The effect of ageing and load on the perception of emotion

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I, Jake Fairnie, 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.

Abstract

This thesis examines the role of ageing and load on the perception of emotion. Previous ageing studies on emotion perception have produced mixed results; in some cases the discrepancies can be accounted for in terms of either visual confounds or response biases. The present thesis addresses the effects of perceptual load and ageing using visually-matched stimuli, and a signal-detection analysis that assesses effects on detection sensitivity independently from response bias (Chapters 2-4). The implications for the effects of ageing and load on emotional distraction are also addressed (Chapter 5). Old adults (aged over 65 years) and IQ-matched young adults (aged 30 or younger) participated. In the signal detection experiments, participants were required to detect either the presence of one of two pictures depicting a negative or neutral emotion (depending on arrangement of the very same visual features, Chapter 2); or the emotional valence of words (Chapters 3-4). Distractor effects from the same words on reaction time (RT) were also assessed (Chapter 5). Tasks of full attention, divided or selective attention under different levels of perceptual load were used. The results established that under conditions of either full attention and short exposure durations, or low perceptual load, old adults retain the negative valence detection advantage typically found in young adults. High perceptual load (search tasks of similar items or subtle line discrimination tasks) modulated both the negative valence detection advantage, and distraction by emotional (versus neutral) content to a greater extent for old compared to young adults. These findings were reflected in detection sensitivity measures and distractor RT interference, not accompanied by any change in the response bias.

Alternative accounts, in terms of visual confounds; age differences in acuity; subjective valence and arousal, were ruled out. The findings demonstrate the importance of considering age and perceptual load in determining the perception of emotion.

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I dedicate this to my dad – Steve Fairnie – who, as I discovered half way through writing this thesis, had penned his own PhD proposal to study the brain in the year before he passed. This is for you.

Chapter 1:

General Introduction

1.1 Preface

Ageing research has provided evidence for a reduced perceptual processing capacity with age (Ball et al., 1988; Humphrey & Kramer, 1997; Lunsman et al., 2008; Maylor & Lavie, 1998; Scialfa, Kline & Lyman, 1987; Scialfa et al., 1994; Sekuler & Ball, 1986). However, this has been studied only in the case of stimuli that can be considered as emotionally neutral (e.g. letters and abstract shapes). In this thesis I investigate how the age-related reduction in perceptual processing capacity affects the processing of emotional information under differing levels of load on perception (or 'perceptual load'). To address perceptual processing per se (e.g. as opposed to response criterion) I use signal detection analysis so that the effects of age and load on perceptual sensitivity for emotion could be determined, irrespective of any potential effect of response bias.

Before addressing the effects of perceptual load, the first aim of the present thesis was to establish whether there are age differences in perceptual sensitivity towards emotional stimuli. A growing body of research has indicated that the way in which emotions are processed change as we grow older (see recent reviews by Grady, 2008, 2012; Mather, 2012). Although much of the ageing literature on emotion processing suggests an age-related increase in orientation and detection of positive valence, research is currently inconclusive with respect to a change in perceptual sensitivity.

Given the well-established bias for processing negative and potentially threatening stimuli in young adults (e.g. Eastwood, Smilek & Merikle, 2001;

Fox et al., 2000; Ohman, Lundqvist, & Esteves, 2001), that has been recently shown to manifest itself in perceptual sensitivity measures (Nasrallah, Carmel & Lavie, 2009), my aim was to elucidate any age differences specifically in the negative valence detection as expressed in perceptual sensitivity measures.

In addition, previous studies using facial expressions have often not accounted for differences in visual features; and while some ageing studies using images taken from the International Affective Picture System (IAPS; Lang, Bradley & Cuthbert, 2005) have equated valence and arousal ratings between age groups (e.g. Mather & Knight, 2005; van Reekum et al., 2011) others obtained ratings from published databases (e.g. Allard & Isaacowitz, 2008; Knight et al., 2007) and thus did not account for age differences in valence and arousal attribution (Gruhn & Scheibe, 2008).

In the present thesis I therefore used either pictorial stimuli that were equated in terms of visual features, or words for which both valence and arousal ratings were collected for each individual so that the stimuli could be equated for valence intensity and arousal both between positive and negative valence conditions and between the age groups.

The second aim was then to address the effects of perceptual load on emotion perception, as well as on the interference effects that emotion perception can produce. As my review describes, previous ageing studies have not directly assessed the effects of manipulating visual informational load on emotional perception. Thus, the question of how perceptual load impacts age differences in detection sensitivity for emotional stimuli and the resultant interference when emotion is irrelevant to the task has not yet been explored.

Finally as expected from literature showing an age-related reduction in perceptual capacity, old adults tend to show a reduction in distraction from emotion compared to young adults (Ashley & Swick, 2009; Lamonica et al., 2010; Thomas & Hasher, 2006). However, no previous ageing study has directly assessed the effect of perceptual load on emotional distraction and this was the final aim of my thesis.

I begin by reviewing the previous literature on load theory and age-related changes in perceptual capacity, followed by age differences in emotional perception and concluding the review with ageing studies that have looked at emotion perception under inattention. Given the behavioural scope of this thesis, my review will focus on the previous behavioural research of these topics.

1.2 Perceptual capacity and load theory

The ability to focus on a particular aspect in our environment while ignoring others is vital given that the brain has a limited information processing capacity. This function is accomplished by selective attention. The amount of information we can process simultaneously is known as an individual's perceptual capacity, and its impact on selective attention has been investigated by the Load Theory of Attention and Cognitive Control (Lavie, 1995, 2005). According to this theory, when a task involves a high level of perceptual load (that consumes all available attentional capacity), focused attention will prevent perception of task-irrelevant stimuli (early selection). In contrast, a task that involves low perceptual load (leaving spare attentional capacity) will result in the automatic perception of irrelevant stimuli (late selection). A number of studies on young adults provide support for load theory in showing that high perceptual load reduces behavioural interference caused by task-irrelevant distractors (Lavie, 1995; Lavie & Cox, 1997). For example Lavie and Cox (1997) presented a circle of six letters and asked participants to search for one of two possible targets. The task was either low load (non-targets were O's; see Figure 1a) or high load (non-targets were angular items similar to the target; Figure 1b). In addition to the central letter search task, a single task-irrelevant distractor appeared in the periphery. This distractor was either congruent (the same letter), incongruent (the alternative target letter) or neutral (no response association) with the target.

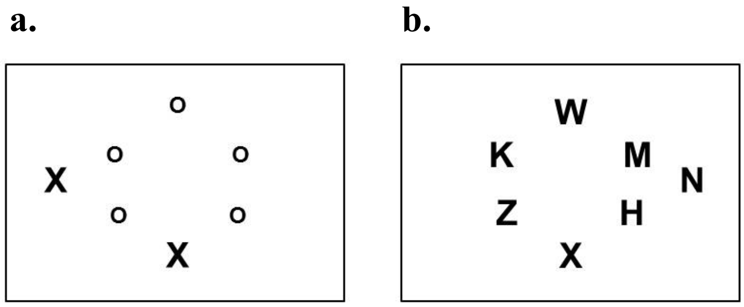

Figure 1.1 Example of a low load (a) and a high load (b) display from Lavie and Cox (1997).

In the low load condition, RTs were slower on incompatible compared to compatible distractor trials (indicating a larger interference effect). In the high load condition, RTs did not differ between compatible and incompatible trials (indicating that interference effects were eliminated). The neural processing associated with unattended stimuli also seems to depend on the level of perceptual load. High perceptual load diminishes distractor related activity in the brain (Bahrami, Lavie & Rees, 2007; O'Connor, Fukui, Pinsk & Kastner, 2002; Pessoa, McKenna, Gutierrez & Ungerleider, 2002; Pinsk, Doniger & Kastner, 2003; Rees, Frith & Lavie, 1997; Schwartz et al., 2005; Yi, Woodman, Widders, Marois & Chun, 2004). For example, Rees et al. (1997) found that neural activity related to visual motion is modulated by perceptual load. V5 response to moving dots was observed under low load, but no increase in associated activity was found under high load.

However, these previous studies used indirect measures (RTs and neural activity) rather than directly assessing whether a high perceptual load reduces conscious perception of irrelevant stimuli. It is therefore difficult to infer with full certainty whether or not participants consciously perceived the distractors. Distractor effects on target RTs under low load, for example, could reflect unconscious processing of stimulus-response associations rather than awareness of the distractor.

In studies that employed more direct measures (explicit tests of awareness), high load impaired explicit detection of stimuli presented in addition to a central task (Cartwright-Finch & Lavie, 2006; Macdonald & Lavie, 2008). For example, in a dual-task paradigm by MacDonald and Lavie (2008) participants were asked to detect a target in a circle of letters and then indicate whether they detected a critical stimulus (a small meaningless grey figure) that occasionally appeared in the periphery. Perceptual load was manipulated by varying the number of letters similar to the target (no similar items in low load; five in high load). In line with load theory, detection sensitivity for the critical stimulus was reduced in the high (relative to low) perceptual load condition, whereas the response bias was unchanged. This would suggest that conscious perception is subject to capacity limits, and consequently is sensitive to the level of perceptual load involved in a task. In the following section I review research showing that there is reduced perceptual capacity with age, which suggests that old[1] adults should be even more sensitive than young adults to the effects of load on conscious detection.

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[1] For the purposes of this thesis the term *old adult* refers to individuals aged over 65 years and the term *young adult* refers to individuals aged under 35 years (unless indicated otherwise).

1.3 Age-related changes in perceptual capacity

1.3.1 Evidence from visual search studies

The notion of an age-related reduction in perceptual capacity has been supported by visual search studies indicating that increasing the demands of the task has a greater impact on old compared to young adults. For example, in a study by Humphrey and Kramer (1997), participants were asked to search for a target defined by a single feature (feature search) or a conjunction of two features (conjunction search) that appeared amongst up to 24 distractors. RTs increased with the number of distractors, and this effect was greater for old compared to young adults. In addition, all participants were slower on conjunction compared to feature task trials, but old adults were slowed to a greater degree compared to young adults. Thus, increasing the demands of the task had a greater impact on old compared to young adults, consistent with an age-related reduction in perceptual capacity.

Another factor that affects visual search performance is the homogeneity of distractors. Scialfa, Thomas and Joffe (1994) asked participants to indicate which of two pre-specified targets was presented amongst either no distractors; distractors with a single orientation (homogeneous distractor condition); or distractors with two orientations (heterogeneous distractor condition). All participants were slower to respond when the target was presented amongst heterogeneous distractors (compared to no or homogeneous distractors); and, of central interest, old adults were slowed to a greater degree by heterogeneous distractors than young adults. This finding provides further evidence that the factors detrimental to task performance during visual search have a greater impact on the old, compared to young adults; consistent with the notion that perceptual capacity reduces with age.

1.3.2 Evidence from useful field of view studies

Another line of evidence for a reduced perceptual capacity with age has come from research on the UFOV (useful field of view; the region of the visual field from which an observer can extract information at any one time; Sekuler, Bennett & Mamelak, 2000). While visual acuity reduces as eccentricity increases for all individuals (Anstis, 1974), there is an age-related reduction in perceptual capacity that cannot be explained exclusively by reduced visual acuity. This is demonstrated in a study by Sekuler and Ball (1986), where participants were presented with two schematic faces: one at fixation and one in the periphery. Participants were asked to make either one response (locate a peripheral target face) or two (identify the facial expression of the central face and then locate the peripheral target face). The peripheral face stimulus was presented either alone, or amongst distractors. The brief exposure duration of the display precluded the use of eye movements to facilitate performance. Central task performance was near ceiling for both groups. The important finding concerns the peripheral task and is illustrated in Figure 1.2. With no distractors (Figure 1.2a), very few errors were made by either age group. However, when the peripheral target face was presented among distractors (Figure 1.2b), both age groups made more errors, particularly as eccentricity of the target increased. Moreover, the distractor effect was greater for old adults compared to young adults. This study also demonstrates the effect of target eccentricity. The increase in error rates with increasing eccentricities for both age groups suggests a general decline in the efficiency with which information can be extracted from the UFOV. The amplified divergence between young and old adults suggests that the reduction in UFOV efficiency is more substantial for old compared to young adults, in line with an age-related reduction in perceptual capacity.

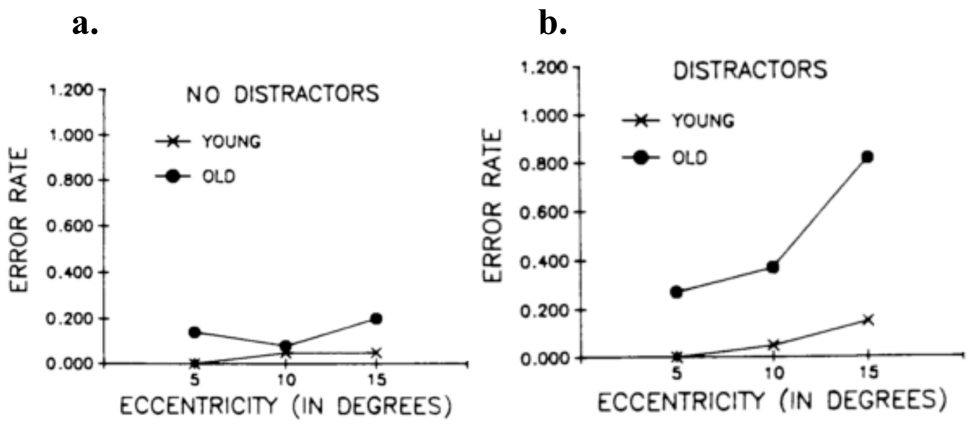

Figure 1.2 Error rates from Sekuler and Ball (1986) for young and old adults on the peripheral localisation task at varying eccentricities either with (b) or without (a) distractors.

The number of distractors has also been found to affect the ability to extract information from the UFOV. For example, Scialfa et al. (1987) asked participants to search a horizontal string of letters for a target letter that was presented among up to 19 distractors, and at varying eccentricities. As in Sekuler and Ball (1986), RTs were slowed as target eccentricity increased, and this effect was larger for old compared to young adults. Further, participants were slower and made more errors as the number of distractors increased; and this effect was greater for the old compared to young adults (see Figure 1.3). These age differences were replicated in a longitudinal study using schematic objects (such as a truck or car; Lunsman et al., 2008).

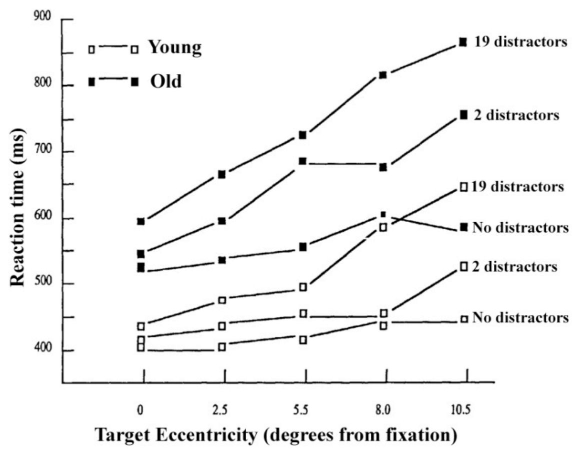

Figure 1.3 Results from Scialfa et al. (1987) indicating RTs on the search task for young and old adults as a function of target eccentricity and number of distractors.

Another line of work has investigated the effect of central task demands on UFOV efficiency. This is particularly relevant for the present thesis given my interest in the effects of perceptual load. Ball et al. (1988) presented participants with a display that contained one central and one peripheral schematic face (see Figure 1.4a). The central task demands were either low (present or absent judgement on central face), medium (smiling or frowning discrimination on central face), or high (indicate whether expression on central face is same or different to the peripheral face expression). A second response was then required to locate the peripheral face.

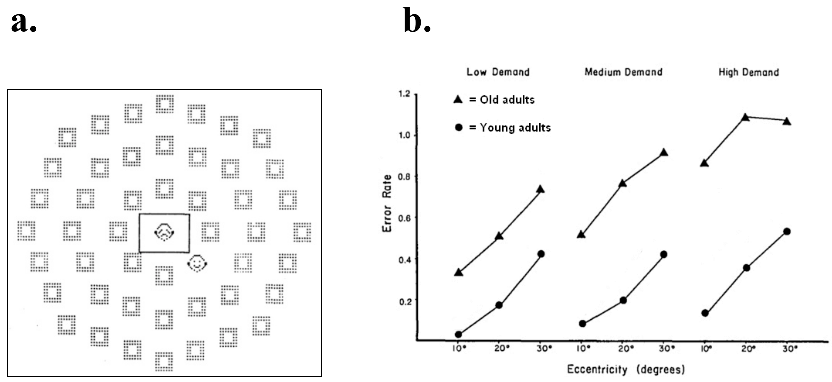

Figure 1.4 Example display (a) and results (b) from Ball et al. (1988).

