadening and shifting as proposed by Fredrickson (Fredrickson, 2004)) or as suggested earlier have less facilitation in neural processing as an adaptive consequence is unknown. However, modulating different facial judgments and facial valences may help to determine the specific role valence plays in modulating attention and in face processing.

Neither the negative valence faces (untrustworthy), nor the relative signal component of untrustworthiness (as compared to neutral faces) were impacted by higher perceptual load modulation in Experiment 12. This result initially appears to cohere with a well-known study (Vuilleumier et al., 2001b), where differential responses to negative valence faces (fearful) in the (and visual cortex) were not modulated by the focus of attention, consistent with the view that the processing of emotional (negative valence) items do not require attention. However, we also found that the amygdala is responsive to the relative facial signal component of trustworthiness as compared to neutral faces. This is consistent with another well-known study (Pessoa et al., 2002), where differential activation was observed for both negative (fearful) and positive (happy) faces. Thus, in this context, a critical variable in understanding the extent of unattended processing is the attentional load of a task – namely, the extent to which it uses up resources and this resolution has been at the forefront throughout this thesis, however given our results only affect the (relative) valence (positive) component of trustworthy faces we propose that valence will also determine responsivity. Needless to say, this assertion also relates to the automaticity debate of facial processing.

Although facial information may be able to be extracted rapidly, effortlessly and unintentionally, facial information is not a unique stimulus class immune to attention constraints. Attentional load interacts with face processing of valenced (emotional faces) and the nature of the valence will regulate its effects. The present results raise a conundrum (notwithstanding task differences between studies) as to why the relative component of facial signals are affected by load as opposed to the absolute values as seen in the study of Pessoa et al. (2002) for example, where differential activation was observed for both negative (fearful) and positive (happy) faces. Given trustworthiness' high correlation with other emotional and trait evaluations it is unlikely to be a corollary of the intrinsic image properties of trustworthiness but could rather indicated how attentional constrictions interact with a range of valence saliences such that relative negative valences are less constricted by attentional resources than positive ones. To test this supposition future research should look at a range of negative valence (e.g. trustworthy faces) to determine whether the same relative pattern is observed as here, or rather that neural responsivity to load is observed in all negative valence face.

A possible explanatory framework for the negative valence face advantage was introduced in Chapter 3 (where a variant of the task in Experiment 12 performed), mentioning evolutionary reasons, that is the assertion that a negatively valenced signal is more important than a positively valenced one for survival of the organism (e.g.(Eastwood, Smilek, & Merikle, 2003)). At a neural level, high load affects only trustworthiness as compared to neutral faces but not untrustworthiness faces, this is plausible within an evolutionary framework, as negative signals may be more important and arguably should be more invariant to attentional constraints (or conversely more salient for subsequent processing such as threat evaluations). Just as the detection of threat-relevant stimuli by the amygdala is an adaptive trait with a current functional role (Öhman, Flykt, & Esteves, 2001), this might also be the case for its evaluation of a face's trustworthiness, particularly of faces which may signal negative potentially harmful evaluations. Facial trustworthiness could be used as a proxy in the evaluations of conspecifics likelihood to harm or help, a critical variable in group membership, particularly from an adaptionist perspective (McDonald, Navarrete, & Van Vugt, 2012). Negative valence facial signals such as untrustworthy faces may thus be extracted more rapidly, effortlessly (appearing as if more automatically processed) than positive ones. Although such a putative facilitation in coding may not necessarily extended to an advantage in explicit behavioural judgments of negative valence appraisals (for example in some of the behavioural experiments in this thesis, overall judgment accuracies for low valence faces (e.g. low threat) were higher than for high negative valence counterparts). A behavioural versus neural amygdala discrepancy may be due to the fact that behaviour is the final single output of diverse neural processes that may not always converge. For example, internal biases, context, or more cognitive-type appraisals may modulate initial more automatic-appearing estimations.

Although the findings here suggest that untrustworthy faces (correlated with threat) may depend less on available processing resources for their perception, the nature of this relationship and its relation with valence may nonetheless be complex. For example (again moving beyond the results of this chapter), in the behavioural experiments of Chapters 3 and 4, high threat facial judgment accuracies, were impacted by load, suggesting that overt classifications and subjective judgments of valences may be susceptible to biases and other modulating factors after their preliminary visual assessment. This could be confirmed or disconfirmed by examining how implicit activation to composite threat images (comprised of the trustworthy and dominance dimensions) neurally interacts with attention, to determine if behavioural load effects for threat are divergent with neural effects. Another possibility is that although threat ratings are correlated with untrustworthy faces, they have different valence components, impacting their processing under perceptual load (for example low threat may be quite different from high trustworthiness. Future research will need to clarify the similarities and distinctions between judgments of threat and trustworthiness (and indeed dominance) facial signals.

Ultimately, to fully understand how valence and face processing interact, will require a better specification of each of their components and their connections with other brain mechanisms associated with modulatory capacities such as attention. In doing so, researchers may need to go beyond the traditional notions of a single attention system or indeed dichotomous categories (e.g. controlled vs. automatic), redefining the corresponding psychological constructs, such as trustworthy judgments (and associated behavioural phenomena) in terms of their underlying neural processes (Pourtois et al., 2013).

Conclusions, valence and facial cues

This work indicates promising directions to explore the relationship between (facial) social judgment and attention, not least among them pursuing an equivalent study as we have done with trustworthiness here, but employing other social and emotional judgments such as dominance and threat. Exploring the neural signature of an expanded range of social images could help clarify the behavioural results of Chapters 3 and 4 and help elucidate how facial valence properties can interact with attentional task load demands. If facial valence is an important factor in determining modulation by load, it is possible that different faces spaces or facial image collections which differ in the valence of their facial stimuli may engender different conclusions of automaticity in facial processing based on how this essential variable is distributed within them.

Although trustworthiness is a social trait judgment and this study is the first looking at how attention and trustworthiness processing interact, we would nevertheless expect these results on rapid and implicit social judgment of trust to generalize to a wide variety of social and emotional evaluations, due to the fact that trait inferences from faces are highly correlated with each other (Oosterhof et al., 2008) and interrelate with emotional expressions such as anger and joy (Oosterhof et al., 2009). However, it is not just the range of judgments that we should explore, but also our notions of the valence associated with them. For example, specific facial content generally associated with “positive” (e.g., sexual) and “negative” (e.g., disgusting) may cause specific attentional patterns that may not be attributable to valence and arousal (Feng, Wang, Wang, Gu, & Luo, 2012) (arousal (ranging from calming to arousing) is a theoretical orthogonal affective dimension, contrasted to valence and commonly considered to explain the principal variance of emotional meaning (e.g. (Lang, Greenwald, Bradley, & Hamm, 1993)).