The difference in the error rates between young and old adults became larger as the demands of the central task increased (see Figure 1.4b), consistent with the notion of an age-related reduction in perceptual capacity.

1.3.3 Evidence from perceptual load studies in ageing

An age-related reduction in perceptual capacity should mean that old adults exhaust their capacity at lower levels of perceptual load compared to young adults. Based on this hypothesis, Maylor and Lavie (1998) used a response competition paradigm to examine the effect of perceptual load on different age groups. Participants were asked to detect which of two target letters was presented in a letter search task. Perceptual load was manipulated by varying the number of letters that were similar to the target (none at the lowest level of load but up to five as perceptual load increased). A task-irrelevant distractor letter was also presented outside of the circle of letters (see Figure 1.5) that was either incongruent with the target (the letter assigned to the incorrect response) or neutral (a letter not assigned to a response). Participants were asked to ignore the distractor.

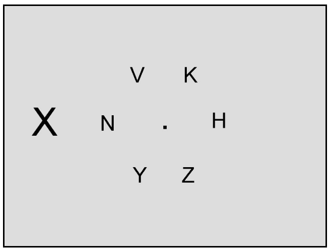

Figure 1.5 An example of a display from Maylor and Lavie (1998) with a set size of 6. The target letter is N and the incongruent distractor is X.

Consistent with load theory, Maylor and Lavie (1998) found that interference from incongruent distractors reduced as set size increased for all participants. Importantly, this effect was more pronounced for old compared to young adults: distraction from incongruent letters was greater at lower levels of perceptual load, but this effect diminished more rapidly as set size increased for old compared to young adults.

Madden and Langley (2003) failed to find age differences in the modulation of distractor response competition effects by load using a paradigm similar to that of Maylor and Lavie (1998) with one exception: the distractor was presented within the same central array as the target (rather than outside it). In this way, manipulating load through the search set size did not only increase demands on capacity but also directly reduced the perceptual salience of the distractor. The result of this was that the distractor effect was already reduced for the old adults at lower levels of load. In other words, the manipulation of load used by Madden and Langley (2003) produced a floor effect for distractor competition at low and intermediate levels of load for both age groups. The presentation of the distractor among the array for which set size was increased was also likely to cause crowding and, as is well established in literature on the UFOV (Lunsman et al., 2008; Scialfa et al., 1987; Sekuler & Ball, 1986), older adults are more sensitive to crowding. However this did not lead to any age difference in the effects of load on distractor processing in Madden and Langley (2003) either due to the use of central rather than peripheral arrays or the unlimited exposure duration.

In summary, these previous ageing studies clearly support the notion of an age-related reduction in perceptual capacity. In the present thesis, I relate this to emotional perception. In the next section I discuss age differences in emotional processing and begin with studies that have focused on age differences in emotional perception irrespective of attention.

1.4 Age differences in emotional perception

The question of whether the perception of emotion changes with age has been the focus of a great deal of ageing literature over the past two decades (see recent reviews by Grady, 2008, 2012; Mather, 2012). A growing body of research indicates that old adults allocate proportionately more processing resources to positive information, and proportionately less to negative information. I review this literature below, and commence with evidence in support of an age-related positivity effect.

1.4.1 Evidence for an age-related positivity effect

A number of studies have found that old adults orient more towards positive information and away from negative information. For example, in a dot probe study by Mather and Carstensen (2003), participants were asked to view pairs of greyscale photographs that contained one emotional (either happy, sad or angry) and one neutral facial expression (see Figure 1.6). When the pair of photographs disappeared, a dot was displayed in the position of one of the two images. Participants were required to indicate the location of this target.

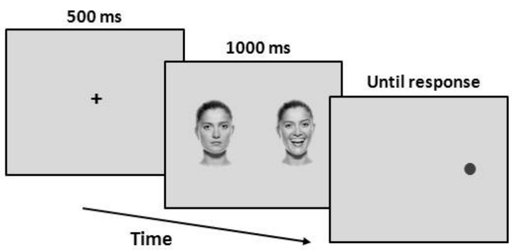

Figure 1.6 An example trial sequence from Mather and Carstensen (2003). After a fixation cross, a neutral and emotional (happy in this example) face-pair was presented on screen, followed by a small grey target dot.

Old adults were faster to detect targets that appeared in the location of happy (vs neutral) facial expressions, and slower when the target appeared in the location of an angry or sad (vs neutral) face. This would suggest that old adults were already oriented to happy facial expressions and away from angry and sad facial expressions. Young adults showed no valence effects on RTs. Further, on a subsequent surprise recognition test, old adults recognised more happy compared to angry and sad faces, whereas young adults showed no valence effects on recognition memory. However, greater recognition memory for happy (compared to angry and sad) faces may simply reflect age differences in the ability to encode the stimulus into memory, rather than any increase in perception.

In a more recent dot probe study (Lee & Knight, 2009), neutral-negative (either angry or sad) face pairs were presented either subliminally or supraliminally (as determined by the exposure duration) before a target dot appeared for participants to locate. Results from the supraliminal condition were in line with an age-related positivity bias: old adults were slower to respond to targets that replaced angry (vs neutral) faces. However, this pattern reversed in the subliminal condition: old adults were faster to locate targets that replaced angry (vs neutral) faces. There were no effects for sad faces, and no effects of emotion for young adults. This would suggest that old adults were able to actively avoid angry faces in the supraliminal condition (in line with age-related positivity bias) but when conscious perception of the stimuli was diminished in the subliminal condition, this orientation pattern was no longer apparent in the old adults.

However, the photographic stimuli of facial expressions used in these two dot probe studies were not equated for low level visual properties. It is therefore possible that a visual difference in the stimuli could have confounded the results. The importance of this issue is illustrated by Purcell et al. (1996) who discovered, when replicating a visual search study that found a threat advantage for angry over happy faces in young adults (Hansen & Hansen, 1988), that a confound contained within the original stimulus set (more black scratch marks on angry compared to happy facial expression photographs) caused the reported effect. Subsequent testing indicated that these scratch marks enabled participants to discriminate between stimuli such that angry faces could be detected more efficiently than happy faces. Moreover, when the black scratch marks were removed from the photographs, differences in search times between the angry and happy stimuli were eliminated. Taking that into consideration, given that the two dot probe studies reported above did not equate low level visual differences in stimuli, the findings could be accounted for by visual confounds, for example more white regions and a lighter contrast on images with happy smiling faces (due to teeth being shown) compared to angry frowning faces.

In order to preserve emotionality while minimising perceptual confounds, a number of studies have used schematic faces to minimise visually distracting features that are present in photographic images (such as prominent wrinkles, hair and skin texture, colour and luminance) that add to the complexity of these stimuli (Wilson, Loffler & Wilkinson, 2002) but may also be attention-grabbing themselves in ways that might covary with age. For example, in a dot probe study by Isaacowitz, Wadlinger, Goren and Wilson (2006), participants were asked to view schematic face pairs and then indicate the location of a target dot that appeared in the location of one of the images, either the emotional (sad or happy) or neutral face. Old adults were faster to respond to the target when it replaced a happy (vs sad or neutral) face (indicating that they were already oriented towards happy faces), but young adults showed no effects of emotion (see Figure 1.7). In line with the RT data, old adults also showed a gaze preference towards happy and away from sad faces. Young adults fixated less on sad faces but showed no bias for happy faces.

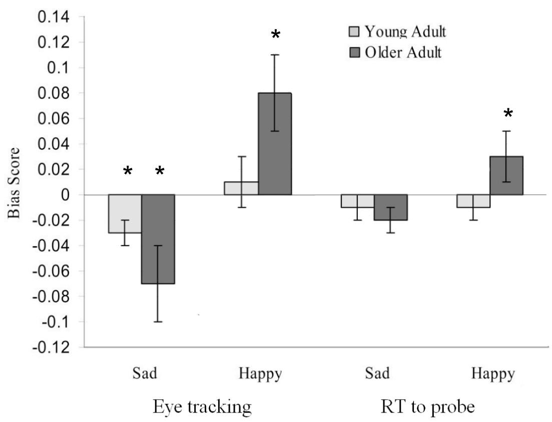

Figure 1.7 RT and eye tracking data showing age differences in the attentional biases for happy and sad faces from Isaacowitz et al. (2006). A positive bias score indicates a looking preference towards the emotional stimulus, whereas a negative bias score indicates a preference away from the emotional and toward the neutral face.

However, schematic stimuli have also faced criticism. Firstly, it is unclear whether differences in responses to altered schematic faces are genuinely connected to the facial expression or are due more to the geometrical forms that are used to portray these expressions (e.g. the orientation of the mouth or height, shape and direction of eyebrows; Goren & Wilson, 2003). Secondly, there is limited scope with regards to what can be conveyed in a schematic face, such that most studies rely on a single facial feature, for example a frowning mouth for angry faces. However, as in the case of a frowning mouth for angry faces, these features often do not correspond with what is considered to be an attribute of the intended real-life expression (Ekman & Friesen, 1976).

In addition, although the dot probe studies presented above might suggest that old adults prioritise positive information and allocate fewer resources to negative information, the conclusions are based on indirect measures (RTs and eye tracking). Without directly measuring age differences in perceptual sensitivity to different types of emotion, one cannot deduce whether old adults have a greater perceptual sensitivity towards positive compared to negative stimuli.

Direct measures of perception

Not all ageing studies researching emotional perception have employed indirect measures; a number of studies have directly measured perception. For example, Moreno et al. (1993) asked participants to categorise greyscale photographs of faces as either happy, surprise, sad or disgust. Old adults were more accurate at categorising happy faces, but less a less accurate at categorising sad faces compared to young adults. Ceiling effects were observed for disgust and surprise for both age groups, precluding any interpretation for these emotions. In addition to the four emotions used by Moreno et al. (1993), Keightley et al. (2006) also included angry, contempt and fearful facial expressions. Old adults were less accurate at categorising negative expressions (anger, contempt, disgust, fear and sad) compared to young adults, but equally accurate (as young adults) at categorising positive facial expressions (happy and surprised). Calder et al. (2003) also found that old adults were less accurate at identifying negative facial expressions (sadness, anger and fear) compared to young adults, but equally accurate at categorising positive facial expressions (happy and surprise) as young adults. However, in contrast to the findings for disgust in Keightley et al. (2006), old adults in Calder et al. (2003) showed greater accuracy for categorising disgust compared to young adults. One possible explanation for this is that disgust is served by a separate neural substrate than other emotional expressions, namely the insula and basal ganglia (see Calder et al., 2001, for review of the neuropsychology relating to the perception of disgust), that is not subject to the same age-related declines as other regions.

Although these studies that directly assessed perception might suggest that detection of negative information reduces with age, while detection of positive information remains constant (Calder et al., 2003; Keightley et al., 2006) or improves with age (Moreno et al., 1993), there are two caveats. Firstly, as with the previous dot probe studies, the photographic face stimuli were not equated for low level visual differences meaning that the findings could be accounted for in terms of age differences in response to low level visual features (such as contrast; Purcell et al., 1996) rather than the emotion. Secondly, these studies did not take response criterion into consideration (the systematic tendency to provide a specific response on some basis other than the specific item content;

Paulhus, 1991). This is particularly important in ageing studies as different age groups may have different response biases, for example old adults having a tendency to provide a positive (vs neutral or negative) response. Therefore the reported detection rates could reflect these biases rather than perceptual sensitivity.

Two studies assessing age differences in the detection of emotion have taken response biases into account and found an age-related positivity bias. McDowell et al. (1994) asked participants to categorise greyscale photographs of faces as happy, sad, angry or fearful. Old adults were less accurate at detecting negative facial expressions (sad, angry and fearful) compared to young adults, but did not differ in their ability to identify happy faces. Both young and old adults were more likely to label neutral faces as angry and there were no other significant criterion biases. Thus, the effect of age on face detection does not appear to stem from age differences in response criterion.

Another emotional detection study that took response biases into account (by calculating kappa scores; see Cohen, 1960, for methodology) also presented surprised and disgusted faces (Isaacowitz et al., 2007). In line with the age-related positivity bias: old adults were less accurate at identifying faces with a fearful expression. There were no age differences for any other emotion. However, the use of photographic stimuli in these two studies means that, as in the dot probe and other emotional categorisation studies outlined above, the reported age differences may have been attributable to low level visual confounds contained within the stimulus set.

Isaacowitz et al. (2007) have also included emotional sentences that would not have been subject to visual confounds in a separate detection test. Participants were asked to read sentences describing an emotional situation and identify the emotion being expressed in the text from anger, disgust, fear, happiness, sadness or surprise. Old adults were significantly more likely to bias happy, sad and surprised responses than young adults, but no other criterion biases were reported. In contrast to the findings for face stimuli, the kappa scores indicated that old adults were less accurate than young adults at categorising happiness, surprise, anger and disgust. There were no other age or emotion effects. These results are inconsistent with research that supports an age-related positivity bias (with the exception of angry sentences).

One possible explanation for the discrepancy is that previous emotional categorisation studies were subject to response biases that may have, for example, inflated accuracy rates for positive stimuli for old adults. Another account is based on the notion that Isaacowitz et al. (2007) did not use well controlled lexical stimuli. Sentences predominantly involved references to young topics (e.g. 'the young boy smiled at the girl') and so, given that individuals are more accurate at identifying emotions expressed by peers of the same age (Malatesta et al., 1987), this could explain why young adults were more accurate at categorising happy, surprised and disgust sentences. Arousal ratings were also likely to have been affected by the reference to young topics; references to own age peers are more arousing, and therefore higher arousal levels could account for why the young individuals were more accurate at categorising happy, surprise and disgust sentences. However, no analysis of arousal ratings were reported and so it is difficult to take make any conclusive interpretations.

To summarise, a number of studies suggest that ageing is associated with a relative preference for processing positive over negative information. However, support has mainly come from studies that have used indirect measures (RT or eye movements), stimuli that may have been subject to differences in low level visual features (in the case of photographs of facial expressions) or arousal (in the case of lexical stimuli), or have not taken age-related response biases into consideration.

1.4.2 Evidence against an age-related positivity bias

Although the studies reported above suggest that there may be an age-related bias for positive information, the literature is not entirely clear cut. This next section will review studies that are not consistent with the age-related positivity effect, starting with research that has failed to find an age-related bias in orientation for positive information.

Two visual search studies found no age differences in search times for threat and happy schematic face targets. In a study by Mather and Knight (2006), participants were asked to search nine schematic faces and indicate whether a discrepant face was present or absent in the matrix. Eight of the nine faces were always neutral and the ninth was either emotional (angry, happy or sad) or neutral (see Figure 1.8). No age differences were found for threat stimuli: both old and young adults were faster to detect angry compared to happy, sad and neutral faces. This would suggest that the threat detection advantage is maintained in later life.

Figure 1.8 Examples of the schematic face stimuli used in Mather and Knight (2006). The faces display neutral, angry, sad and happy expressions (from left to right).

Hahn, Carlson, Singer and Gronlund (2006) also required participants to locate a discrepant face target (displaying either an angry or happy expression) in a matrix of up to 20 schematic faces. Both old and young adults were faster to detect angry compared to happy and neutral faces. However, when the angry faces served as non-target distractors, young adults' search was less effective than when happy or neutral faces were used as non-target distractors. In contrast, old adults showed a more efficient search with angry distractors than happy or neutral distractors, suggesting that old adults are better at automatically searching among angry facial expressions. This is in line with evidence for an age-related reduction in perceptual capacity (the reduced interference is likely to reflect a reduced capacity for taking in additional information; see section 1.5.2 for further discussion). Taken together, these two visual search studies would suggest that there is a bias for detecting threat stimuli in both young and old adults.

In a different visual search study that used colour photographs of objects (Leclerc & Kensinger, 2008), participants were asked to indicate whether a discrepant target (a stimulus of a different category to other items in the display, such as a snake amongst cars) was present or absent in a matrix of nine images. Images were either positive or negative and either high or low arousal (based on ratings provided by participants). Both age groups were faster to detect high arousal images compared to low arousal and neutral images. Old adults detected positive and negative images equally (and both faster than neutral images), whereas young adults were faster to detect positive (vs negative) high arousal images. This finding is inconsistent with the hypothesis that old adults allocate proportionately more resources to positive relative to negative information, as here the young adults appear to bias positive information; old adults displayed no valence preferences. However, the colour photographs used by Leclerc and Kensinger (2008) were not equated for low level visual differences and so an alternative account could be that the results were subject to visual confounds (Purcell et al., 1996). Further, the indirect assessment of perception, namely RTs, do not inform us about age differences in perceptual sensitivity for stimuli.

In a word valence detection study by Keightley et al. (2006) that was not subject to low level visual differences, however, no age differences emerged when participants were asked to classify words as either positive, negative or neutral. In fact, both age groups were slower and less accurate at categorising neutral compared to positive and negative words. This could be due to the neutral words being more ambiguous than the positive and negative words, meaning that categorisation decisions for neutral words would have been less clear cut (leading to more errors and longer RTs). That said, response criterion was not taken into consideration and so it is unclear whether the findings reflect perceptual sensitivity or whether the true perceptual sensitivity was masked by response biases.