We have only briefly commented on where in the facial processing stream the modulatory effect of perceptual load may occur on trustworthiness judgments. However, given that valence properties may be distributed in diverse ways among both differing facial judgments and differing facial stimuli may mean that depending on the aforementioned, attention could interfere with an ongoing task at very different levels of cognitive involvement (Carretié, 2014). A more precise specification of valence may help. It is currently unknown whether valence attributes can be decomposed into particular image frequencies either higher (parvocellular) or lower more course ones (magnocellular), although the question of what type of information and which anatomical pathways trigger or inhibit attentional facilitation is critical for understanding facial processing and attentional influences upon it. For example, coarse visual inputs (conveyed by the magnocellular system) might induce greater amygdala responses as opposed to higher (parvocellular) frequencies (Kveraga, Ghuman, & Bar, 2007) and this coarse low spatial facial information may be less susceptible to manipulations of attention and awareness (De Gardelle & Kouider, 2010).

Presumably there is some image component of the trustworthy faces, e.g. speculatively the indicative features of facial stimuli such as large baby faced features associated with higher trustworthiness could possess distinctive spatial frequency information which interacts with attention yielding an explanation for the relative preferential influence of perceptual load upon them. Future research embracing more complex models connecting the interrelationships between valence, emotion and trait judgments to image properties are needed to characterize the precise neural pathways involved in trustworthy and other facial social judgments to establish their facility and limitations to attentional modulation.

A different approach to clarify why trustworthy judgments compared to neutral are preferentially impacted by load is to seek to reveal any principle cues used in such evaluations, such as in the case of fearful expressions where enlarged eye whites (Whalen et al., 2004) may drive amygdala activation. Potentially, parametrically modulating attention could provide a more fine-grained account of how particular brain regions respond to attentional constraints. In our analysis exploring social facial judgments (where attention is sustained but the perceptual capacity is modulated) and throughout this thesis we have used a simple modulation of attention into low and high capacity. However changes in attention or load may not impinge on social trait processing in a dichotomous mode, meaning that different brain areas implicated in social valence and trait processing may respond or indeed code differentially valence when modulated parametrically with attention. This proposition is suggested by our results, where there appear to be asymmetries in positive and negative valence evaluations, such that untrustworthy faces would require a greater amount of attentional load than their trustworthy counterparts to modulate their neural responses. Although the features associated with facial trustworthiness judgments are multifaceted (Oosterhof et al., 2008), identifying the cues and magnitudes of perceptual load effects required to impact their processing could aid in a greater understanding of how facial judgments such as trustworthiness are structured (Said et al., 2011).

There are of course some noticeable caveats to the generalizability of our findings. For example, the faces are ultimately computer generated, male and Caucasian (a necessary first step for experimental control), this is notwithstanding the possibility that there may be cross-cultural differences in these trustworthy assessments (although Chinese and Caucasian participants seem to use similar facial cues to judge trustworthiness (Xu et al., 2012)). Future research will need to ascertain if the results here would have been comparable with different ethnicities and/or female images, or indeed even with different eye colours, which can effect trustworthy judgments (Kleisner, Priplatova, Frost, & Flegr, 2013). In spite of these stipulations, the findings in this Chapter have clear application in situations in rapid social and facial judgment which may be subject to attentional constraints, circumstances for example within which eyewitness testimony often arises in. Attentional limits may come to the fore in a crime scene situation, an eyewitness may be overloaded with information and may not process events and faces accurately, impacting the veracity of any subsequent eyewitness testimony and eyewitness identification.

To conclude, the neuroimaging results presented here add and build upon the prior work in this thesis. Taken together with the results of the behavioural experiments (Chapters 3-5) and the background literature and methodologies of Chapters 2-3, imply that the discrepancy between studies suggesting that emotional and trait perception is automatic and those illustrating their dependence on attention can partially be accounted for by the concept of (perceptual) attentional load. However, focusing solely on perceptual load as a determining variable, omits an important component in the facial-attentional processing association, namely that the effects of load can also interact with the valence of facial stimuli.

Our ability to perceive evolutionary important social stimuli such as trustworthy or approachable faces is limited by our bounded representational capacity, although our findings here suggest that within this representational capacity, there may be asymmetries in their processing.

Overall the proposition of the importance of valence adds a distinction to the debate in the literature. The findings here sustain the view that faces are not a special class of stimuli, vis-à-vis that processing takes place in an automatic fashion independently of top-down factors such as attention. Moreover, although not unexpected, these findings demonstrate that attentional load also modulates trait judgment characteristics such as trustworthiness, as opposed to only emotional ones. Finally, the neural effects of perceptual load can now be extended to another stimuli class and strengthen the claim of the presence of perceptual load effects in facial social judgment.

7 *Conclusion*

"One of the tantalizing questions which has confronted everyone from philosophers to politicians is the extent to which human beings can 'grasp things as they really are'; yet in many ways this is an absurd question that could only arise in a mono-dimensional reality which subscribed to the concept of there being only one way in which 'things' can be. Even if there is only one way, it is unlikely that as human beings we would be able to grasp that 'pure' 'objective' form, for all we have available is symbols which have their own inherent limitations, and these symbols and representations are already circumscribed by the limitations of our own language. Language is NOT neutral. It is NOT merely a vehicle that carries an idea. It is itself a shaper of ideas, a programme of mental activity. Humans themselves have created or constructed that world and they have reflected themselves within it." Dale Spender. Man-made Language, 1980

"Scepticism is the chastity of the intellect, and it is shameful to surrender it too soon or to the first comer: there is nobility in preserving it coolly and proudly through a long youth, until at last, in the ripeness of instinct and discretion, it can be safely exchanged for fidelity and happiness." George Santayana, Scepticism and Animal Faith

Even if you fall on your face, you're still moving forward. Victor Kiam

Overview

This chapter begins with a brief discussion of this thesis' findings (7.1) and their relation to facial social judgment and attention research, focusing on how specific facial cues (7.2) and exogenous top-down information can also factor into attentional performance (7.3). Following on from this, there is a brief look at alternative computational and Bayesian approaches to attention in contrast to the Broadbentian bottle neck approach that has characterized this thesis (7.4). This section's discussion centres on alternate models of selective attention paradigms and questions whether the long-held explanation of limited capacity, while useful as a first approximation, may be a stepping stone into a broader reformulation of selective attention. Such a reformulation would require more complex generative and computational perceptual models to see its fruition. Nevertheless, the limitations in task perception and cognition, however labelled to date, have engendered notions of selective attention and have been productive and valuable in associating neuronal mechanisms with behavioural consequences.