Another line of research using lexical stimuli that appears inconsistent with the age-related bias for positive information used the emotional blink paradigm (Langley et al., 2008). Participants were required to identify coloured target words in an RSVP stream (see Figure 1.9). The first target word (T1) was always neutral, and the second target word (T2) was either emotional (positive or negative) or neutral. The T1 to T2 interval was manipulated (using a lag of between 1 to 8 items). Following the RSVP stream, participants were asked to identify T1 and then T2.

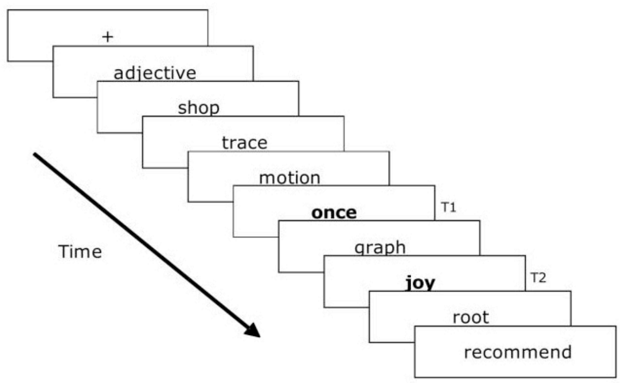

Figure 1.9 An example of a RSVP stream from Langley et al. (2008). The target words (T1 and T2) were presented in red and green (shown in bold here), and the rest of the words were presented in black.

Old adults were less accurate at identifying T1 and T2 compared to young adults. Therefore in order to compare the effects of emotion, baseline accuracy for T1 identification was equated between age groups (by reducing the exposure duration of words in the RSVP stream for young adults). Once baseline accuracy was equated, old adults showed enhanced T2 identification for both positive and negative words relative to neutral words. Conversely, young adults showed an enhanced identification of positive words and reduced identification of negative words. This would appear inconsistent with the age-related positivity effect. However, only three positive, three negative and three neutral words were used in the experiment. Such small stimulus sets mean that there may have been a sampling bias between age groups such that one of the word categories could have been more meaningful to one age group than the other. Thus, meaningfulness rather than valence could have accounted for the age effects.

To summarise, studies using the visual search (Hahn et al., 2006; Leclerc & Kensinger, 2008; Mather & Knight, 2006), emotional categorisation (Calder et al., 2003; Keightley et al., 2006) and emotional blink task (Langley et al., 2008) have produced findings that are inconsistent with the age-related positivity bias. However, the indirect measures from the visual search paradigm do not explicitly inform us about perceptual sensitivity; the detection tasks may have been subject to age differences in response biases (meaning that the results may reflect response criterion rather than perceptual sensitivity); and the use of such small stimulus set sizes in the emotional blink task (meaning that an age-related sampling bias could account for the findings) preclude further conclusions from being drawn about age differences in detection sensitivity for positive and negative information.

The research presented so far has been limited to stimuli that were fully attended. At the same time, there is a large body of work that looks at the effect of dividing attention on age differences in emotional perception that relates to my aim of assessing the role of attention in age-related changes to emotion perception. I review this literature in the next section.

1.5 Emotional perception under inattention

1.5.1 The effect of attention on age differences in emotional perception

One line of work studying the effect of attention on age differences in emotional perception has used the spatial cuing paradigm. In a recent fMRI study, Brassen, Gamer and Buchel (2011) presented a valid, invalid or neutral cue that was superimposed on a task-irrelevant colour photograph (displaying a face with either a happy, sad, fearful or neutral expression). Participants were required to indicate the location of a dot that appeared shortly after the cue and picture onset (see Figure 1.10). After scanning, participants provided arousal ratings for the face stimuli presented in the experiment to ensure that there were no age differences in subjective arousal (indeed no age differences in arousal ratings emerged).

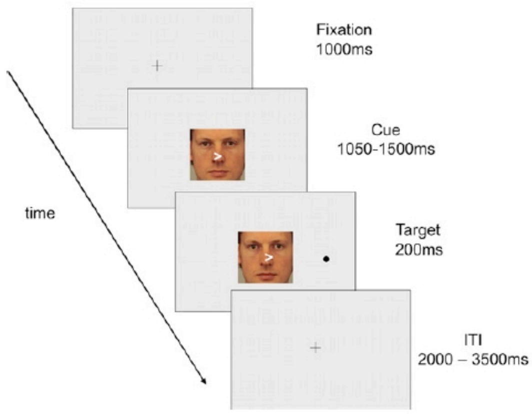

Figure 1.10 Experimental design from Brassen et al. (2011). A valid cue and a neutral facial expression are displayed in this example.

Both age groups were slower to respond to the probe when a neutral (vs valid) cue was shown, indicating an effective manipulation of attention by the different cues. Of central interest in the present thesis were the effects of emotion. Old adults were slower at detecting the target on happy (vs neutral) face trials when a neutral cue was shown (but showed no effects of emotion on valid or invalid cue trials). This suggests that attentional resources are required for old adults to bias positive information (neutral cues have been found to allow greater face processing, whereas spatial cues reduce attentional resources on emotional faces by shifting covert attention to the cued region; Brassen et al., 2010). Young adults did not show any effects of emotion, or effects of validity on emotion, and fearful and sad faces did not produce any effects for either age group. The neuroimaging data supported the behavioural findings: old adults showed greater anterior cingulate cortex (ACC) activity during happy (vs neutral) face exposure on neutral (vs cued) trials. Young adults showed no effects of validity on emotion with regards to AAC activity, and there was no difference in ACC activity for sad or fearful faces for either age group.

Although the findings of Brassen et al. (2011) would suggest that attentional resources are required by old adults to bias positive information, the pictorial stimuli were not equated for low level visual differences (such as colour or contrast; Purcell et al., 1996). Therefore, as in previous studies, visual confounds contained within the facial stimulus set could not be ruled out. In addition, the indirect measures of RTs and neural activity do not inform us about age differences in perceptual sensitivity.

Other research looking at age difference in the effect of dividing attention on emotional perception has produced mixed results. One study found that dividing attention does not affect the age-related bias for positive information (Allard & Isaacowitz, 2008), whereas two other studies have found that a bias for positive information is no longer apparent in old adults when attention is divided (Knight et al., 2007; Mather & Knight, 2005). In the study by Allard and Isaacowitz (2008), participants were asked to view positive, negative and neutral images taken from the IAPS that were presented individually on screen in either a full (simply view the images) or divided attention condition (view the images and engage in an auditory word/non-word discrimination task). Eye tracking was recorded so that age differences in gaze preferences could be assessed. Old adults had a fixation preference for positive and neutral over negative images in both the full and divided attention conditions, indicating that the positivity bias in old adults may not necessitate full cognitive control to implement the goal of biasing positive information. Young adults showed a fixation preference for neutral over positive images, and positive over negative images in the full attention condition, but an advantage only for neutral over negative images in the divided attention condition. These findings for young adults are inconsistent with previous research showing that young adults allocate proportionately more resources towards negative information.

In another divided attention study, Mather and Knight (2005) asked participants either to just view positive, negative and neutral pictures taken from the IAPS (full attention condition) or to look at the images and engage in an audio discrimination task (indicate whether a sound changed once or twice during the trial; divided attention condition). A surprise recall test was given after the experiment, and subjective valence and arousal ratings were collected for the images (to ensure that ratings were equated between conditions and age groups). Old adults recalled more positive (vs negative and neutral) images in the full attention condition, but the pattern for old adults was reversed in the divided attention condition: more negative (vs positive and neutral) stimuli were recalled. This suggests that attentional resources are required by old adults to allocate attention to positive (and away from negative) information. Young adults recalled more negative compared to positive stimuli in both the full and divided attention conditions. However, it is possible that these results were due to age related memory biases rather than any differences in perception.

A more recent eye tracking study using IAPS pictures and also greyscale photographs of facial expressions (Knight et al., 2007) presented neutral-emotional (positive or negative) image pairs. Participants were asked either to look at the image pairs (full attention condition) or to look at the image pairs and indicate whether a concurrently playing tone changed twice or three times (divided attention condition). In line with the age-related positivity bias, old adults spent proportionately more time looking at positive compared to negative images in the full attention condition, whereas young adults spent more time looking at negative compared to positive images. However, in the divided attention condition a different pattern emerged: old adults showed a fixation bias for negative (vs positive) images and young adults no longer showed a negative bias (fixation preferences were the same for negative and positive pictures). This trend was the same for IAPS pictures and facial expressions. Thus when attentional resources were available, old adults prioritised positive images but when attentional resources were consumed by a secondary task, a negative bias emerged in old adults.

One explanation for the inconsistency in results between Allard and Isaacowitz (2008) and Knight and colleagues (Knight et al., 2007; Mather & Knight, 2005) is a difference in the level of demand incurred by the secondary task. In Allard and Isaacowitz (2008), the secondary task involved a brief auditory (word/non-word) stimulus presented at the beginning of the (2 second) image presentation. This was likely to have placed minimal demands on attentional resources meaning that the old adults were still able to actively prioritise the positive information. In contrast, the studies conducted by Knight and colleagues (Knight et al., 2007; Mather & Knight, 2005) appeared to use more demanding secondary tasks that required attention for the full duration of image pair presentation. It is therefore possible that the negativity bias found in divided attention conditions for old adults by Knight and colleagues (Knight et al., 2007; Mather & Knight, 2005) was due to more consistent demands being placed on cognitive control abilities (leaving no spare capacity to prioritise the positive stimuli). The less demanding secondary task in Allard and Isaacowitz (2008) was likely to have left spare capacity for cognitive control abilities to still prioritise the positive stimuli.

Of the three divided attention studies reported above, only one matched age groups on subjective valence and arousal ratings (Mather & Knight, 2005). The other two (Allard & Isaacowitz, 2008; Knight et al., 2007) used ratings taken from published norms (based on data from young adults). Consequently, valence and arousal attribution could have differed between the age groups. The importance of matching idiosyncratic valence and arousal ratings between age groups has been demonstrated by Gruhn and Scheibe (2008) who asked old and young adults to rate IAPS images for valence and arousal. Old adults rated negative pictures as more negative but positive and neutral pictures as more positive compared to young adults. The old adults also rated negative and neutral images as more arousing and positive pictures as less arousing than young adults. Stimuli that are more arousing are more attention-grabbing than less arousing images, and so if stimuli are not equated between age groups, then differences in arousal could bias the results. In addition, the measures taken in these studies (e.g. memory and eye movements) do not inform us about age differences in perceptual sensitivity.

The effects of age differences in selective attention on emotional perception have been studied in another line of work looking at distractor interference effects. This literature is reviewed in the next section.

1.5.2 The effect of selective attention on emotional distraction

The majority of ageing research examining interference effects from task-irrelevant emotion has shown that old adults have a reduced distractor interference effect relative to young adults (Ashley & Swick, 2009; Hahn et al. 2006; Lamonica et al., 2010; Thomas & Hasher, 2006). However, two previous studies have found no such age differences. For example, in an emotional Stroop study by Monti, Weintraub and Egner (2010), participants were asked to indicate whether a target face expressed fear or happiness. The word 'fear' or 'happy' was superimposed on top of the face (see Figure 1.11). Both old and young adults were slower and less accurate when the word and face were incongruent compared to congruent, but no age differences in these congruency effects on RT or error rates were found.

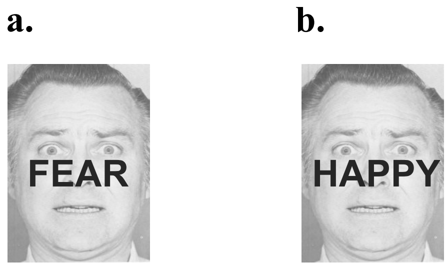

Figure 1.11 Stimuli used in Monti et al. (2010). Participants identified the emotional expression of the face while a congruent (a) or incongruent (b) distractor word was superimposed on the face.

Sammerz-Larkin et al. (2009) also found no age differences in the interference effects from emotional words. Participants were required to indicate whether centrally located words were positive or negative while ignoring two flanking stimuli of either the same (congruent), opposite (incongruent) or no (non-word) valence category. Incongruent flanking words slowed RTs more than congruent flanking words for all participants. For both young and old adults, negative incongruent flanking words produced greater interference on positive word trials than positive incongruent flanking words on negative word trials. No age differences were reported. However, as in previous emotional categorisation studies (e.g. Isaacowitz et al., 2007), these two distraction studies did not control for age differences in subjective arousal or valence intensity ratings for lexical stimuli. Therefore age differences in arousal or valence attribution may have distorted the results. For example, old adults may have found the words more intense and arousing compared to young adults, and this could have masked the age-related reduction in emotional distraction.

Indeed, Wurm et al. (2004), who collected valence and arousal ratings from an independent group of young and old adults in their emotional Stroop study, found that word arousal had a critical effect on interference for old, but not young adults. Whereas high arousal words slowed RTs more than low arousal words for old adults; for young adults high and low arousal words were equally distracting (i.e. RTs were not affected by arousal for young adults).

With the exception of Monti et al. (2010) and Sammerz-Larkin et al. (2009), ageing research has tended to find that old adults show a reduced distractor interference effect from emotion compared to young adults. Indeed in the visual search study by Hahn et al. (2006; presented in section 1.4.2), young adults' search was less effective when angry schematic faces served as non-target distractors (vs happy or neutral faces). In contrast, angry schematic faces did not cause greater interference than happy or neutral faces for old adults, suggesting that old (vs young) adults are better able to inhibit task-irrelevant angry facial expressions.

A number of studies using word stimuli have also found that old adults are less susceptible to emotional distraction than young adults. For example, in an emotional Stroop task by Lamonica et al. (2010) participants were asked to indicate the colour of words (that were either positive, negative or neutral) presented individually on screen. Stroop-type interference was assessed as any increases in colour naming RTs for emotional compared to neutral words. Old adults made more errors on neutral compared to emotional word trials, whereas young adults made more errors on emotional compared to neutral word trials. In other words, the emotionality of stimuli was detrimental to task performance for young adults but not old adults.

Ashley and Swick (2009) conducted a similar emotional Stroop paradigm but were specifically interested in whether there were age differences in the sustained interference from emotional words (i.e. whether emotional words affect task performance on subsequent neutral word trials). Participants were asked to name the ink colour of words presented individually on screen that were either negative or neutral. In contrast to Lamonica et al. (2010), no age differences emerged: young and old adults showed equivalent interference effects from the negative words (slower RTs in the negative compared to the neutral condition). Crucially, however, old adults did not show a sustained effect from the negative information, but young adults showed a persistent slowing that carried over from negative words to (up to seven) subsequent words. Note that Ashley and Swick (2009) only used negative words and so it is difficult to make any inferences about whether negative valence was specifically driving the sustained effect, or whether a general effect of emotion was responsible (and so positive vs neutral valence would have the same effect).

Additional evidence for an age-related reduction in emotional distraction has been provided from the flanker task (Thomas & Hasher, 2006). Participants were asked to indicate whether two numbers were the same (both odd or both even) or different (one odd and one even number). Task-irrelevant words (positive, negative or neutral) appeared between the two digits on each trial (see Figure 1.12).

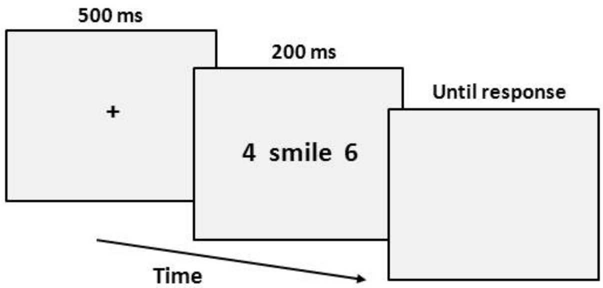

Figure 1.12 An example trial sequence from Thomas and Hasher (2006). After a fixation cross, participants indicated whether two numbers were the same (both odd or both even; shown here) or different (one odd and one even number). A task-irrelevant word (negative, neutral or positive; shown here) appeared between the two digits.

Old adults showed no RT differences based on the valence of the distractors. In contrast, young adults produced slower RTs when distractor words were negative, compared to when they were neutral or positive.

One explanation for the reduced interference from emotion in old compared to young adults can be found when combining perceptual load theory with evidence for an age-related reduction in perceptual capacity. The reduced perceptual capacity in old adults mean that they run out of available resources at a greater rate as load increases than young adults, and therefore smaller increases in load reduces interference. Indeed, as outlined above (section 1.2), there is a well-established literature on the effects of attentional load on perception.

1.6 Summary and aims of present thesis

In summary, my review has demonstrated that the literature on an age-related positivity bias is not entirely clear cut. On one side, dot probe and emotional categorisation studies using faces and emotional sentence have found that old adults show an orientation preference towards positive (vs negative) information (Isaacowitz et al., 2006; Lee & Knight, 2009; Mather & Carstensen, 2003) and an enhanced detection of positive relative to negative information (Calder et al., 2003; Isaacowitz et al., 2007; Keightley et al., 2006; McDowell et al., 1994; Moreno et al., 1993). Conversely, studies using schematic faces in the visual search task (Hahn et al., 2006; Leclerc & Kensinger, 2008; Mather & Knight, 2006); and lexical stimuli in both the emotional categorisation (Calder et al., 2003; Keightley et al., 2006) and emotional blink tasks (Langley et al., 2008) have produced findings that are inconsistent with an age-related positivity bias. On the other hand, indirect measures from the visual search task do not inform us about perceptual sensitivity; the detection tasks have either not accounted for age differences in response biases (meaning that the results may reflect response criterion rather than perceptual sensitivity); or did not account for age differences in valence and arousal attribution, and the use of small stimulus set sizes in the emotional blink task (meaning that a sampling bias between age groups could account for the findings) preclude conclusive inferences from being drawn regarding age differences in detection sensitivity for emotional information. Thus in the present thesis I used stimuli that were equated for low level visual properties and valence and arousal attribution to assess age-differences in valence detection sensitivity.

With respect to research on age-differences in emotional perception under inattention, mixed findings have also emerged. Whereas one study found that dividing attention does not affect the age-related positivity bias (Allard & Isaacowitz, 2008), a spatial cuing study has indicated that attentional resources are required for old adults to show increased interference from positive (vs negative) information (Brassen et al., 2011) and two other divided attention studies found that the age-related positivity bias is no longer apparent in old adults when attention is divided (Knight et al., 2007; Mather & Knight, 2005). The discrepancy can be accounted for in terms of the level of demands incurred by the secondary task: the study that placed minimal demands on attentional resources found that old adults were still able to prioritise positive information (Allard & Isaacowitz, 2008), whereas the studies with a more demanding secondary task (Knight et al., 2007; Mather & Knight, 2005) showed that the positivity bias is no longer apparent in old adults when attention was divided. However, these previous divided attention tasks used indirect measures (RTs and eye movements) that do not inform age differences in perceptual sensitivity towards the emotional stimuli. Further, whereas some studies controlled for age differences in subjective valence and arousal ratings (Mather & Knight, 2005), others could have been subject to age differences in valence intensity or arousal attribution (Allard & Isaacowitz, 2008; Knight et al., 2007).

The majority of ageing research examining interference effects from task-irrelevant emotion has shown that old adults have a reduced distractor interference effect, relative to young adults (Ashley & Swick, 2009; Hahn et al. 2006; Lamonica et al., 2010; Thomas & Hasher, 2006; but see Monti et al., 2010 and Sammerz-Larkin et al., 2009). This can be accounted for by combining perceptual load theory and evidence for an age-related reduction in perceptual capacity (the reduced perceptual capacity in old adults mean that they run out of available resources at a greater rate than young adults as load increases). Therefore the final aim was to assess whether high perceptual load conditions could have the positive consequence of reducing old adults' susceptibility to task-irrelevant emotional distraction to a greater extent than young adults. Next, I describe the methodological approach used in this thesis to test the important issues raised by this review.

1.7 General methodological approach and overview

The experiments in the following chapters used a signal detection approach to assess age differences in perceptual sensitivity to valence, free from any response biases. Participants were required to detect the presence (Chapter 2) or emotionality (Chapters 3 and 4) of stimuli in tasks that allowed detection sensitivity (d') and response bias (β) to be estimated.

In Chapter 2, I used the recently established load induced blindness paradigm (Macdonald & Lavie, 2008) to examine age differences in the effects of perceptual load on detection sensitivity for threat and neutral stimuli that were visually equated. To ensure that any observed differences in detection sensitivity were purely due to valence, stimuli in which one feature arrangement depicted a high threat stimulus (a spider; known to elicit consistent emotional responses even in non-phobic individuals, Kindt, Bierman & Brosschot, 1997; Arrindell et al., 1991), and an alternative arrangement of the very same features that depicted a neutral stimulus (a flower), were used (see Vuilleumier & Schwartz, 2001, for a previous report using these stimuli). Perceptual load was manipulated using a letter search task that required participants to search for an X or N in a circle of letters under either low (no target-similar items), or high load conditions (five target-similar items; Lavie & Cox, 1997). As reviewed in section 1.2, high (vs low) perceptual load has previously led to a consistent reduction in sensitivity for detecting neutral stimuli (e.g. Macdonald & Lavie, 2008).

Chapter 3 extended the findings of Chapter 2 to a wider range of stimuli, including stimuli of positive valence. Previous emotional detection tasks using photographs of facial expressions have generally not accounted for low level visual differences. Conversely, lexical stimuli are not subject to differences in visual appearance and can convey meaningful emotional information pertaining to our complex social environment. Thus the task in Chapter 3 required participants to report whether briefly presented words were emotional or neutral (see Nasrallah et al., 2009, for a similar paradigm). Note that unlike Chapter 2, the task did not require present or absent detection (as a word was presented on every trial), but a response as to whether the word was emotional or neutral (i.e. detection of emotional valence). Each block contained neutral words and one type of emotional word (either positive or negative). In this way, separate false alarm rates (misclassifying neutral words as negative or as positive) could be calculated and sensitivity derived for each valence condition. To achieve valid, robust and reliable findings, a large corpus of words was used (88 negative, 88 positive, and 176 neutral words; Appendix I) and subjective pleasantness and arousal ratings were taken for each participant. Therefore, in addition to controlling for word length and lexical frequency, differences in subjective valence and arousal ratings could be equated between conditions.

Only one stimulus was presented on each trial in Chapter 3 and so the valence detection task should have received full attention. The purpose of Chapter 4 was to assess whether age differences in emotional perception are dependent on the availability of attentional resources. As in Chapter 3, a signal detection method was used to measure sensitivity differences between positive and negative valence conditions. An experiment was devised that integrated a perceptual load task and the valence detection paradigm. The perceptual load task was the same as the letter search task used in Chapter 2: participants searched for an X or N in a circle of letters under low (no target-similar items) or high load conditions (five target-similar items). A word was also presented at fixation on every trial (as in Chapter 3) simultaneously with the circle of letters. Word valence was either emotional (negative or positive depending on the block) or neutral, and participants were required to categorise the word according to its valence.

Finally, I considered the issue of emotional distraction in Chapter 5. The goal was to reveal any age differences in interference from task-irrelevant emotion (as indexed by a RT and error rates) under different conditions of perceptual load. Participants were asked to make speeded responses as to whether or not two peripheral lines were parallel, whilst ignoring task-irrelevant distractor words (either positive, negative or neutral) presented at fixation. Perceptual load was manipulated by varying the angular difference of lines on non-parallel trials so that the task was either low load (90° angular difference between lines on non-parallel trials) or high load (12° angular difference between lines on non-parallel trials).

Chapter 2:

The effects of load on detection sensitivity of threat

2.1 Chapter Introduction

A bias for processing negative (vs positive or neutral) stimuli (e.g. Eastwood et al., 2001; Fox et al., 2000; Ohman et al., 2001) that manifests itself in perceptual sensitivity measures (Nasrallah et al., 2009) is well established in young adults. In contrast, ageing research specifically relating to threat perception is mixed. Old adults were slower to detect targets on the dot probe task that replaced supraliminally presented angry (vs neutral) facial expressions (Mather & Carstensen, 2003; Lee & Knight, 2009), but not when angry faces were presented subliminally (Lee & Knight, 2009). Moreover, a number of visual search studies found that old (and young) adults had faster search times for threat compared to neutral schematic face targets (Hahn et al., 2006; Mather & Knight, 2006). These studies used indirect measures, such as RTs and fixation preferences, and as discussed in depth in the General Introduction, consequently do not necessarily reflect detection sensitivity for the stimuli.

Studies that have directly assessed conscious perception have found that old adults are less accurate at categorising angry and fearful facial expressions compared to young adults (Calder et al., 2003; Keightley et al., 2006), even when age differences in response strategy and general biases are taken into account (Isaacowitz et al., 2007; McDowell et al., 1994). However, the photographs of facial expressions in these studies were not equated for low level visual differences, and therefore visual confounds contained in the stimuli can not be ruled out (Purcell et al., 1996).

In the present chapter I assess age differences in the effects of load on perceptual sensitivity of threat (vs neutral) pictorial stimuli that are visually matched. I used stimuli in which one feature arrangement depicted a high threat stimulus (a spider; known to elicit consistent emotional responses even in non-phobic individuals; Arrindell et al., 1991; Kindt et al., 1997), and an alternative arrangement of the very same features that depicted a neutral stimulus (a flower; see Vuilleumier & Schwartz, 2001, for a previous report using these stimuli).

Previous perceptual load studies on young adults have presented detection stimuli in the periphery (e.g. Macdonald & Lavie, 2008). Therefore I begin in Experiment 1 by presenting detection stimuli in the periphery. However, due to the issue of age differences in UFOV processing as outlined in the General Introduction, in Experiment 2 I presented the detection stimuli in more foveal locations to rule out the possibility that age differences in the UFOV processing could confound the results. Conscious detection of stimuli was measured directly via a present/absent response on every trial. I employed a signal-detection approach and measured both sensitivity and response bias to assess whether any valence-detection advantage reflect enhanced sensitivity, rather than a mere response bias. Each block of trials contained presentations of neutral words and one type of emotional word (either positive or negative), thus allowing the separate measurement of hits and false alarm rates (misclassifying neutral words as emotional) for each valence.

Ageing research using dual-task paradigms have tended to find a negativity bias (Knight et al., 2007; Mather & Knight, 2005, but note Allard & Isaacowitz, 2008). Since a divided attention task is being employed in the current chapter, an advantage for threat (over neutral) stimuli is predicted for both old and young adults. Based on the evidence for an age-related reduction in perceptual capacity outlined in the General Introduction, I also predicted that the detection sensitivity advantage for threat (over neutral) stimuli will be modulated to a greater extent for old compared to young adults.

2.2 Experiment 1

Participants were presented with a circle of letters and asked to search for a specific target (X or N). Following the search response, participants were required to indicate (present or absent) whether or not they detected an additional stimulus (that was either threat or a neutral) located outside the circle of letters. Perceptual load was manipulated by varying the number of letters that were similar to the target (no similar items in low load condition; five in high load condition; Lavie & Cox, 1997).

Method

Participants

Participants in this and all subsequent experiments were native English speakers, had normal or corrected-to-normal vision and reported no history of neurological or psychiatric disorders. Participants were excluded if mean search RT was greater than two standard deviations from the overall mean, if performance accuracy on the search task was lower than 50% or if the Snellen visual acuity score was less than 6/10.

Old adults. Forty-five old adults were recruited via advertisements placed in community centres. Five participants were excluded for having performance accuracy on the search task lower than 50%, nine were excluded for having a Snellen visual acuity score of less than 6/10 and a further seven were excluded for failing to fulfill task requirements. The age range of the old adults included in the final analysis was 65 to 80 years (M = 70.75, SD = 3.63; 7 male).

Young adults. Twenty-seven young adults were recruited via the UCL Department of Psychology subject pool. Three participants were excluded for having a mean accuracy on the search task lower than 50% and two were excluded for having a mean search RT greater than two standard deviations from the overall mean. The age range of the young adults included in the final analysis was 18 to 29 years (M = 22.38, SD = 3.16; 13 male).

Screening

All participants were tested on a battery of cognitive and visual tests. IQ was assessed using the 88-item Mill Hill Vocabulary Scale (Raven & Rust, 2008; see Table 2.1), visual acuity was measured using the Freiburg Visual Acuity Test (Bach, 1996) and the Mini-Mental State Examination was administered to evaluate mental health (Becic, Kramer & Boot, 2007; Fischer et al., 2005; Neiss et al., 2009; Wright et al., 2006). Independent samples t-tests indicated that young and old adults included in the analysis did not significantly differ on any measure other than age (all p-values > .13).

Table 2.1 Participant characteristics and screening results for Experiment 1.

	Old adults (*n* = 24)		Young adults (*n* = 22)		*p* -value
Measure	*Mean*	*(SD)*	*Mean*	*(SD)*	
Age*	70.75	*(3.63)*	21.54	*(3.49)*	< .01
Years in education	14.75	*(2.66)*	15.90	*(2.40)*	.131
IQ (raw score from Mill Hill Vocabulary Scale)	67.17	*(6.16)*	64.67	*(5.75)*	.153
Mini Mental State Questionaire Score	29.40	*(.80)*	29.60	*(.70)*	.425
Foveal visual acuity (Snellen decimal)	1.10	*(.12)*	1.16	*(.15)*	.144
Peripheral visual acuity (Snellen decimal)	1.03	*(.14)*	1.06	*(.15)*	.561

*Asterisks highlight significant differences between age groups.

Apparatus and stimuli

The experiment was presented using Matlab (The MathWorks, Inc., 1994-2008) on a laptop computer with a 15” display (60 Hz refresh rate). A viewing distance of 57 cm was maintained with a chinrest throughout the experiment. Six letters were presented, equally spaced (nearest contours 0.95° apart), in a circle of 1.7° radius that was centred at fixation. The background of the display was mid-grey (RGB values: 187, 187, 187), the letters were black and the detection stimuli was dark grey (RGB values: 168, 168, 168 for young and 117, 117, 117 for old adults). Pilot testing indicated that the stimuli used for old adults produced a ceiling level of detection sensitivity scores for the young adults. The stimuli contrast was therefore set at a level at which mean percentage hit rates and detection sensitivity scores did not significantly differ between young (*M* hit rate = 61%; *M d*’= 1.32) and old adults (*M* hit rate = 60%;

M d'= 1.32) for neutral stimuli in the low load condition ($t(44) = .378$, $SEM = 2.979$, $p = .707$ for hit rate; $t(44) = .017$, $SEM = .152$, $p = .986$ for *d*').

The target letter, equally likely to be either a Z or X (0.5° by 0.5°), was equally likely to appear in one of the six letter locations (see Figure 2.1). The remaining five locations were occupied by small zeros (0.2° by 0.2°) on low load trials, and by the letters K, F, V, T and L (same size as the target letter) on high load trials. The detection stimulus (0.7° by 0.7°) was presented at one of six equally spaced locations arranged in a circle of radius 4.5°. Each detection stimulus location lay on an imaginary line that passed through the fixation point and bisected two adjacent letter locations.

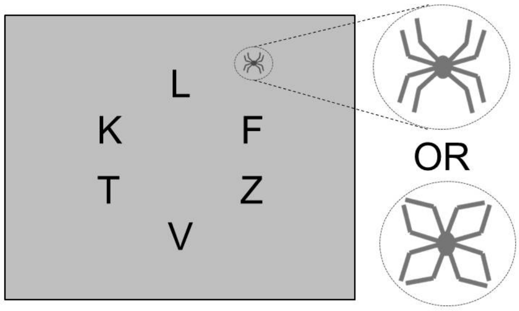

Figure 2.1 An example of a stimulus display from a high load trial in Experiment 1. The threat or neutral stimulus could appear in one of six locations. Not drawn to scale.

The combinations of target letter location and detection stimulus location were counterbalanced, so that for each target letter location the detection stimulus was presented once in each of four locations, the two nearest locations to the target letter (one on either side) and the two furthest locations. The stimuli were presented in four blocks of 72 trials with threat and neutral critical stimuli each presented on 12 randomly selected trials per block (threat stimuli presented on 17% of trials and neutral stimuli presented on 17% of trials). In each block, each of the stimulus types appeared twice in each of the six locations forming the circle. A counterbalanced set of 288 different stimulus displays consisted of each of the target letters (X or Z) in each of the letter circle locations (six), either with or without the critical stimulus in each location (six), and its location relative to the target (near or far). The control block used a quarter of the displays from each experimental block, such that the detection stimulus still appeared twice at each of the six locations.

Procedure

At the start of each trial, a fixation dot was presented in the centre of the screen for 1 s, followed by a 100 ms search task display (which included a detection stimulus on 34% of trials). A mask (a black mesh pattern covering the whole screen) was then presented for 500 ms, followed a blank screen that lasted for 1.5 s (making a total of 2 s during which participants could make the search task response; see Figure 2.2). Next, a display containing a question mark at fixation was presented for 100 ms. Participants were required to make their detection task response upon the presentation of this question mark. This was followed by a blank screen for 1.9 s (making a total of 2 s during which participants could make the detection task response). Both 2 s time windows elapsed regardless of whether a response was given.