Gaps in knowledge and potentially fruitful areas for future research are pointed out in (7.5), asking if more potent signals, whether multimodal, by increased exposure time, repetition or the higher temporal resolution of event-related brain potentials (ERP) studies can clarify facial judgment processing. The Chapter concludes with a summary (7.6), affirming the role of perceptual load in visual facial processing and the role of facial valence as a key component in how the effects of perceptual load are implemented.

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7.1 Overview of findings

The research described in this thesis has presented modest but convergent evidence for the role of top-down control in influencing visual facial awareness in subjective social judgment, contributing to the understanding of perceptual load theory and the role of facial processing within that domain. Additionally, it has augmented the evidence for the role of amygdala activation in trustworthy valence judgments. This thesis sought to identify the role of attention as a modulatory factor on visual facial processing, principally with regards to the automaticity and attention debate. At the outset, several theories were described and conflicting evidence was reviewed regarding the role of attention in modulating facial processing (section 1.2-1.4). This evidence concentrated principally on emotional stimuli, as to our knowledge, modulating social "trait" judgments such as trustworthiness by attention has not been attempted before. By analysing the moving parts and interrelationships among social judgment (such as trust) and attention, I have sought to explore how this crucial cognitive component influences the myriad levers and pulleys involved in our processing of the social gateway to the world, the face..

Chapter 3 suggested that attention, specifically perceptual load, affects subjective judgments, although crucially the valence and type of traits/social judgments were important for the effects. This formed a compelling body of evidence that argues against the existence of i) hardwired or ii) an innate mechanism for trait/social facial judgment processing (as there existed variability in responses to facial stimuli, not only for their valence but for their type also (threat, dominance, trustworthiness) even though all images generated from the same face space). The foregoing evidence therefore supports the view that attention or at least perceptual capacity can mediate some forms of facial processing.

The aim of the experiments reported in Chapters 4 was to further explore these effects and any possible criticisms. In Chapter 4 I found that these perceptual load effects were not due to the need to allocate attention between dual tasks (Experiments 4-6), indicating that the results were indeed due to the influence of load rather than allocation strategy (e.g. a reduction in the priority of responding to the dual stimuli). Importantly, the effects of perceptual load were not due to working memory effects (Experiments 7-9). Moreover, sensitivity in a present/absent detection task was consistently reduced under high perceptual load (Experiment 10), and was even evident in both a clinical (Parkinson's disease) and older population (Experiment 11 in Chapter 5).

Consistent with the prediction of the perceptual load model, the experiments on the neural effects of load reported in Chapter 6, were replicated under conditions of implicit judgment, indicating the importance of valence in perceptual load capacity; specifically the immunity of untrustworthy faces to load here and in other Chapters. This immunity to load for social judgments, specifically trustworthiness judgments is supported by the results from Experiment 1, in an accuracy task and the results from Experiments 10, in a detection sensitivity context. Taken together, these results suggests a preliminary solution to the disparate results in the literature regarding the role of attention and facial social judgments, being contingent not only on attentional capacity but also on the valence of the facial stimuli.

More work is need however to isolate the effect of valence on facial processing, as the valence of facial expressions most likely interacts in complicated ways with certain facial judgments, such as threat and dominance. Segregating valence is somewhat possible in constructed faces spaces (as employed in this thesis), although this can be challenging in naturalistic stimuli, where a purported increase in valence for a trustworthy face may not necessarily be concomitant with that of a dominant one for example in real-life images. Nonetheless, despite these technical challenges, highlighting the specific role of valence in the attention and automaticity debate as this thesis has done offers a new avenue to explore how these twin forces interact in facial judgment processing.

Conjointly, the results from both the behavioural and neuroimaging approaches employed within this thesis suggest that while facial social judgment processing may be prioritized, in many contexts, judgments such as trustworthiness can be contingent on available processing (attentional) resources. Indeed, taken together with the (although conflicting) existing body of evidence reviewed in Chapter 1, where for example perceptual load modulates overall levels of activity in human visual cortex (Schwartz et al., 2005) and affects the spatial tuning of population receptive fields in early visual cortex (V1–V3) (de Haas et al., 2014), one would expect that perceptual load should modulate expression processing (if attentional capacity is sufficiently consumed. We affirm this expectation, although with the addition that the extent of this consumption may be a function of how the valence of the facial stimuli interacts with attention.

The experiments contained within this thesis support the role of top-down modulators in social facial judgment; specifically confirming the role of perceptual load in facial judgments and providing insight into the polemical attention and automaticity debate introduced in the first Chapter. The proposition is that the manifestation of automaticity in certain forms of facial processing will be subject to (amongst other factors) both attentional capacity and the valence of the facial stimulus.

In the following sections I describe several interesting directions, relevant issues and outstanding questions for future research that stem directly from the results presented in this thesis on how attention and face processing interact.

7.2 Relation to Facial Social Judgment Research

Social emotion and social judgment research has tended to concentrate on the signals in the face that elicit evaluations in conspecifics. Indeed, to some extent the facial stimuli employed in the experiments in this thesis rely on the presupposition that such signals are structurally present and can in fact be categorized into a dimensional face space. However, such stimuli and the associated dimensional models assume consensual uniformly perceived facial properties of specific characteristics (e.g. trustworthiness). As a first approximation this is of use, for example taking the social judgment characteristic that is normally taken to be the most invariant, namely attractiveness (see (Langlois et al., 2000) for a meta-analysis on the reliability of physical attractiveness judgments), contrary to the proverb that “beauty is in the eye of the beholder”, there is relatively high consensus among raters for this judgment. Approximately fifty percent of variance in attractiveness judgments can be attributed to consensus contributions with the reminder falling to personal contributions (Honekop, 2006). This consistency in impressions could be based on cues with adaptive significance such as similarity to emotional expressions (Montepare et al., 2003) or neotenous features (Zebrowitz & Montepare, 2005). Nevertheless, we should we should bear in mind that by definition, consensual uniformly perceived facial properties discount the uncommon features of face perception (e.g. self-resemblance); features which may have very different characteristics under attentional load.

Facial resemblance is a particularly interesting example of one of the many features that can influence the intricate estimation of facial judgments such as trustworthiness (perhaps because similarity is used as proxy cue for relatedness (kin semblance)) and thus may interact with perceptual load modulation in unexpected ways. As an illustration, by morphing images of faces to more or less resemble experimental participants, a variety of prosocial behaviours correlated with facial similarity can be demonstrated (Alvergne et al., 2009; DeBruine et al., 2008; DeBruine, 2005; DeBruine, 2002). Even in economic games, subjects perceive and evidence more prosocial behaviours with self-resembling partners (Krupp, DeBruine, & Barclay, 2008). In the political sphere (worryingly so) it seems that individuals are more likely to vote for political candidates who resemble them (Bailenson, Iyengar, Yee, & Collins, 2008).

The effectiveness of self-resemblance in influencing social judgments such as trustworthiness, raises the broader question of the key facial features in such evaluations and hence whether such critical cues engage attention preferentially. For instance, are there critical feature cues which effect the discriminability between trustworthy and dominance judgments, and are these essential in determining attentional engagement? For example, although the stimuli employed in this thesis for the trustworthy judgments varied on a number of parameters, this does not preclude the possibility that there may be certain critical facial features which are not amenable to perceptual load (see **Figure 7-1**). For instance, certain characteristics such as V shaped eyebrows, may have a particularly critical role in influencing visual search for emotional faces (contingent on being embedded in a face) (Öhman et al., 2001). While the visual saliency of specific facial features e.g. especially the smiling mouth (Schmidt et al., 2012) may be a critical factor which interacts with load in face processing.

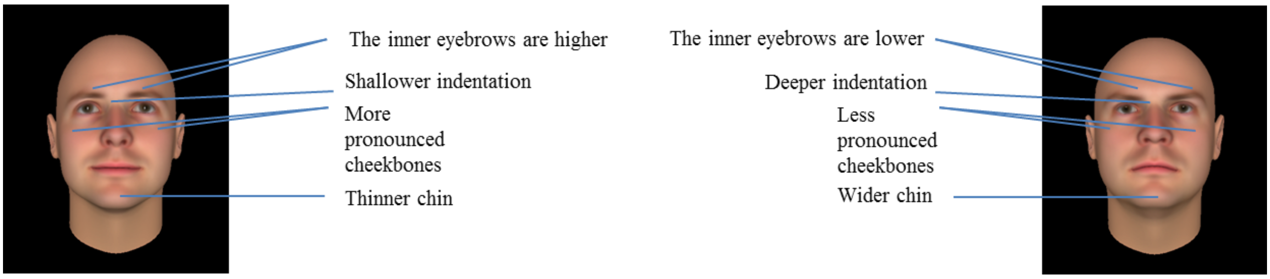

Figure 7-1 What are the key structural drivers for perceptual load effects in facial social judgment?

Most likely judgments such as trustworthiness are assembled from multiple cues with complex interactions not only with face processing, but how they interact with attention. For example, although earlier work emphasized the importance of emotional signals to attributions of trustworthiness (Oosterhof & Todorov 2008, Todorov 2008, Todorov et al. 2008), it is clear that many other cues are used to make this attribution. Trustworthy-looking faces not only look happier than untrustworthy-looking faces, but they are also more feminine and older. Succinctly, social judgments are constructed not only from cues with adaptive significance, such as masculinity/femininity, but also to resemblance to emotional expressions (Todorov, Olivola, Dotsch, & Mende-Siedlecki, 2015).

Exploring the modulatory effects of individual state-trait characteristics such as anxiety (briefly mentioned in the introduction in Chapter 1) may also reveal some of the causal interplay between top-down and bottom-up processing features in social facial judgments (Davis et al., 2011). However, to further explore the relation between earlier facial processing stages such as facial detection ability and expression recognition capacity may require subtle amendments to the methodologies adopted here. The experiments in this thesis have focused on facial trait discriminations (primarily trustworthiness ones). However, face detection, the process of finding a face in a visual scene, is an indispensable step in face processing and an instance of a stage in processing presupposed by discrimination. One could ask for example whether participant's subjective detection/judgment abilities correlated with detection tests such as the two-tone face detection task (where participants have to find a face in a visual array). Furthermore, since the focus in this thesis is the role of attention in facial processing, examining how individuals perform such judgments and whether perceptual load is efficacious on such stimuli could help provide evidence for the nature of (possibly separate) detection and recognition mechanisms in face processing (and indeed whether attention acts preferentially upon them).

In a similar vein to facial detection, tests such as the Cambridge Face Perception Test (CFPT) Test (Duchaine, Germine, & Nakayama, 2007) and the Cambridge Face Memory Test (CFMT) (Duchaine & Nakayama, 2006) can be modified and employed to explore the associations between the primary stages in face processing: detection, perception, memory and subjective judgments - and whether attention modulates these phases of processing. The CFPT can be used to explore at least two of the most important aspects of facial social processing, the ability to track identity and expression. While the CFMT (initially developed to detect prosopagnosia) is designed to evaluate face recognition or face memory (showing large and reliable differences in ability across the typical adult population (Bowles et al., 2009)). Determining how capacity limits (manipulated by perceptual load) interact with the stages of facial processing could help clarify the similarities and differences between emotional and trait processing and also create a more fine-grained model of how (and why) attention interacts with valenced facial features in the face processing pathway. This would help us to examine the reason why not only faces call attention more than other visual stimuli, but also help us clarify (again as suggested in thesis) whether certain types of trait judgments are treated differentially by attention e.g. dominance as opposed to threat.

Experimental data on these issues are not available yet, but these theoretical proposals highlight how perceptual load modulations can be extended to explore how facial judgments are sustained and modulated by attention (and potentially providing further possible indices of attentional capture by faces).

There is still much debate about the underlying mechanisms of how social judgments are computed within a single rapid glance of a face (150 ms in this thesis). The processing may rely on factors ranging from holistic information (Abbas & Duchaine, 2008) to feature information (Schyns, Petro, & Smith, 2009). However, by focusing on the salient facial features for attention in face and trait judgments (Calvo & Nummenmaa, 2008) and utilizing one of the core feature of automaticity, the independence of processing from influences that can affect attention, a feature which may be enjoyed by some facial cues more than others, we can seek to decipher the elaborate syntax of social facial trait processing.

7.3 Relation to Attention, Automaticity and Attentional Performance

In general, the discrepancy between studies suggesting that social judgments and emotional facial perception are automatic and those illustrating the dependence on attention may be partly accounted for by the concept of attentional load. To expose that social facial (emotional) perception is not immune to the effects of attention, processing resources need to be largely consumed, if not, performance will appear to be relatively automatic. The results from the previous Chapters concur with this view, however as delineated in the above section, this does not mean that that the story of attention and facial and social emotional processing is closed or complete. As I said above in the prior section, perhaps due to specific facial characteristics, there may be instances by which behavioural output concomitant with automaticity is still detected.

The studies in this thesis suggest that affective processing is, in certain circumstances, influenced by attention. However, our effects indicating the impact of attention were often modest or lacking in certain judgments such as dominance assessments. While I have focussed on the inherent image facial statistics as being causative of these effects, personality traits may also influence assessments such as dominance and threat. For example, anxious participants exhibit greater interference from threat-related stimuli (Stout, Shackman, & Larson, 2013; Mocaiber et al., 2009) and amygdala responses to threat-related distractors depends upon individual anxiety levels (Bishop et al., 2004). This is notwithstanding the multiple auxiliary endogenous factors that will also be involved in how attention interacts with facial evaluations (in spite of the experimenter’s best wishes). Factors ranging from motivation (Lu & Chang, 2012; Raymond & O'Brien, 2009) reward (Shomstein & Johnson, 2013) to expectations or decision making criteria (Jiang, Summerfield, & Egner, 2013; Summerfield & Egner, 2009).