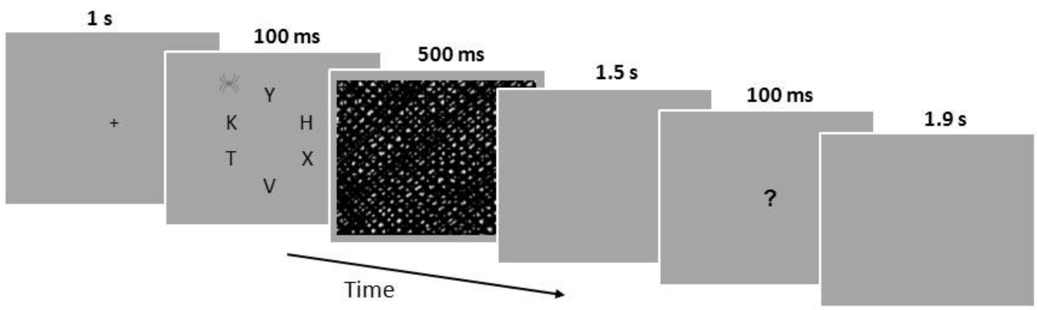

Figure 2.2 An example of a high load trial sequence from Experiment 1. A fixation dot preceded the letter search task display of either high (shown) or low perceptual load. A neutral or threat (shown) stimulus was presented on some trials. Participants indicated by key press whether the

target letter was X or Z and then, when the question mark appeared, whether they noticed an additional stimulus. Diagram not to scale.

Participants were required to press ‘1’ with the middle finger of their left hand if X was shown, or ‘2’ with the index finger of their left hand if Z was shown. Participants were instructed to make responses as quickly and as accurately as possible. Detection of the additional stimulus was indicated by pressing the left arrow for ‘present’ or the down arrow for ‘absent’ using the index and middle fingers of their right hand, respectively. No feedback was provided on either the search or detection task.

Before starting the experiment, participants were shown ten example trials with no additional detection stimulus, followed by ten example trials with a detection stimulus. Each participant then completed four experimental blocks of 72 trials. The order of the block was equally likely to be *High-Low-Low-High* or *Low-High-High-Low*, followed by a control block (72 trials; including 24 trials with an additional detection stimulus) in which participants were instructed to respond to the presence of the additional stimulus and completely ignore the circle of letters.

Results and discussion

Letter search

Trials were excluded if the search response was incorrect (12% of trials for young; 23% of trials for old adults) or RT was greater than two standard deviations from the participants' overall mean RT (2% of trials for young; 3% of trials for old adults) in this and all subsequent experiments in this thesis. Mixed model two-way ANOVAs were conducted on mean search RTs and mean search error rates (presented in Table 2.2), with age (young or old) as a between-subjects factor and perceptual load (low or high) as a within-subjects factor. Both ANOVAs revealed a main effect of load ($F(1, 44) = 189.657$, MSE = 5393.0, $p < .01$, $\eta_p^2 = .812$ for search RTs; $F(1, 44) = 53.409$, MSE = 48.2, $p < .01$, $\eta_p^2 = .548$ for error rates): RTs were significantly slower (M = 936 ms) and error rates were significantly higher (M = 23%) in the high compared to low load condition (M RT= 722 ms; M error rate = 13%), confirming that the load manipulation was effective. As is typically found in ageing literature, older adults were slower (M = 895 ms) and made more errors (M = 23%) than young adults (M RT = 757 ms; M error rate = 12%), as indicated by a main effect of age for RTs ($F(1, 44) = 10.186$, MSE = 42851.6, $p = .003$, $\eta_p^2 = .118$) and errors ($F(1, 44) = 21.075$, MSE = 141.0, $p < .01$, $\eta_p^2 = .548$). There was an interaction between load and age for RTs ($F(1, 44) = 8.494$, MSE = 5393.0, $p = .006$, $\eta_p^2 = .162$) and error rates ($F(1, 44) = 5.824$, MSE = 48.2, $p = .020$, $\eta_p^2 = .117$): load increased RTs and error rates more for old (256 ms slower and 14% less accurate in high vs low load) compared to young adults (166 ms slower and 7% less accurate in high vs low load; see Humphrey & Kramer, 1997; Madden, Pierce & Allen, 1996; Plude & Doussard-Roosevelt, 1989, for similar findings).

Table 2.2 Search task performance for old and young adults in Experiment 1.

	Old adults				Young adults			
	Low load		High load		Low load		High load	
Search task	Mean	*(SD)*	Mean	*(SD)*	Mean	*(SD)*	Mean	*(SD)*
RTs (ms)	767	*(176)*	1023	*(173)*	674	*(139)*	840	*(123)*
Error rate (%)	16	*(9)*	30	*(14)*	8	*(6)*	15	*(7)*

Detection

Mean percentage hit rate and false alarm rate were calculated for all trials with a correct search response, and detection sensitivity (*d*') was derived from these values. These are presented in Table 2.3.

Table 2.3 Mean (*SD* in brackets) percentage hit rate, false alarm rate, *d'* and beta values for young and old adults under low and high load for threat and neutral stimuli.

	Neutral				Threat			
	Low load		High load		Low load		High load	
	Mean	*(SD)*	Mean	*(SD)*	Mean	*(SD)*	Mean	*(SD)*
Young adults								
Hit Rate (%)	61	*(16)*	41	*(16)*	67	*(13)*	65	*(15)*
False Alarm Rate (%)	20	*(14)*	20	*(12)*	20	*(14)*	20	*(12)*
d'	1.32	*(.96)*	0.73	*(.76)*	1.50	*(.98)*	1.39	*(.96)*
Beta	2.01	*(1.70)*	1.72	*(1.12)*	1.87	*(1.81)*	1.64	*(1.04)*
Old adults								
Hit Rate (%)	60	*(14)*	37	*(19)*	72	*(13)*	50	*(15)*
False Alarm Rate (%)	18	*(10)*	16	*(8)*	19	*(10)*	17	*(8)*
d'	1.32	*(.75)*	0.71	*(.61)*	1.69	*(.81)*	1.04	*(.53)*
Beta	2.04	*(1.73)*	1.64	*(.82)*	1.61	*(.94)*	2.08	*(1.48)*

Percentage hit rates and *d′* values were entered into mixed model ANOVAs with valence (threat or neutral) and perceptual load (high or low) as within-subject factors and age (young or old) as a between-subjects factor. As expected from previous research, hit rates and *d′* were reduced from low to high load ($F(1, 44) = 75.085$, $MSE = 179.5$, $p < .01$, $\eta_p^2 = .631$ for hit rates; $F(1, 44) = 52.404$, $MSE = .2$, $p < .01$, $\eta_p^2 = .544$ for *d*') and there was an advantage for threat over neutral stimuli both for hit rates ($F(1, 44) = 115.077$, $MSE = 74.2$, $p < .01$, $\eta_p^2 = .723$) and *d′* ($F(1, 44) = 100.100$, $MSE = .1$, $p < .01$, $\eta_p^2 = .695$).

There was an interaction between load and valence for hit rates ($F(1, 44) = 11.133$, $MSE = 81.1$, $p = .002$, $\eta p^2 = .202$) and *d′* ($F(1, 44) = 6.238$, $MSE = .1$, $p = .016$, $\eta p^2 = .124$), indicating that there was a greater load modulation for neutral (22% load modulation for hit rates; .60 load modulation for *d*') compared to threat stimuli (12% load modulation for hit rates; .38 load modulation for *d*'). This is in line with studies that have found that processing of threat stimuli is not modulated by attention to the same extent as neutral stimuli (Anderson et al., 2003; Attar & Muller, 2012; Vuilleumier et al., 2001).

Age did not affect hit rates ($F(1, 44) = 1.262$, $MSE = 589.6$, $p = .267$, $\eta_p^2 = .028$) or *d′* ($F(1, 44) = .041$, $MSE = 2.2$, $p = .841$, $\eta_p^2 = .001$). However, this is likely to be a result of matching hit rates and *d′* values between young and old adults in the low load condition for neutral stimuli that would have diluted any potential differences in other conditions by looking at the average. There was no interaction between age and valence for hit rates ($F(1, 44) = .560$, $MSE = 74.2$, $p = .458$, $\eta p^2 = .013$) or *d′* ($F(1, 44) = .932$, $MSE = .1$, $p = .340$, $\eta p^2 = .021$). More importantly, age interacted with load both for hit rates ($F(1, 44) = 8.121$, $MSE =$

179.5, p = .007, ηp^2 = .156) and d' (F(1, 44) = 4.301, MSE = .2, p = .044, ηp^2 = .089). This interaction suggests a larger load effect for the old (M load effect for hit rates = 23%; for d' = .63) compared to young adults (M load effect for hit rates = 11%; for d' = .35), this result however is qualified by the three-way interaction between load, valence and age for hit rates (F(1, 44) = 10.211, MSE = 81.1, p = .003, ηp^2 = .188) and d' (F(1, 44) = 8.640, MSE = .1, p = .005, ηp^2 = .164). Closer, inspection of Table 2.3 indicates that the interaction between age and load was driven by a load modulation of neutral (M hit rate = 20%; d' = .59) but not threat stimuli (M hit rate = 2%; d' = .11) for young adults (F(1, 21) = 35.578, MSE = 46.6, p < .01, ηp^2 = .629 for hit rates and F(1, 21) = 34.617, MSE = .1, p < .01, ηp^2 = .622 for d') but an equal reduction in both hits (see Figure 2.3a) and d' scores (see Figure 2.3b) for threat (M hit rate = 22%; d' = .65) and neutral stimuli (M hit rate = 23%; d' = .61) for the old adult group (F(1, 23) = .007, MSE = 112.6, p = .932, ηp^2 = .000 for hit rates and F(1, 23) = .066, MSE = .1, p = .799, ηp^2 = .003 for d').

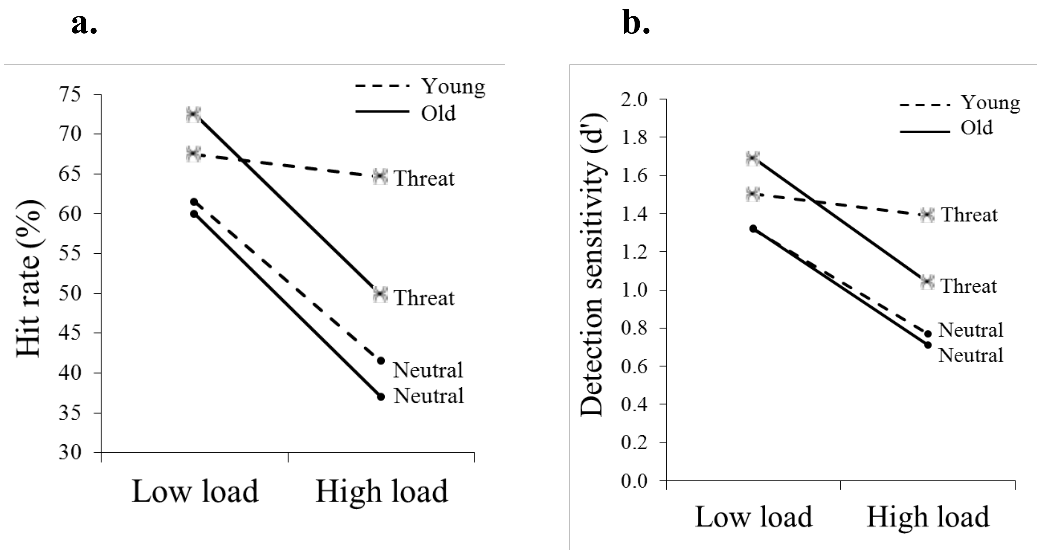

Figure 2.3 Mean hit rate (a) and d′ (b) for threat and neutral stimuli under low and high load for young and old adults in Experiment 1.

Mean response bias was also calculated for participants. Response criterion did not change between load conditions, between valence conditions or between age groups (all $F < 1$). The interactions between load and valence ($F(1, 44) = 1.428$, $MSE = 1.1$, $p = .238$, $\eta p^2 = .031$), age and load ($F < 1$), age and valence ($F < 1$) and age, load and valence ($F(1, 44) = 2.529$, $MSE = 1.1$, $p = .119$, $\eta p^2 = .054$) were all non-significant.

In the control block, where participants were not required to engage in the letter search task but just indicate when they noticed any additional stimulus, detection did not differ between high (M hit rate = 87%; M d' = 2.42) and low load conditions (M hit rate = 86%; M d' = 2.63) for hit rates ($F < 1$) or for d' ($F < 1$). This indicates that the reduction in hits and d' in the high (vs low) load blocks was related to engagement with the search task rather than any differences in the appearance of the displays.

In conclusion. Experiment 1 clarifies that there is a detection sensitivity advantage for threat (vs neutral) stimuli in both young and old adults. This was reflected in perceptual sensitivity measures, typically not accompanied by any response biases. Visually matched stimuli were used that were not subject to the alternative account of low level visual differences in previous studies that have used photographs of facial expressions (Calder et al., 2003; Isaacowitz et al., 2007; Keightley et al., 2006; Lee & Knight, 2009; Mather & Carstensen, 2003; McDowell et al., 1994). While the threat advantage was modulated by the level of perceptual load for old adults, for young adults it was not.

2.3 Experiment 2

Introduction

As outlined in the General Introduction, UFOV studies have shown that the efficiency of peripheral processing (above and beyond changes in visual acuity) declines with age. Therefore, although peripheral acuity scores were matched between old and young adults in Experiment 1, it remains possible that the greater modulation of threat by load in old adults was due to an age-related deterioration in the efficiency with which information could be extracted from the UFOV. Experiment 2 attempted to more conclusively rule out this alternative account. A new group of participants were asked to perform the letter search task and indicate whether they detected an additional stimulus. In addition to matching age groups on peripheral visual acuity scores, the location of detection task stimuli was moved from the periphery into more foveal regions. Instead of being presented outside the circle of letters (as in Experiment 1), detection stimuli were presented within the circle of letters in Experiment 2. This should allow for a more conclusive interpretation of whether the greater modulation of threat stimuli in old adults in Experiment 1 was due a general age-related reduction perceptual capacity, or whether it can simply be explained by an age-related decline in UFOV processing.

Method

Participants

Old adults. Thirty old adults were recruited from the University of the Third Age community in London. Two participants were removed due to a mean accuracy on the search task lower than 50%, three participants were removed due to a Snellen visual acuity score of less than 6/10, and one further participant was removed for failing to fulfil the task requirements. The age range of the old adults included in the final analysis was 65 to 82 years (*M* age = 69.75, *SD* = 3.77; 8 males).

Young adults. Twenty-five new young adults were recruited from the UCL Department of Psychology subject pool. One participant was excluded due to a mean accuracy on the search task lower than 50%. The age range of the young adults included in the final analysis was 18 to 26 years (*M* age = 22.11, *SD* = 2.70; 10 males).

Screening

As in Experiment 1, all participants were tested on a battery of cognitive and visual tasks (see Table 2.4 for results). Independent samples t-tests indicated that young and old adults did not significantly differ on any cognitive or visual test (all *p*-values > .23).

Table 2.4 Participant characteristics and screening results for participants in Experiment 2.

	Old adults		Young adults	
Measure	*Mean*	*(SD)*	*Mean*	*(SD)*
Age*	69.75	*(3.77)*	22.11	*(2.70)*
Years in education	17.08	*(2.93)*	16.71	*(3.03)*
IQ (raw score from Mill Hill Vocabulary Scale)	69.92	*(6.41)*	67.63	*(6.56)*
Mini Mental State Questionaire Score	29.63	*(.49)*	29.75	*(.44)*
Foveal visual acuity (Snellen decimal)	1.13	*(.11)*	1.18	*(.16)*
Peripheral visual acuity (Snellen decimal)	1.00	*(.15)*	1.06	*(.14)*

*Asterisks highlight significant differences between age groups.

Apparatus, stimuli and procedure

The apparatus, stimuli and procedure were the same as in Experiment 1, with one exception. The detection task stimulus was now always presented within the visual search task circle of letters at one of six equally spaced locations arranged in a circle of radius .85°.

In order to equate the cortical representation (termed cortical magnification; see Daniel & Whitteridge, 1961) of the peripheral stimuli used in Experiment 1 with the parafoveal stimuli used in Experiment 2, the stimuli sizes were scaled in accordance with the cortical magnification equations of Rovamo and Virsu (1979) and Virsu and Rovamo (1979). Specifically, stimulus size was scaled according to the average of the following two equations:

$$M(\text{nasal visual field}) = 1 + 0.33\,E + 0.00007\,E^3$$

$$M(\text{temporal visual field}) = 1 + 0.29\,E + 0.000012\,E^3$$

where E refers to the eccentricity in degrees of visual angle and M is the magnification factor.

According to the above cortical magnification equations, stimuli were reduced to .37° x .37° in order for the stimuli to activate the same amount of primary visual cortex.