A central question for future research is how robust briefly presented facial inferences are in general to interference (discounting attentional effects), not only from the affective state of the perceiver but also from supplemental top-down, exogenous information. As opposed to the traditional studies of load which have employed simple distractor stimuli (Lavie & Tsal, 1994; Lavie, 1995), top-down information can influence social facial evaluations. For example, personality information can affect the evaluation of physical appearance (Kniffin & Wilson, 2004) and desired personality traits influence judgments of facial attractiveness (Little, Burt, & Perrett, 2006), for instance simply learning whether someone is kind-hearted or not (Hassin et al., 2000).

Attention itself could even be construed as another informational factor, or more specifically another's attention, which could potentially influence facial inferences. Selective attention is typically considered an egocentric mechanism, biasing sensory information based on its behavioural relevance to the self only. However we can imagine scenarios where attention might be influenced by the group one is embedded in and the allocentric mechanisms that permit passive observers to selectively attend to information from the perspective of another person. For example, Frischen, and colleagues demonstrated that observing another person selectively reach for targets (among distractors that differ in their level of salience), steers the observer to inhibit the same distractors that are most salient from the observer's own perspective (Frischen, Loach, & Tipper, 2009). This implies that witnessing another's action leads the observer to simulate the same selective attention mechanisms such that they effectively perceive their surroundings from the other person's perspective.

Investigating the links between facial inferences and other modulators of facial processing outside of attention, be it trait characteristics such as anxiety proneness, external top-down information, or even joint-attention effects, will help to clarify the degree to which rapid social facial judgments are susceptible to modulation. Examining alternate modulators of facial processing will not only enrich the attention and automaticity debate, but more importantly may clarify the importance of certain structural features in facial processing. For example, is the putative attentional bias to untrustworthy faces (such that they were not impacted by perceptual load) and which we have attributed to an asymmetry in valence detection competencies, a property of particular trait judgments (such as trustworthiness), or can this asymmetry be generalised (contingent on how valence is distributed amongst them) to other types of facial judgments outside of the ones studied in this thesis? To rephrase, the question for future research, is to answer to what extent can valence information be construed like a Bayesian "prior" (a probabilistic belief) which can shifted by exogenous, supplementary information (be it the affective state of the perceiver, or ancillary facial information)?

The notions of Bayesian inference and their possible relationship to visual attention are further explored in the following section.

7.4 The Broadbentian Creed: Computational and Bayesian Alternatives

Selective attention is an actively studied domain of mental life never too far away from the important conceptual supposition of limited capacity, the allocation of which has generated continual debate regarding early and late selection. A persuasive and prominent resolution of this debate, as we are now familiar, is based on the notion of perceptual load (Lavie, 1995) which suggests that low-load, less demanding tasks, because they under-employ the total capacity of attention, result in the processing of stimuli that are extraneous to the current attentional set. In contrast, high-load, or more demanding tasks appropriate all spare capacity for themselves, reducing or indeed disregarding the processing of distractors. This is the theoretical model that I have employed to direct the research presented in this thesis and while appealing as a model of attentional attenuation, contrariwise this approach also arguably implies that perceptual load has the unfavourable characteristics of limited control in low load tasks, allied with high-level automatic attentional selection as to what can be attended in high-load ones.

The arguably less than optimal features of the perceptual load model provide some impetus to consider alternative models of attentional functioning. It is worth noting, moving further away from the underlying dynamics of perceptual load that the Broadbentian creed, formulated in the fifties that the function of attention is the management of cognitive limitations, although ultimately underlying the research in this thesis is not without criticism. One of the earliest critiques by Ulric Neisser and colleagues revealed that an appropriately trained subject can perform two attention involving tasks, concurrently, without much interference between them (Neisser, 1976). The interpretation of these experiments was that, insofar as there was a bottleneck, then attention is required to manage a bottleneck in behavioural coordination e.g. looking in two directions at one time, rather than in simple information processing capacity. This position is perhaps analogous to the view that constraints are placed on cognition by the need to maintain a "coherent" course of action (selection-for-action) (Allport, Antonis, & Reynolds, 1972). It is worth highlighting that coherence theories may be selective in ways that do not involve limitations at all, but rather the management of capacity excess (mechanisms of attention are required to provide selectivity and coherence simply because we can process and be distracted by multiple stimuli).

In the long run, we will require both better computational and more neurally plausible models of selective attention and perceptual load to progress in our understanding of the ontological nature of attention. The idea of a limited capacity resource does seem to be an appealingly accessible metaphor, but we will need to move beyond it, not only to relate how competition between representations and top-down biases are triggered to resolve competition in favour of our attentional targets, but also, ultimately to stimulate theorizing.

A promising current avenue is research indicating that local competitive interactions may underlie the perceptual load effect. When attention is directed to multiple competing objects simultaneously, competitive interactions among them may impair their representation (Scalf, Torralbo, Tapia, & Beck, 2013). Competitive mechanisms, are in fact one of the simplest, selective yet non-bottleneck mechanisms (in so far as with minimal organization, it is always possible to find a winner) and again, as in the coherence theories mentioned above, selectivity here does not necessarily entail a limit in processing capacity.

The notion that attentional selection is not necessarily about bottleneck processing appears in other influential theories of attention and given this thesis' provisional results about the importance of valence and which properties are affected by attention (see also **Figure 7-1**) a brief mention of John Duncan's classic spotlight theories is germane. Duncan and colleagues showed that attention shifts more readily between two locations that fall within the bounds of a single object than between equidistant locations that are separated by an object boundary (Duncan, 1984). Bottleneck metaphors have generally guided the theories that attempt to locate the cognitive resources that operate only on attended stimuli, but it has been spotlight metaphors that have guided the theories that attempt to determine which features of a stimulus influence whether attention is being paid to that stimulus at any given moment. The essential idea suggested by the spotlight metaphor is that the determinant of whether or not a stimulus is attended is that stimulus's location or the distribution of objects in space. However, how this is applied to facial contours under constraints is unknown.

In the end, if we are to fully understand the interaction between face processing and attention a more detailed elucidation of the involved cognitive processes will be required (Wei, Kang, & Zhou, 2013). I have used the changing nature of task load to direct theorizing on how facial social judgment can be impaired. However, to address questions such as whether local competitive interactions underlie this putative phenomenon, or whether there are privileged facial components under attention (such as the eyes (Kikuchi et al., 2011)) and how these may interact with face processing modules would be better served by moving away from a descriptive stance and towards the provision of a formal computational model of perceptual load.