Results and discussion

Letter search

Two-way mixed model ANOVAs were conducted on mean search RTs and mean error rates (shown in Table 2.5), with age (young or old) as a between-subjects factor and perceptual load (low or high) as a within-subjects factor. In line with Experiment 1 and previous literature, there were main effects of load ($F(1, 46) = 160.689$, $MSE = 7907.9$, $p < .01$, $\eta_p^2 = .777$ for RTs; $F(1, 46) = 220.426$, $MSE = 10.5$, $p < .01$, $\eta_p^2 = .827$ for error rates) and age ($F(1, 46) = 15.937$, $MSE = 29825.9$, $p < .01$, $\eta_p^2 = .257$ for RTs; $F(1, 46) = 8.465$, $MSE = 87.1$, $p = .006$, $\eta_p^2 = .155$ for error rates). RTs were slower ($M = 936$ ms) and the error rate was greater ($M = 20\%$) in the high compared to low load condition (M RT = 706 ms; M error rate = 11%) and older adults were significantly slower ($M = 891$ ms) and made significantly more errors ($M = 20\%$) than young adults (M RT = 750 ms; M error rate = 11%). The interaction between load and age was significant for RTs ($F(1, 46) = 10.784$, $MSE = 7907.9$, $p = .002$, $\eta_p^2 = .190$) and error rates ($F(1, 46) = 11.972$, $MSE = 10.5$, $p < .01$, $\eta_p^2 = .207$): load increased RTs and error rates more for old (290 ms slower and 12% less accurate in high compared to low load) compared to young adults (170 ms slower and 7% less accurate in high compared to low load). This is in line with Experiment 1 and previous studies which found that increasing the number of non-targets was more detrimental to old compared to young adults (e.g. Humphrey & Kramer, 1997; Madden et al., 1996; Plude & Doussard-Roosevelt, 1989).

Table 2.5 Search task performance for participants in Experiment 2.

	Old adults				Young adults			
	Low load		High load		Low load		High load	
Search task	Mean	*(SD)*	Mean	*(SD)*	Mean	*(SD)*	Mean	*(SD)*
RTs (ms)	746	*(154)*	1036	*(130)*	665	*(125)*	836	*(139)*
Error rate (%)	14	*(7)*	26	*(9)*	7	*(5)*	14	*(6)*

Detection

Mean percentage hit rate and false alarm rate were calculated for all trials on which participants gave a correct search task response, and detection sensitivity (*d*') was derived from these values (presented in Table 2.6).

Table 2.6 Mean (*SD* in brackets) percentage hit rate, *d'* and beta values in the high and low load conditions for threat and neutral stimuli.

	Neutral				Threat			
	Low load		High load		Low load		High load	
	Mean	*(SD)*	Mean	*(SD)*	Mean	*(SD)*	Mean	*(SD)*
Young adults								
Hit Rate (%)	59	*(16)*	36	*(19)*	66	*(15)*	60	*(19)*
d'	1.68	*(.68)*	1.05	*(.74)*	1.96	*(.65)*	1.41	*(.77)*
Beta	2.82	*(1.21)*	3.11	*(2.79)*	3.62	*(3.35)*	3.79	*(1.79)*
Old adults								
Hit Rate (%)	60	*(25)*	37	*(18)*	69	*(19)*	47	*(20)*
d'	1.32	*(1.03)*	0.71	*(.77)*	2.17	*(.87)*	1.41	*(.79)*
Beta	2.44	*(1.84)*	1.60	*(3.37)*	3.10	*(1.95)*	3.79	*(3.30)*

Percentage hit rates and *d'* scores were entered into mixed model ANOVAs with valence (threat or neutral) and perceptual load (high or low) as within-subject factors; and age (young or old) as a between-subjects factor.

Consistent with the results of Experiment 1, hit rates and *d′* were reduced from low to high load ($F(1, 46) = 126.866$, $MSE = 134.1$, $p < .01$, $\eta_p^2 = .734$ for hit rates and $F(1, 46) = 156.682$, $MSE = .1$, $p < .01$, $\eta_p^2 = .773$ for *d*') and an advantage for threat (vs neutral) stimuli was found for both hit rates ($F(1, 46) = 67.894$, $MSE = 153.6$, $p < .01$, $\eta_p^2 = .596$) and *d′* ($F(1, 46) = 63.372$, $MSE = .2$, $p < .01$, $\eta_p^2 = .579$).

Also in line with Experiment 1, the interaction between load and valence was significant for hit rates ($F(1, 46) = 57.188$, $MSE = 20.5$, $p < .01$, $\eta p^2 = .554$) and *d′* ($F(1, 46) = 21.440$, $MSE = .0$, $p < .01$, $\eta p^2 = .318$), revealing a greater load modulation for neutral (24% load modulation for hit rate; .71 load modulation for *d'*) compared to threat stimuli (14% load modulation for hit rate; .48 load modulation for *d'*).

Age did not affect the rate of detection ($F(1, 46) = .840$, $MSE = 1130.1$, $p = .364$, $\eta_p^2 = .018$) or detection sensitivity ($F(1, 46) = .011$, $MSE = 2.2$, $p = .919$, $\eta_p^2 = .000$). As discussed earlier (in Experiment 1 results) this is a likely result of matching hit rates and *d′* values between age groups for neutral stimuli in the low load condition, there was no interaction between age and valence for hit rates ($F(1, 46) = .069$, $MSE = 153.6$, $p = .794$, $\eta p^2 = .001$) or *d′* ($F(1, 46) = .803$, $MSE = .2$, $p = .375$, $\eta p^2 = .017$).

Crucially, age interacted with load for both hit rates ($F(1, 46) = 7.903$, $MSE = 134.1$, $p = .007$, $\eta p^2 = .147$) and *d′* ($F(1, 46) = 14.267$, $MSE = .1$, $p < .01$, $\eta p^2 = .237$): load modulated hit rates and sensitivity more for old (*M* reduction from low to high load = 24% for hit rates; .78 for *d′* scores) compared to young adults (*M* reduction from low to high load = 14% for hit rates; .42 for *d′* scores).

Closer inspection of Figure 2.4 indicates that this was driven by a load modulation of neutral but not threat stimuli for young adults ($F(1, 23) = 78.075$, $MSE = 25.4$, $p < .01$, $\eta p^2 = .772$ for hit rates and $F(1, 23) = 22.828$, $MSE = .1$, $p < .01$, $\eta p^2 = .498$ for *d*'); but an equal reduction in hits and sensitivity for threat and neutral stimuli for old adults ($F(1, 23) = 1.007$, $MSE = 15.7$, $p = .326$, $\eta p^2 = .042$ for hit rates and $F(1, 23) = .618$, $MSE = .0$, $p = .440$, $\eta p^2 = .026$ for *d'*). This is evidenced by a significant three-way interaction between age, load and valence for hit rates ($F(1, 46) = 39.948$, $MSE = 20.5$, $p < .01$, $\eta p^2 = .465$; see Figure 2.4a) and *d'* ($F(1, 46) = 15.466$, $MSE = .0$, $p < .01$, $\eta p^2 = .252$; see Figure 2.4b).

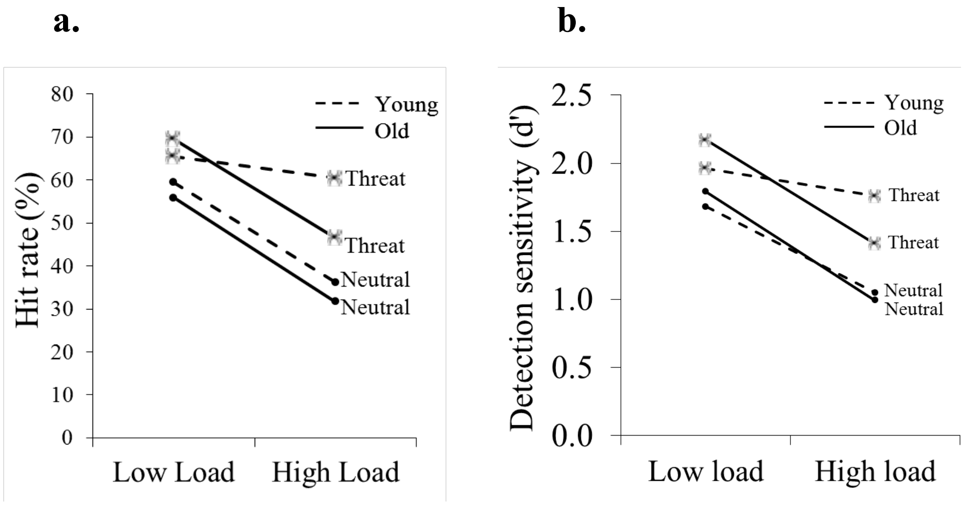

Figure 2.4 Mean hit rate (a) and d′ (b) for threat and neutral stimuli under low and high load for young and old adults in Experiment 2.

Mean response bias was calculated for both age groups under each condition of load and valence. As in Experiment 1, response criterion did not change between load conditions, between valence conditions or between age groups (all $F < 1$). The interactions between load and valence, age and valence, age and load; and age, load and valence were all non-significant ($Fs < 1$).

In the control block (where participants did not engage with the letter search task), detection performance was equivalent in high (*M* hit rate = 93%; *M* $d' = 2.87$) and low load conditions (*M* hit rate = 94%; *M* $d' = 3.03$) both for hit rates ($F < 1$) and d' ($F < 1$). This indicates that the reduction in hit rates and sensitivity in high relative to low load blocks in the main experiment was related to engagement with the search task rather than any differences in the appearance of the displays.

2.4 Chapter Conclusions

The present chapter demonstrates a threat (vs neutral) detection sensitivity advantage in both young and old adults under divided attention conditions. This was found under low and high perceptual load conditions. Whereas the threat and neutral stimuli were equally modulated by load for old adults, detection sensitivity for threat was not modulated by load for young adults. Alternative accounts in terms of age differences in UFOV processing, and low level visual differences in stimuli (faced by previous research using photographs of facial expressions; Calder et al., 2003; Isaacowitz et al., 2007; Keightley et al., 2006; Lee & Knight, 2009; Mather & Carstensen, 2003; McDowell et al., 1994) were ruled out.

The threat detection sensitivity advantage is in line with previous research showing that threat is prioritised over neutral stimuli in young adults (e.g. Eastwood et al., 2001; Fox et al., 2000; Ohman et al., 2001) and visual search studies that have found faster search RTs for threat compared to neutral schematic face targets in both young and old adults (Hahn et al., 2006; Mather & Knight, 2006). Whereas previous studies have tended to use indirect measures (e.g. RTs and fixation preferences) that may not reflect conscious perception, the present chapter employed a signal-detection approach that measured both sensitivity and response bias to directly assess perceptual sensitivity.

The finding that detection sensitivity for threat is not modulated by load for young adults would appear at odds with load theory. One potential explanation is that the threat stimulus is not subject to the same attentional constraints as neutral stimuli used in previous load studies (e.g. the meaningless grey figure used in MacDonald & Lavie, 2008). Indeed the threat image (known to elicit consistent emotional responses even in non-arachnophobic individuals; Arrindell et al., 1991; Kindt et al., 1997) may have a special socio-biological significance which meant that it is not subject to the same effects of perceptual load as neutral stimuli (see Lavie, Ro & Russell, 2003, for similar explanation regarding distractor faces that were affected by search load) due to a greater socio-biological evaluative strength (Matthews et al., 1997).

One possible explanation for the load modulation of threat in old but not young adults is that old adults are able to show an advantage for threat when attention can be paid to a stimulus to enhance its discrimination (i.e. under low load conditions), but when attention cannot be employed (i.e. under conditions of high load) then old adults are no longer able to discriminate between the threat and neutral stimuli to a level that can facilitate the threat (compared to neutral) detection. Conversely, young adults appear to be able to discriminate between the threat and neutral stimuli (and detect it) regardless of the level of available attentional resources. This suggests some age-related deterioration in pre-attentive perception of threat at least so far as the threat is conveyed through a visual image. In the next chapter I address the more general issue of negative valence detection in lexical processing of words.

Chapter 3:

Detection of emotional valence in words

3.1 Chapter Introduction

In the low load condition in Chapter 2, a threat detection advantage was found for both old and young adults. This raises the question of whether the findings are specific to the threat stimulus that was used (i.e. the spider), or whether is it the case that negative stimuli in general have an advantage over visually equated neutral stimuli when there are no attentional constraints. Further, the findings could reflect a more generic advantage for emotion, in which case the same would be found for positive (vs neutral) stimuli. Perhaps an even larger advantage would be found for positive (vs negative) stimuli in old adults given the evidence for an age-related positivity effect (Calder et al., 2003; Isaacowitz et al., 2006; Isaacowitz et al., 2007; Keightley et al., 2006; Lee & Knight, 2009; Mather & Carstensen, 2003; McDowell et al., 1994; Moreno et al., 1993). To address these questions, in Chapter 3 I used a wider range of stimuli, both positive and negative. I chose to use word stimuli to ensure that there would be no effects due to low level visual features.

Previous studies assessing age differences in emotional perception have tended to use photographic stimuli, such as IAPS images (Allard & Isaacowitz, 2008; Knight et al., 2007; Mather & Knight, 2005), pictures of objects (Leclerc & Kensinger, 2008) or photographs of facial expressions (Brassen et al., 2011; Calder et al., 2003; Calder et al., 2003; Isaacowitz et al., 2007; Keightley et al., 2006; Keightley et al., 2006; Lee & Knight, 2009; Mather & Carstensen, 2003; McDowell et al., 1994; Moreno et al., 1993). However, as discussed in the General Introduction, photographic stimuli are likely to differ in terms of low level visual properties that could confound the results (Purcell et al., 1996), and idiosyncratic valence and arousal ratings have often not been matched between age groups for IAPS images (Allard & Isaacowitz, 2008; Knight et al., 2007). Lexical stimuli are not subject to the same low level visual issues and can convey meaningful emotional information pertaining to our complex social environment. In addition, words can be equated for subjective valence and arousal ratings.

The few previous ageing studies that have used emotional lexical stimuli have either not taken response criterion into account (Keightley et al., 2006) or have used complex emotional sentences that predominantly involve references to young topics (e.g. 'the young boy smiled at the girl'; Isaacowitz et al., 2007). Given that individuals are more accurate at identifying emotions expressed by same age peers (Malatesta et al., 1987), this could have confounded with the emotion contained in the sentences. Further, no analysis of arousal ratings were reported and so it is impossible to determine whether subjective arousal for the lexical stimuli differed between age groups. In the present chapter, I took response biases into account and collected subjective valence and arousal ratings for all words in the experiment (meaning that valence, arousal and lexical frequency could be equated across conditions of valence and between age groups).

I used a new paradigm devised by Nasrallah et al. (2009) that allowed me to adopt signal detection analysis using lexical stimuli. Participants were asked to classify words as either emotional (positive or negative, depending on the block) or neutral. Splitting positive and negative valence into separate blocks allowed a separate measure of hit rate and false alarm rate to be recorded for each valence, meaning that a criterion-free measure of detection sensitivity could be calculated.

As in Nasrallah et al. (2009), I included a short and long word exposure duration to assess how reduced conscious perception affects emotional detection advantages for the words. In a previous ageing study that used short (50 ms for old adults, 20 ms for young adults) and long durations (1500 ms for both age groups; Lee & Knight, 2009), old adults were slower to respond to a dot probe that replaced a supraliminal angry (vs neutral) face, but were faster to locate dot probes that replaced subliminally presented angry (vs neutral) faces. This suggests that old adults actively avoid angry faces when provided with a sufficient exposure duration, but when conscious perception was diminished, this orientation pattern was no longer apparent and a negative orientation bias emerged. However, that was in a dot probe paradigm using photographic stimuli did not appear to rule out visual confounds.

If indeed negative information is prioritised by old adults when conscious perception is diminished then I would expect to find a negative advantage to emerge in the short duration condition for old adults in the present chapter. In the long duration condition, given that Lee and Knight (2009) found a reduced negative orientation bias when old adults are able to actively prioritise positive information, I predicted a reduced negative (vs positive) valence advantage in the long (vs short) duration condition for old adults. A detection advantage for negative over positive valence was expected for young adults in both exposure duration conditions, based on the findings by Nasrallah et al. (2009).

3.2 Experiment 3

Method

Participants

Old adults. Twenty-four old adults were recruited from the University of the Third Age in London. Ages ranged from 65 to 81 years (*M* = 72.21, *SD* = 4.78; 5 male).

Young adults. Thirty young adults were recruited from the UCL Department of Psychology subject pool and paid £5 for participating. Ages ranged from 18 to 30 (*M* = 23.53, *SD* = 3.30; 9 male).

Screening

The results of the screening tests are presented in Table 3.1. Independent samples t-tests indicated that young and old adults did not significantly differ on any cognitive or visual test (all *p*-values > .28).

Table 3.1 Participant characteristics and screening results for Experiment 3.

	Old adults		Young adults	
Measure	Mean	*(SD)*	Mean	*(SD)*
Age*	72.21	*(4.78)*	23.53	*(3.30)*
Years in education	15.96	*(1.54)*	15.33	*(.58)*
IQ (raw score from Mill Hill Vocabulary Scale)	67.17	*(6.16)*	63.67	*(4.04)*
Mini Mental State Questionaire Score	29.42	*(.78)*	29.67	*(.58)*
Foveal visual acuity (Snellen decimal)	.98	*(.12)*	1.06	*(.07)*

*Asterisks highlight significant differences between age groups.

Apparatus and stimuli

Eighty-eight negative, 88 positive and 176 neutral words (Appendix I) were selected from the Handbook of Semantic Word Norms (Toglia & Battig, 1978). Words were selected such that on a scale of 1 (negative) to 7 (positive), ratings were lower than 2.5 for negative words (M = 2.24, SD =.18), higher than 5.5 for positive words (M = 5.75, SD =.20) and mid-range for neutral words (M = 4, SD = .11, range = 3.82 - 4.19). Word length ranged from 3 to 8 letters and a one-way independent measures ANOVA indicated that mean word length did not significantly differ between negative (M = 5.43, SD = 1.39), positive (M = 5.31, SD = 1.51) and neutral conditions (M = 5.15, SD = 1.27; $F(2, 349)$ = 1.345, p = .262).

The experiment took place in a dimly-lit room where a viewing distance of 57 cm was maintained throughout the experiment using a chinrest. E-Prime 1 (Psychological Software Tools) was used to run the experiment on a PC with a 15” CRT screen (90 Hz refresh rate). All stimuli were presented in the centre of the screen in light grey (target word = 3.45 cd/m^2, mask = 5.58 cd/m^2) on a black background (0.014 cd/m^2). Words were presented in lower-case ‘Arial Narrow’ font. Word length ranged between 0.67° and 3.15°, and word height ranged between 0.47° and 0.86°.

Following pilot testing that indicated a reduced detection sensitivity and reduced confidence ratings for old (vs young) adults, I increased the exposure duration of words until percentage hit rates and confidence ratings for neutral words did not significantly differ between young (M hit rate = 51; M confidence rating = 2.93) and old adults (M hit rate = 55; M confidence rating = 2.69) in the short duration condition ($t(52) = .1.025$, $p = .310$ for hit rates and $t(52) = .946$, $p = .349$ for confidence ratings; for similar matching procedures see Lee & Knight, 2009; Langley et al., 2008). This was 22 ms for young and 55 ms for old adults. Similarly, exposure durations in the 'long' condition were set so that percentage hit rates ($t(52) = .597$, $p = .553$) and confidence ratings ($t(52) = .515$, $p = .609$) did not significantly differ between young adults (*M* hit rate = 69; *M* confidence rating = 3.95) and old adults (*M* hit rate = 71; *M* confidence rating = 4.08) for neutral words (33 ms for young and 99 ms for old adults).

Procedure

Trials began with a 500 ms fixation cross, followed by a 67 ms mask that comprised of eight hash characters (see Figure 3.1). This was immediately replaced by a word (presented for either the 'short' or 'long' duration) then another mask for 67 ms. Participants were required to indicate whether the word was emotional (positive or negative, depending on the block) or neutral using their right hand on the number pad ('0' for emotional or '2' for neutral). Following each response, a confidence rating was provided on a scale of 1 (pure guess) to 5 (absolutely sure).

Participants completed four practice blocks of 12 trials (different words were used in practice and experimental blocks and each word was presented just once during the experiment) and then eight experimental blocks of 44 trials (22 emotional and 22 neutral words, presented in random order). There were four positive valence and four negative valence blocks; for each valence condition there were two 'short' and two 'long' duration blocks. Participants were informed of the valence and duration at the start of each block and the order of valence and duration was counterbalanced across participants. The combinations of word pairings (which neutral words were presented with which positive or negative words for each duration) were also counterbalanced.

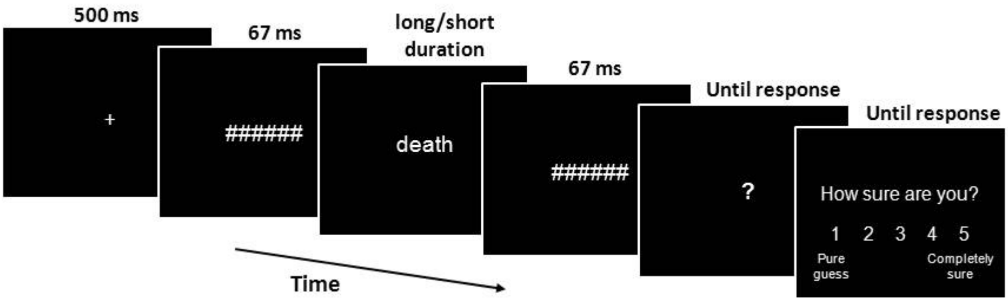

Figure 3.1 An example of a trial sequence from Experiment 3. Each trial began with a fixation cross. A mask was then presented and immediately followed by a word (either negative, positive or neutral) and then another mask. Participants indicated whether the word was emotional or neutral, and then provided a confidence rating for their response.

Upon completion of the experiment, participants provided subjective valence ratings for each word on a scale of 1 (negative) to 7 (positive), and then arousal ratings on a scale of 1 (not at all arousing) to 9 (very arousing) using the Self-Assessment Mannequin scale (Lang, 1980). Valence ratings were used to ensure that emotional word categories were equally distributed at each extreme. For each individual, when the mean rating for one category was closer to the extreme than the mean rating for the other category, the most extreme words from that category and least extreme words from the other category were removed from further analysis. This process was repeated until the mean valence rating of word categories were at an equal distance from the relevant extreme. Additional words were excluded from word sets for all participants until the mean arousal ratings, lexical frequency (score taken from the English Lexicon Project database) and mean word length were matched between word categories.

Results

Initial word sets

Valence. For young adults, valence ratings were initially 1.89 (SD = .45) for negative, 5.85 (SD = .36) for positive and 4.03 (SD = .45) for neutral words. For old adults, initial ratings were 1.93 (SD = .40) for negative, 5.94 (SD = .31) for positive and 4.07 (SD = .66) for neutral words. Independent samples t-tests revealed that there were no significant age differences in the initial ratings for negative (t(52) = .294, SEM = .123, p = .770) positive (t(52) = .878, SEM = .098, p = .385) or neutral words (t(52) = .245, SEM = .162, p = .808).

Arousal. For young adults, arousal ratings were initially 5.80 (SD = 1.02) for negative, 5.63 (SD = 1.10) for positive and 4.44 (SD = .67) for neutral words. For old adults, initial ratings were 5.72 (SD = .94) for negative, 5.83 (SD = 1.05) for positive and 4.36 (SD = .88) for neutral words. Independent samples t-tests revealed that there were no significant age differences in the initial arousal ratings for negative (t(52) = .304, SEM = .284, p = .762), positive (t(52) = .637, *SEM* = .310, *p* = .527) or neutral arousal ratings (*t*(52) = .362, *SEM* = .226, *p* = .719).

Lexical frequency. Log HAL lexical frequency values were initially 8.50 (*SD* = 1.68) for negative words, 9.48 (*SD* = 1.58) for positive words and 9.46 (*SD* = 1.81) for neutral words. Note that word sets were the same for young and old adults, so lexical frequency scores were identical across age groups.

Word length. The mean word length of stimuli was initially 5.43 (*SD* = 1.39) for negative words, 5.28 (*SD* = 1.49) for positive words and 5.15 (*SD* = 1.27) for neutral words. Note that word sets were for young and old adults, so lengths did not differ between age groups.

Word sets following matching

Valence. Although valence ratings were not significantly different between age groups, after words were removed to fully equate conditions, ratings remained non-significant between age groups for negative words (*M* = 1.99, *SD* = .17 for young adults; *M* = 2.00, *SD* = .48 for old adults; *t*(52) = .120, *SEM* = .104, *p* = .905) or positive words (*M* = 6.04, *SD* = .53 for young adults; *M* = 6.02, *SD* = .48 for old adults; *t*(52) = .155, *SEM* = .145, *p* = .878). There was no difference in the distribution of ratings from the scale midpoint between positive and negative conditions for young adults (*t*(29) = .081, *SEM* = .114, *p* = .936) or old adults (*t*(23) = .183, *SEM* = .141, *p* = .856).

Arousal. Subsequent arousal ratings remained non-significant between age groups for negative words (*M* = 5.71, *SD* = .51 for young adults; *M* = 5.76, *SD* = .94 for old adults; *t*(52) = .229, *SEM* = .219, *p* = .820), and there were also no rating differences between young (*M* = 5.73, *SD* = .44) and old adults (*M* = 5.79, *SD* = 1.05) for positive words ($t(52) = .262$, *SEM* = .232, $p = .794$). Again, arousal ratings did not differ between positive and negative conditions for young ($t(29) = .162$, *SEM* = .149, $p = .873$) or old adults ($t(23) = .124$, *SEM* = .281, $p = .902$).

Lexical frequency. Log HAL lexical frequency values did not differ between negative and positive valence conditions for young adults (*M* = 8.93, *SD* = 1.45 for negative; *M* = 9.31, *SD* = 2.05 for positive; $t(29) = .788$, *SEM* = .485, $p = .437$) or for old adults (*M* = 8.47, *SD* = 1.47 for negative words; *M* = 9.31, *SD* = 1.98 for positive words; $t(23) = 1.175$, *SEM* = .487, $p = .252$). Further, there were no age differences in lexical frequency for negative ($t(52) = .469$, *SEM* = .399, $p = .641$) or positive words ($t(52) = .004$, *SEM* = .553, $p = .996$).

Word length. Mean word length did not differ between negative and positive conditions for young adults (*M* word length = 5.22 for negative valence and 5.30 for positive valence; $t(29) = .265$, *SEM* = .325, $p = .793$) or old adults (*M* word length = 5.28 for negative valence and 5.36 for positive valence; $t(23) = .217$, *SEM* = .378, $p = .830$). Further, there were no age differences in the length of negative ($t(52) = .164$, *SEM* = .350, $p = .871$) or positive words ($t(52) = .137$, *SEM* = .386, $p = .891$).

Note that even after excluding words in order to match word categories, there were still 50 negative, 48 positive and 176 neutral words - on average - remaining in the analysis for young adults and 50 negative, 49 positive and 176 neutral words remaining in the analysis for old adults.

Emotional categorisation task

Correctly categorising word valence (as either emotional or neutral) was defined as a 'hit,' and was used to calculate the percentage hit rate for each participant. Together with the false alarm rate (percentage of neutral words misclassified as emotional), detection sensitivity (*d*') was calculated. The results are presented in Table 3.2.

Table 3.2 Mean (*SD* in brackets) percentage hit rate, *d*', beta values and confidence ratings for negative and positive valence in the long and short duration conditions in Experiment 3.

	Long Duration				Short duration			
	Negative Valence		Positive Valence		Negative Valence		Positive Valence	
	Mean	*(SD)*	Mean	*(SD)*	Mean	*(SD)*	Mean	*(SD)*
Young adults								
Hit Rate (%)	77	*(17)*	59	*(16)*	63	*(22)*	50	*(23)*
d'	2.14	*(1.05)*	1.64	*(.68)*	1.34	*(1.01)*	1.06	*(.77)*
Beta	2.15	*(1.71)*	4.12	*(3.89)*	2.03	*(2.46)*	2.63	*(2.34)*
Confidence Ratings	3.95	*(.92)*	4.04	*(.83)*	2.99	*(1.19)*	2.91	*(1.18)*
Old adults								
Hit Rate (%)	75	*(10)*	74	*(11)*	64	*(15)*	55	*(10)*
d'	1.85	*(.56)*	1.98	*(.59)*	1.18	*(.77)*	0.87	*(.48)*
Beta	1.56	*(.82)*	2.55	*(2.11)*	1.28	*(.62)*	1.37	*(.46)*
Confidence Ratings	4.08	*(.51)*	4.00	*(.50)*	2.75	*(.31)*	2.67	*(.42)*

Confidence ratings. Confidence ratings from old and young adults were entered into a mixed model ANOVA with valence (positive or negative) and duration (long or short) as within-subject factors and age (young or old) as a between-subject factor. Overall confidence ratings were significantly lower in the short (M = 2.85) compared to long duration conditions (M = 4.01), as indicated by a significant main effect of duration ($F(1, 52) = 154.555$, $MSE = .5$, $p < .01$, $\eta p^2 = .748$). This indicates that participants felt more like they were guessing in the short compared to long duration condition. No age effects were found, as pilot testing enabled confidence ratings to be equated between age groups ($F < 1$). There was also no difference in confidence ratings between positive (M = 3.41) and negative valence conditions (M = 3.45), as indicated by a non-significant main effect of valence ($F < 1$). The interaction between duration and age was also not significant ($F(1, 52) = 2.282$, $MSE = .5$, $p = .137$, $\eta p^2 = .042$), nor were any other interactions (all F-values < 1). For clarity, the two groups were then considered separately.

Old adults. A repeated measures ANOVA with duration (short or long) and valence (positive or negative) indicated that confidence ratings were significantly lower in the short duration condition (M = 2.71) compared to the long duration condition (M = 3.75; $F(1, 23) = 219.215$, $MSE = .2$, $p < .01$, ηp^2 = .905). However, even in the short duration condition the mean confidence ratings were nowhere near the "pure guess" score of 1. There was no main effect of valence ($F(1, 23) = 2.849$, $MSE = .1$, $p = .105$, $\eta p^2 = .110$) or an interaction between valence and duration ($F < 1$).

Young adults. Overall confidence ratings were significantly lower in the short duration condition (M = 2.95) compared to the long duration condition (M = 4.00; $F(1, 29) = 45.437$, $MSE = .7$, $p < .01$, $\eta p^2 = .610$). However, even in the short duration condition the mean confidence ratings were nowhere near the "pure guess" score of 1. As with old adults, there was no main effect of valence

($F(1, 29) = .010$, $MSE = .1$, $p = .921$, $\eta p^2 = .000$) or an interaction between valence and duration ($F(1, 29) = 2.497$, $MSE = .1$, $p = .125$, $\eta p^2 = .079$).

Percentage hit rates and *d′* values were entered into mixed model ANOVAs with valence (positive or negative) and duration (long or short) as within-subject factors and age (young or old) as a between-subject factor. As expected from previous research, hit rates and detection sensitivity were reduced in the short (*M* hit rate = 58%; *M d′* = 1.12) compared to long duration condition (*M* hit rate = 71%; *M d′* = 1.90; $F(1, 52) = 50.393$, $MSE = 169.5$, $p < .01$, $\eta p^2 = .492$ for hit rate and $F(1, 52) = 128.465$, $MSE = .3$, $p < .01$, $\eta p^2 = .712$ for *d*'). Hit rates and *d′* scores were also greater for negative (*M* hit rate = 70%; *M d′* = 1.64) compared to positive valence (*M* hit rate = 59%; *M d′* = 1.38; $F(1, 52) = 32.609$, $MSE = 168.1$, $p < .01$, $\eta p^2 = .385$ for hits and $F(1, 52) = 10.629$, $MSE = .3$, $p = .002$, $\eta p^2 = .170$ for *d*'), replicating the negative valence detection advantage found in previous research (Nasrallah et al., 2009). The effect of valence did not interact with duration for hit rates ($F(1, 52) = .021$, $MSE = 65.6$, $p = .884$, $\eta p^2 = .000$) or *d′* scores ($F(1, 52) = 1.116$, $MSE = .1$, $p = .296$, $\eta p^2 = .021$).

The main effect of age was not significant ($F(1, 52) = 1.653$, $MSE = 655.6$, $p = .204$, $\eta p^2 = .031$ for hit rates; $F(1, 52) = .174$, $MSE = 1.7$, $p = .678$, $\eta p^2 = .003$ for *d′* scores), but this is likely to be the result of matching the hit rate for neutral words between young and old adults and is qualified by the significant interactions that were found for age. Hit rates and *d′* scores were reduced from the short to long duration conditions for both the old (*M* reduction for hit rates = 16%; for d' = .89) and young adults (*M* reduction for hit rates = 12%; for d' = .69), resulting in a non-significant interaction between age and duration ($F(1, 52) = 1.226$, $MSE = 196.5$, $p = .273$, $\eta p^2 = .023$for hit rates; $F(1, 52) = 1.957$, $MSE = .3$, $p = .168$, $\eta p^2 = .036$ for d')

More importantly, age interacted with valence both for hit rates ($F(1, 52) = 11.155$, $MSE = 168.1$, $p = .002$, $\eta p^2 = .177$) and d' ($F(1, 52) = 4.158$, $MSE = .3$, $p = .047$, $\eta p^2 = .074$). The overall advantage for negative (compared to positive) valence was larger for young (*M* negative valence advantage for hit rates = 16%; for d' = .39) compared to old adults (*M* negative valence advantage for hit rates = 4%; for d' = .09). There was also a significant three-way interaction between age, duration and valence ($F(1, 52) = 5.624$, $MSE = 65.6$, $p = .021$, $\eta p^2 = .098$ for hit rates; $F(1, 52) = 9.466$, $MSE = .1$, $p = .003$, $\eta p^2 = .154$ for d'): the negative valence advantage was of the same magnitude for old and young adults in the short but not in the long duration condition. In the long duration condition, old adults did not show a negative valence advantage, but young adults did.