A computational model of perceptual load would be an instance of a model of visual attention that includes a formal description for how attention is computed and can ideally be tested by providing image inputs (see (Tsotsos, 2011)). Bayesian models provide an exciting avenue to focus on the computational goals of selective processing, i.e. a normative outline for why attentional selection acts the way it does in different situations, instead of a descriptive picture of how it operates. From a Bayesian perspective, selective processing (similar to some of the other examples of non-bottleneck processing cited above), rather than being subject to any resource limitation issue, could be advantageous for the sake of computational optimality for the agent. This is relevant, because given the results of the facial importance of valence in the prior chapters, selective filtering may arise for the reason that elements of sensory input, or rather aspects or judgments regarding the face, may be more significant for the agents' current behavioural objectives, while the residual elements, if included for processing (or under "attentional" constraints), may be unfavourable to the current task.

Bayesian models bring to mind the Helmholtzian notion, propounded in 1878 that sensory processing involves an active inductive process of ‘unconscious inference’, where different pieces of information, from immediate sensory inputs or past knowledge, are weighted according to its associated uncertainty, their relevance and informativeness, all as part of the inductive process (Von Helmholtz, 1977). In other words, selection for computation implies selection for some form of optimizing.

There have been are few recent attempts to build computational (Zhaoping, 2006) and probabilistic models for selective attention (e.g. see (Yu, Dayan, & Cohen, 2009)). In the Bayesian framework, inference refers to the computation of an interpretation of sensory inputs grounded in an internal model of how events and properties of the environment generate these observations. With regard to face processing (indeed all sensory processing), both learning and inference are important avenues for understating environmental stimuli, even without the mitigating role of attention. From a Bayesian normative viewpoint, the claim is that attention for learning requires a greater amount of learning be accorded to aspects of the environment that are less well known (Dayan & Yu, 2003), while attention for prediction and inference requires greater emphasis on the most precise sources of information in the environment (Yu & Dayan, 2005). This is a somewhat different approach to how perceptual load theory addresses questions of facial processing.

Bayesian models could be attractive from a theoretical perspective, particularly a parsimonious one, as it may be possible that that a fundamental bottleneck emerges naturally within such models of perception (Whiteley & Sahani, 2012). Whiteley and Sahani suggest that computationally, a failure to engage selective processing under low load settings, even when such selection would benefit performance, raises the possibility that perhaps extant experimental evidence reflects a basic consequence of distributed coding rather than variations in selection (Dayan & Solomon, 2010). This is because the receptive fields of visual neurons are spatially extended (e.g. peripheral discriminability in the presence of flankers, can in some instances be asymmetrical with respect to the relative proximity to the fovea of target and flanker). Moreover, Whiteley and Sahani propose that the resource bottleneck actually results from the computational intractability of exact perceptual inference in complex settings and that attention reflects an evolved mechanism for approximate inference which can be shaped to refine the local accuracy of perception. Taken together, these observation seem to be powerful support for a deeper investigation of Bayesian models of attention.

Indeed, another attractive feature from a theoretical perspective for Bayesian models is that the long acknowledged observation that sensory processing exhibits many types of inductive biases (many of the twentieth century Gestalt laws of psychophysics can be interpreted this way (Elder & Goldberg, 2002)). These inductive biases can generally be readily accommodated in a Bayesian framework. If such biases exist for certain visual and facial properties, as this thesis suggests, the Bayesian approach suggest a parsimonious approach to facial judgments

The Bayesian approach is a powerful framework for understanding selective processing, offering statistically optimal tools for the quantification and integration of imperfect information streams. This allied with the idea that there might be reasons for attentional selection that have nothing to do processing bottlenecks, offers a comparatively new and stimulating theoretical paradigm for selective attention research (irrespective of whether the object of that selection is a face or otherwise). However, although such models seeking to demonstrate that behaviour can be explained from principally rational norms (generally employing optimality assumptions) are promising, they are not without challenges (Jones & Love, 2011).

For example, although the Bayesian models that I have discussed do seek support in (visual) neurological models, they are still appreciably unconstrained in both the assumptions that the models employ and their absence of empirical measurement support. In fact, the current Bayesian models could be considered concordant to the perceptual load model, as their emphasis is arguably more on post-focus information integration, than how attention is attenuated. The Bayesian models such as Whiteley and Sahani's (Whiteley et al., 2012) or indeed others (e.g. (Dayan et al., 2010)) lack an explicit attentional mechanism in inference which has the capacity to downplay some input units over others. These models know the location of the targets and automatically, through inference, focus all its resources on them, but do not have any means of boosting or suppressing some receptive fields compared with others (Dayan et al., 2010). Strictly speaking, the form of selection they study is an output from inference rather than an input into it.

A more important criticism relates to reaction times measurements, a central variable that is employed in this thesis and in general for a large portion of attentional and perceptual load selection paradigms. Currently, integrating reaction time effects within a purely computational inferential framework is challenging. Until these reaction times are represented in an explicit neural model (a level of complexity a while at way at least), this extensive class of behavioural observations cannot be adequately amalgamated into a Bayesian framework.

A way forward for both perceptual load theorizing and Bayesian modelling could perhaps be in developing more complex generative models for perception (from neural populations upwards), allowing for better testing between computational models and behavioural observations. Creating better computational models may mean that progress is more likely to be achieved in having a better understanding of perceptual load mechanics (perhaps even their reformulation) and of the putative Bayesian descriptions of attention which seek to move beyond limited capacity approaches. While I welcome this future advancement, currently, as a first approximation for theorizing, perceptual and cognitive limitations apropos to task goals engender notions of (selective) attention, whether categorised or labelled as a capacity limitation or otherwise. These notions underlie Perceptual load theory (and the experimental paradigms employed within this thesis) which to date, have been productive and valuable in linking neuronal mechanisms with behavioural consequences and tying attention to domains such as face processing and social judgments.

A great deal of work still remains in understanding attentional selection in a common theoretical framework. Clearly, more needs to be understood about how the different forms of attention discussed here interact with each other. Our understanding of the underlying neural mechanisms is still in its infancy.

7.5 Future Research

The research presented in this thesis, directed by load theory and employing an arguably uncontroversial definition of attention (selective attention is a preferential allocation of limited processing resources to task goals such as trustworthiness evaluations), has provided convergent evidence that top-down cognitive and neural mechanisms are involved in influencing the degree to which facial visual judgments are processed. Although this implies that the availability of attentional resources are a necessary precondition for accurate facial social judgment, the relationship between perception, attention and social facial judgment is nonetheless likely to be complex. Perception does not solely originate from the mere stimulation of our senses by external stimuli but are potently governed by internal processes and states that select and organize sensory inputs for goal-oriented behaviour (Pourtois et al., 2013). Moreover, important theoretical challenges remain in positing reasonable biological and social processes that can explain variance in face inferences and why and when such social traits are susceptible to modulation or not, and what makes them so within the broader framework of cognitive functioning from an information processing perspective (Marr, 1982). This complex interplay between judgments of faces and attention control mechanisms and the many factors that may influence emotional and social processing means that many unanswered questions will arise from the experiments undertaken in this thesis (incorporating all the latter variables).

Although, future research ideas have been mentioned for particular contexts throughout this chapter, here will we briefly mention some open, unaddressed questions arising from the work presented here.

The section is aimed at presenting two main general question areas that arise from the experiments in this thesis. The first one regards the nature of the stimuli and particularly the temporal aspects of their processing and whether there is a qualitative difference in facial judgment processing as for example exposure time is manipulated. The second question is of a broader nature and deals with the conceptual features of categories such as trustworthiness.

7.5.1 Multimodal Stimuli, Exposure Time, Repetition and Temporal Dynamics

How do multimodal stimuli and exposure time affect social facial judgment?

Our manipulation of attentional processes has relied on static, one-dimensional stimuli, as opposed to richer multimodal stimuli. This raises the question of whether there is a qualitative difference between these types of information. There is evidence that facial expressions of emotion are perceived with the help of bodily and vocal expressions. Indeed participants are unable to ignore the influence of the body (using posed facial and body expression pictures) even when participants are instructed to concentrate on the face for their emotional judgment (Aviezer, Hassin, Bentin, & Trope, 2008). It is also instructive to take into account the results produced in this thesis in the context of studies in which subjects made personality judgments from dynamic video clips of social interaction (Carney, Colvin, & Hall, 2007). In Carney and colleagues study, accuracy (defined as the correlation between a judge's ratings and the target's) increased with exposure time. This study (and others, e.g. (Horstmann &

Ansorge, 2009)) suggest that not only might the dynamism of the stimuli be important, but also the exposure time to it.

Taking the idea of exposure time and pushing it to the limit also raises interesting questions as to the extent that facial perception and judgments about facial valence properties can occur in the absence of awareness. We know that extremely short exposure to faces (100 ms) suffice for subjects to discriminate between different levels of facial attractiveness (Locher et al., 1993), perhaps even less time is required (13ms according to (Olson & Marshuetz, 2005)). But as we reduce the exposure time does it become more challenging to make arguably more complex judgments such as trustworthiness? For example, Murphy's and Zajonc's classic study suggests that affective priming from facial expressions can occur under very brief exposure (4 ms) (Murphy et al., 1993). Moreover, subliminal presentation of faces has even been found to influence behavioural decisions unrelated to face processing (Chen & Bargh, 1999), even the masked presentation of happy and angry faces can influence subsequent behavioural actions of pouring and consuming a beverage (Winston et al., 2007).

The ability to make facial judgments with rapid presentation times highlights how potent a social signaller the face can be, nevertheless, how precisely attention interacts with exposure time, awareness and facial judgment accuracy is an open question. For example would perceptual load capacity-like restraints interact with faces suppressed from awareness by continuous flash suppression (in which monocular presented stimuli are masked by a dynamic pattern presented to the other eye)? Do stronger multimodal signals may make facial social judgments more resistant to modulation? Or conversely, does decreasing the visual channel capacity with richer representations mean that attentional load is in fact more efficacious in impacting facial evaluations?

Future studies are needed to test these hypotheses and clarify the gaps in knowledge in how facial judgment processing interacts be it with trait or emotional judgments, with awareness and attentional constraints.

Repetition and temporal dynamics of attention and trustworthiness; where to next?

Almost all studies on social face evaluation rely on fMRI measures, typified by relatively slow hemodynamic brain responses, rather than the higher temporal resolution of event-related brain potentials (ERP) studies. Exploring temporal dynamics may be useful in the investigation of the important question of "when" the effects of attention or perceptual load in facial social judgment processing occur. Specifically, where in the stages of the face processing stream are complex facial judgments such as trustworthiness (or dominance) modulated by load? Whether at an early "perceptual processing" stage or (or possibly and) at a later "cognitive stage". Clarifying the temporal dynamics of the results that we have observed in this thesis may also help in understanding whether judgments such as trustworthiness happen concurrently, asynchronously or indeed are indistinguishable with emotional evaluations. For example, by way of comparison, intracranial recordings in the amygdala indicate long latency modulations (between 200-800 ms) when attention is explicitly directed at facial expression, but not during gender (Krolak-Salmon, Henaff, Vighetto, Bertrand, & Mauguiere, 2004), can a similar process be employed with trustworthiness judgments?

There are very few studies employing ERPs to investigate the temporal dynamics of trustworthiness evaluations (Rudoy & Paller, 2009; Marzi et al., 2014), where researchers have sought to identify the specific ERP correlates of trustworthy facial expressions. Interestingly, the ERP components identified in these studies, such as the early P100 component (recorded over the posterior cortex), are found to be influenced by facial expressions (Pourtois, Dan, Grandjean, Sander, & Vuilleumier, 2005), but also reflect attentional mechanisms (Hillyard, Vogel, & Luck, 1998). Moreover, the P100 component is enhanced for untrustworthy faces, consistent with the results in Experiment 12 and coherent with the view that signals of potential threat are given precedence in neural processing (Marzi et al., 2014).

In a similar vein to the discussion above, the evidence of the role of experience-related, or repetition effects may also be helpful in elucidating the effects of load on social facial stimuli.

There is some evidence that there is a second versus first face presentation difference, contingent on facial emotion (e.g. fearful, happy or neutral faces), influencing neural responses at early perceptual processing stages such the N170 or M170 (Morel, Ponz, Mercier, Vuilleumier, & George, 2009). Furthermore, as demonstrated in the experiments in this thesis, the valence of a face may also be an important factor in the nature of repetition effects, as the N170 and M170 are differentially sensitive to the repetition of neutral and emotional faces. For example, both components show similar effects, but with increased amplitude for neutral faces when repeated (but not for emotional faces).

If modulations of face processing can be influenced by experience-related factors, this may have consequences for the efficacy of load, where the familiarity of the face and its valence may interact with its susceptibility or resistance to load. Perceptual load effects may be subtly modulated by repeated exposure of facial stimuli. This is conjecture however, as equally such effects may habituate with repetition.

There are still may unresolved questions to be addressed in future research regarding the temporal aspects of face processing and how they may be influenced by attention, not only for trustworthy judgments (where there may be specific ERP patterns for facial trustworthiness (Marzi et al., 2014) but also for under-studied evaluations such as dominance judgments.

7.5.2 Cultural Influences: Where Does Culture End and Cognition Begin?

As in many areas of cognitive neuroscience there are still methodological and theoretical issues which bedevil facial social judgments research, not least as the Dale Spenders quote at the beginning of this Chapter indicates; the language that we employ for subjective judgments presupposes a level of conceptual understanding that we all share regarding facial judgments such as trustworthiness and their proto-typicality. However, simply peeking over into another field such as administrative and organizational psychology, reveals the polysemous nature of the term in real world contexts (e.g.

ability, benevolence or even predictability) (Dietz, Gillespie, & Chao, 2010; Dietz & Den Hartog, 2006). Nevertheless, experimentally within this thesis, the high levels of rater agreement mitigates the criticism that we have substantially divergent notions of trustworthy faces (and indeed dominant or threatening ones).

Exploring, alternative face stimuli spaces would aid in increasing the generalizability of these results (although this may mean that valence may not be as accurately delimited as the (Oosterhof et al. stimuli (Oosterhof et al., 2008)). Moreover, extending the range of stimuli to those that we encounter daily e.g. female and different ethnicities (along with cross cultural replications) would improve the validity and robustness of the findings of facial judgments under attention presented in Experiments 1-12. Most likely there are many degrees of freedom at work in these subjective judgments, as something as simple and primary as the red-green axis of skin colour influences the perceived aggression, dominance and attractiveness of photographs of men's faces when rated by female participants (Stephen et al., 2012), while manipulating facial-width ratio can influence attributions of trustworthiness (Stirrat & Perrett, 2010).

Facial social judgment is a task that the human visual system seems to execute naturally, in spite of the attendant computational difficulties due to the malleability and diversity of facial expressions and the tracking and locating of faces within a dynamic, noisy, environment. The approach I have taken in this thesis expounds upon the role of attentional, specifically perceptual load effects in facial judgments; however it is not the whole story, there may be many other modulatory factors outside of individual attentional effects in expression processing. For instance, a subject's judgments may nudged by the group they are embedded in (Verosky, Turk-Browne, & Todorov, 2013; Todorov et al., 2011). Such "learning" may be another source of variation in facial social judgments (perhaps even compounded with individual differences or personality factors).

How facial cues and signals operate in groups and social environments and how structurally stable they are from the influence of social psychological herding forces such as compliance or conformity is far from clear (Raafat, Chater, & Frith, 2009). There are number of studies which indicate that the boundary between cognitive and cultural judgments may be indistinct. For example, the words used to express certain emotions differ in both intensity and meaning across cultures and some languages may be better at conveying emotional concepts than others (Mesquita & Walker, 2003). In contrast, although some authors question whether for example emotions are indeed a natural kind (Barrett, 2006), an almost axiomatic assumption of emotion research, there are nevertheless communal points of agreement in social facial trait judgments, Indicated by both by the high overall facial judgment accuracies observed in this thesis and by evidence within the research literature, e.g. both Chinese and Canadians appear to use similar facial cues to judge trustworthiness (Xu et al., 2012).

In general, the demarcation between where cultural and cognitive trait judgments begin and end is an understudied but promising area of research. Hopefully, this area will be more systemically explored in the future.

7.6 Contribution to the Field and Summary

My doctoral work has sought to contribute to the field of social cognitive neuroscience in the developing of behavioural visual search paradigms to manipulate facial social judgments and in seeking to disentangle the delicate embrace that attention enjoys with facial processing. I have shown ways in which attention can influence the perception of social judgments, specifically focusing on the novel interaction of facial trait evaluations and attention. While at a neural level, I have demonstrated how attentional (anterior cingulate cortex), face processing (fusiform face area) and valence-saliency regions (the amygdala) are influenced and interact with the presence of perceptual load demands and facial valence. Moreover, I opened up a new chapter in perceptual load research by investigating the association of facial expression judgment impairment and Parkinson's disease and whether this association could be secondary to one produced in other cognitive processes involved in facial processing, such as selective attention. Future research programs may benefit by investigating clinical populations which may be impacted by deficits in facial processing such as those of Parkinson's disease (as done within this thesis) or Autism spectrum disorders, with a view to inferring models of normal social facial judgment functioning from patients or sufferers who show deficits or immunity to attentional modulators (Dawson et al., 2004).

The studies contained in this thesis were designed to provide a better understanding of the functional relationships between faces, attention and automaticity. Ultimately, this understanding is subsumed in the broader goal to further comprehend the circumscribed set of brain regions and cognitive processes (not all specifically social since they can be applied in other domains) that are dedicated to social cognition and have been driven to ever higher levels of sophistication by the everlasting complexities of social interaction (Frith, 2007).

Although the nature of how attention and facial processing interact is still currently a highly debated issue in the literature (e.g. (Okon-Singer et al., 2013; Pourtois et al., 2012)), this thesis confirmed the role of attention in visual facial processing, where the valence of the face is a key component in how the effects of perceptual load are implemented. The research reported here advocates the importance of considering both the level of load and the influence of valence in the efficacy of visual facial judgment processing under attentional constraints. Moreover it is possible that the type of facial judgment (e.g. dominance rather than trustworthy) may also influence the capacity of perceptual load modulation.

As discussed in Chapter 1, neither attention nor facial processing is most likely a unitary phenomenon, providing ample opportunities for putative facial automaticity to be interrupted and for facial perceptual representations to be degraded when there are attentional constraints. The particular mechanisms still need to be elucidated, for example a visual load task that impairs perceptual representation resources may directly interact with the retinal visual cortex responses to incoming visual stimuli, reducing the fidelity of a visual stimulus.

The findings presented here extend perceptual load theory to now incorporate the category class of facial trait stimuli. The findings propose that when processing "loads" attention, cognitive control pathways (most likely drawing on frontal cortices) that maintain processing priorities will interact with facial valence signal properties, and thus impinge on our facial judgments.

As so often, the notions that we have can be expressed far more eloquently and indeed pithily by those before us;

"Often a silent face has voice and words". [Lat., Saepe tacens vocem verbaque vultus habet.]
- Ovid (Publius Ovidius Naso), Ars Amatoria
… with the addendum, that listening to it, is akin to attention!

The challenge for future research is to reformulate social facial judgments such as trustworthiness in terms of their underlying neural and information processing components. Doing so may bring us closer to achieving a comprehensive understanding of not only how capacity constraints influence face processing in general, but also why faces seem to capture attention so readily, permitting the unravelling of the intricate and perpetual flickers of social judgments signalled by facial expression that continually transmit and accompany us throughout our lifetime.

8 References

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