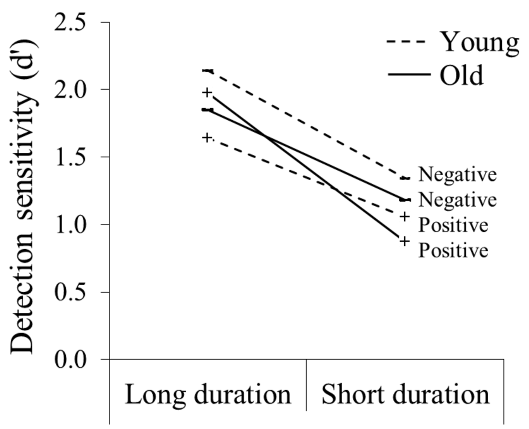

Figure 3.2 Mean detection sensitivity for negative and positive valence in the short and long duration conditions for young and old adults.

Response criterion tended to be higher for young (M = 2.73) compared to old adults (M = 1.69; $F(1, 52) = 6.342$, $MSE = 9.2$, $p = .015$, $\eta p^2 = .109$), higher in the long (M = 2.66) compared to short duration condition (M = 1.88; $F(1, 52) = 9.050$, $MSE = 3.5$, $p = .004$, $\eta p^2 = .148$) and lower for negative (M = 1.79) compared to positive valence (M = 2.75; $F(1, 52) = 11.338$, $MSE = 3.9$, $p = .001$, $\eta p^2 = .179$). There was no interaction between valence and age ($F(1, 52) = 1.957$, $MSE = 3.9$, $p = .168$, $\eta p^2 = .036$), between duration and age ($F < 1$) or between age, valence and duration ($F < 1$) for beta values.

3.3 Chapter Conclusions

The present chapter demonstrates that young and old adults have a negative valence detection advantage (as compared to both neutral and positive valence) for lexical stimuli presented for short exposure durations and with full attention. Whereas the negative valence detection advantage was also found in the long duration condition for young adults, old adults did not show any valence detection advantages under long exposure durations. The findings were not subject to visual differences in stimuli, or age differences in valence or arousal attribution.

The negative valence detection advantage found here for young adults directly replicates Nasrallah et al. (2009). The finding that older adults also show negative valence detection advantage in the short duration condition adds to previous ageing research showing a greater interference effect from negative (vs positive) words on a response competition task (Sammerz-Larkin et al., 2009); and a bias for sad (vs neutral) schematic faces (Isaacowitz et al., 2006) and angry (vs neutral) facial expressions (presented subliminally; Lee & Knight, 2009) on the dot probe task for old and young adults. It is also consistent with research showing a bias for detecting angry (vs happy and neutral) schematic faces (Hahn et al., 2006; Mather & Knight, 2006) and negative (vs positive or neutral) objects (e.g. a grenade; Leclerc & Kensinger, 2008) in visual search tasks. However, unlike these previous studies that used indirect measures of conscious perception, the present chapter directly assessed perceptual sensitivity, free from any age differences in response biases.

However, old adults did not show any valence detection advantages in long exposure durations condition. One possible explanation comes from the socioemotional selectivity theory (e.g. Carstensen, 1993), which posits that with age, individuals become increasingly selective with regards to the information they process and invest greater resources towards positive and away from negative information (see reviews by Carstensen, Mikels & Mather, 2006; Mather & Carstensen, 2005). Since there would have been a greater strategic opportunity to adapt attention processing to be consistent with the goals of allocating proportionately more resources to positive information in the long duration condition, this may have led to a positivity strategy that counteracted the negative bias in old adults. In other words, the negative bias may have been concealed by a positive strategic bias (possibly in later stages of processing) in the long duration condition, resulting in neither a positive or negative valence detection advantage.

Previous research supporting the notion of a positivity strategy comes from studies using long exposure durations, for example in dot probe studies using facial expressions presented for over 1000 ms (Isaacowitz et al., 2006; Mather & Carstensen, 2003). Old adults were faster to detect dot probes that appeared in the location of positive (vs neutral) facial expressions and slower to detect targets in the location of negative (vs neutral) faces, indicating an orientation preference towards positive and away from negative facial expressions. The notion also fits with Lee and Knight's (2009) dot probe study where old adults were faster to detect dot probes that appeared in the location of subliminally presented angry (vs neutral) facial expressions, but slower to detect targets that appeared in the location of supraliminally presented angry (vs neutral) faces. The subliminal condition is in line with the findings of the short duration condition and the supraliminal condition is consistent with the long duration condition in the present chapter. Note that the short exposure duration condition in the present chapter could not be considered subliminal (for young or old adults) as confidence ratings were above pure guess level.

Chapter 4:

Perceptual load and processing word valence

4.1 Chapter Introduction

In Chapter 3, old adults showed a negative valence detection advantage when subjective awareness was restricted, but the advantage was no longer apparent when a sufficient exposure duration provided the opportunity for old adults to allocate resources towards positive information. Considering that a single stimulus was presented on every trial, each word would have received the participants' full attention. In conditions where attentional resources are not fully available (e.g. in divided attention tasks) previous ageing research has found that old adults show a negative valance advantage (Brassen et al., 2011; Knight et al., 2007; Mather & Knight, 2005, but note Allard & Isaacowitz, 2008).

However, previous ageing studies have either manipulated spatial attention (rather than load; Brassen et al., 2011) or assessed cognitive demands from another modality, such as the effect of auditory load on eye movements (Allard & Isaacowitz, 2008; Knight et al., 2007) or surprise recognition memory for IAPS images (Mather & Knight, 2005). No previous ageing study has observed the effects of manipulating visual load on perceptual sensitivity for emotion within the same modality. Further, alternative accounts of low level visual differences between photographic stimuli (Purcell et al., 1996) and age differences in idiosyncratic valence and arousal attribution were often not ruled out as alternative explanations. In addition, the indirect measures (e.g. fixation preferences) do not inform us about perceptual sensitivity, and so it is difficult to make meaningful inferences about age differences in conscious detection.

To directly assess perceptual sensitivity, and to avoid low level visual confounds or age differences in valence and arousal attribution, I employed the same word valence categorisation task used in the previous chapter. In order to assess the effects of perceptual load, a circle of letters was presented simultaneously around the word (presented at fixation on every trial) that either contained no target-similar items (low load) or five target-similar items (high load). Participants were required to search for a target in the circle of letters and then categorise the word as emotional (negative or positive, depending on the block) or neutral. As in previous chapters, signal detection analysis was used so that age differences in sensitivity could be measured between positive and negative valence conditions.

Based on Chapter 2 and previous research, I expected detection sensitivity in general (i.e. for both positive and negative valence) to be reduced in the high (relative to low) load condition. Further, given that threat was modulated to a greater extent by load for old (vs young) adults in Chapter 2, and evidence for an age-related reduction in perceptual capacity (Ball et al., 1988; Humphrey & Kramer, 1997; Maylor & Lavie, 1998; Scialfa et al., 1987; Scialfa et al., 1994; Sekuler & Ball, 1986), I predicted that detection sensitivity would be modulated by load to a greater degree for old compared to young adults. However, given the mixed findings in the literature with regards to the effects of attention on emotion, no specific predictions were made with respect to whether valence detection advantages would be reduced under high (compared to low) perceptual load.

4.2 Experiment 4

Method

Participants

Old adults. Thirty-one old adults were recruited from the University of the Third Age community in London. Two participants were excluded for having performance accuracy on the search task lower than 50%, two were excluded for having a Snellen visual acuity score of less than 6/10; and a further three were excluded for failing to fulfil task requirements. The age range of old adults included in the final analysis was 66 to 86 years (M = 71.33, SD = 5.16; 8 male).

Young adults. Twenty-six young adults were recruited from University College London's online participant pool. Two participants were excluded for having performance accuracy on the search task lower than 50%. The age range of young adults included in the final analysis was 18 to 33 years (M = 21.08; SD = 2.64; 10 male).

Screening

The results for the screening tests are presented in Table 4.1. Independent samples t-tests indicated that young and old adults did not significantly differ on any cognitive or visual test (all p-values > .21).

Table 4.1 Participant characteristics and screening results for Experiment 4.

	Old adults		Young adults	
	Mean	*(SD)*	*Mean*	*(SD)*
Age*	71.33	*(5.16)*	21.08	*(2.64)*
Years in education	16.92	*(2.66)*	16.10	*(1.91)*
IQ (raw score from Mill Hill Vocabulary Scale)	66.50	*(6.16)*	64.60	*(3.94)*
Mini Mental State Questionnaire Score	29.67	*(.78)*	29.80	*(.42)*
Foveal visual acuity (Snellen decimal)	1.12	*(.12)*	1.19	*(.14)*

*Asterisks highlight significant differences between age groups.

Apparatus and stimuli

The apparatus and stimuli were the same as the previous experiment, with the addition of a letter circle that appeared simultaneously with the word. A target letter (equally likely to be X or N, in randomised order) was presented in one of six locations (equal probability of appearing in each) that were positioned around the circumference of an imaginary circle with a radius of 2.8º (measured from fixation to the top of the letter). The remaining positions in the circle were occupied either by zeros (low load; see Figure 4.1) or by non-target letters (Y, H, Z, K, V; high load). Target and non-target letters measured 0.7 º by 0.5 º visual angles. All words were shown in lowercase, size 12, Arial Narrow font and word length and height ranged between 0.5 º to 2.3 º and 0.4 º to 0.5 º, respectively.

Pilot testing indicated that using the same presentation durations for young and old adults produced significantly different *d′* scores and confidence ratings. The presentation duration of the word was therefore set at a level (94 ms for young adults; 156 ms for old adults) at which mean hit rates and confidence ratings were not significantly different between the young (*M d′* score = 1.95; *M* confidence rating = 3.22) and old adults (*M d′* score = 2.02; *M* confidence rating = 3.17) in the low load neutral condition ($t(46) = .294$, $SEM = .244$, $p = .770$ for hit rates; $t(46) = .273$, $SEM = .182$, $p = .787$ for confidence ratings). This ensured that the task was challenging but did not produce a floor or ceiling effect on the valence detection task for either age group.

Procedure

Trial onset was indicated by a 500 ms fixation dot, followed immediately by the simultaneous presentation of the letter search and word categorisation task (see Figure 1.4). Participants were required to use the keypad to press ‘0’ if ‘X’ was shown or ‘2’ if ‘N’ was presented as quickly and accurately as possible. A blank screen was presented until a response was given (or a 2 s response window elapsed). Auditory feedback (a short ‘beep’ sound) was played when an incorrect response was made or no response was given.

Immediately following the letter search response, the appearance of a question mark signalled that participants should indicate whether the word was emotional (by pressing ‘A’) or neutral (by pressing ‘S’). The emotional word was either positive or negative, depending on the block. The allocation of neutral to negative and positive blocks was counterbalanced across participants. It was made clear that participants should prioritise the letter search task, and treat the valence detection task with secondary importance. If the participant did not report seeing the word, they were reassured and asked to provide their best guess. Once a response was given on the word valence detection task, participants were then asked to provide a confidence rating for their response on a scale 1 (pure guess) to 5 (completely sure).

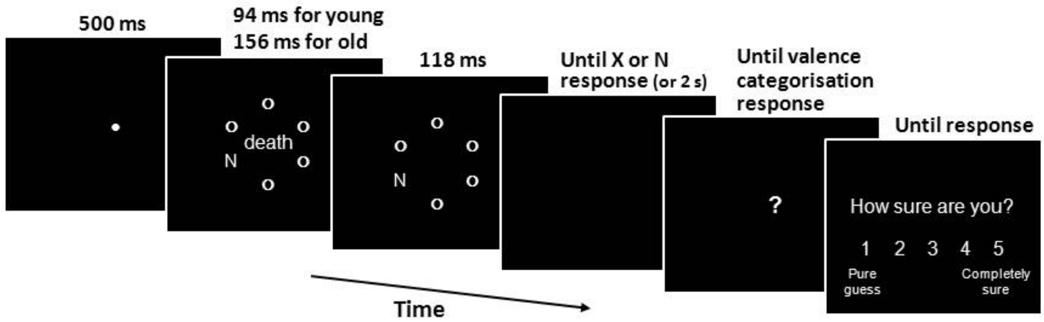

Figure 4.1 An example of a low load trial from Experiment 4. A fixation dot was followed by a letter circle that was either low (shown here) or high load. A word was simultaneously presented that was either emotional (shown here) or neutral. Participants indicated by key press whether the target letter was X or N and then, when the question mark appeared, whether the word was emotional or neutral. This was immediately followed by their valence categorisation confidence rating.

Participants completed four practice blocks of 12 trials and then eight experimental blocks of 44 trials (22 emotional and 22 neutral word trials in each block, in random order). There were four positive and four negative emotion blocks (two low and two high load blocks for each valence condition). Participants were informed of the load and valence condition at the start of each block. Load was ordered in an ABBAABBA manner (with A and B representing either high or low load), counterbalanced across participants. Valence was arranged in an ABABABAB order (with A and B representing positive and negative valence), also counterbalanced across participants. Each word was presented just once and different words were used for the practice and experimental blocks.

As in the previous chapter, each participant provided subjective valence and arousal ratings at the end of the experiment. These values were used to ensure that valence was equally distributed at each extreme and mean arousal ratings were matched between word conditions and age groups. Again, lexical frequency and word length were also equated between word categories.

Results

Initial word sets

Valence. For young adults, valence ratings were initially 1.81 (SD = .47) for negative, 5.89 (SD = .34) for positive and 3.92 (SD = .44) for neutral words. For old adults, initial ratings were 1.90 (SD = .40) for negative, 5.92 (SD = .33) for positive and 4.43 (SD = .52) for neutral words. Independent samples t-tests revealed that there were no significant age differences in the initial ratings for negative ($t(46)$ = .718, SEM = .126, p = .476) or positive words ($t(46)$ = .348, SEM = .097, p = .730), but old adults provided higher ratings for the neutral words compared to young adults ($t(46)$ = 3.732, SEM = .138, p < .01; see Langley et al., 2008, Experiment 1a for similar finding).

Arousal. For young adults, arousal ratings were initially 6.09 (*SD* = 1.50) for negative, 5.28 (*SD* = 1.15) for positive and 4.53 (*SD* = .79) for neutral words. For old adults, initial ratings were 5.84 (*SD* = .99) for negative, 5.53 (*SD* = 1.13) for positive and 4.33 (*SD* = .90) for neutral words. Independent samples t-tests revealed that there were no significant age differences in the initial ratings for negative ($t(46) = .673$, *SEM* = .368, $p = .504$), positive ($t(46) = .739$, *SEM* = .330, $p = .464$) or neutral arousal ratings ($t(46) = .824$, *SEM* = .245, $p = .414$).

Lexical frequency. Log HAL lexical frequency values were initially 8.50 (*SD* = 1.68) for negative words, 9.48 (*SD* = 1.58) for positive words and 9.46 (*SD* = 1.81) for neutral words. Note that word sets were the same for young and old adults, so lexical frequency scores were identical across age groups.

Word length. The mean word length of stimuli was initially 5.43 (*SD* = 1.39) for negative words, 5.28 (*SD* = 1.49) for positive words and 5.15 (*SD* = 1.27) for neutral words. Note that word sets were identical for both age groups (so lengths did not differ between young and old adult groups).

Word sets following matching

Valence. Similar to before the matching, the subsequent ratings did not significantly differ between young (*M* = 1.98, *SD* = .51) and old adults (*M* = 2.01, *SD* = .51) for negative words ($t(46) = .195$, *SEM* = .147, $p = .846$), or between young (*M* = 6.04, *SD* = .53) and old adults (*M* = 6.03, *SD* = .30) for positive words ($t(46) = .037$, *SEM* = .124, $p = .971$). Further, valence ratings now did not differ between young (*M* = 4.02, *SD* = .44) and old adults (*M* = 4.06, *SD* = .46) for neutral words ($t(46) = .335$, *SEM* = .131, $p = .739$). Within each age group, there was no difference in the distribution of ratings from the scale midpoint between positive and negative conditions ($t(23) = .111$, $SEM = .162$, $p = .913$ for young adults; $t(23) = .352$, $SEM = .120$, $p = .728$ for old adults).

Arousal. Non-significant differences remained between young ($M = 5.48$, $SD = .41$) and old adults ($M = 5.51$, $SD = .21$) for negative words ($t(46) = .271$, $SEM = .094$, $p = .787$); and there were also no rating differences between young ($M = 5.49$, $SD = .44$) and old adults ($M = 5.55$, $SD = 1.01$) for positive words ($t(46) = .299$, $SEM = .226$, $p = .766$). Within each age group, arousal ratings did not differ between positive and negative conditions ($t(23) = .059$, $SEM = .128$, $p = .954$ for young adults; $t(23) = .2400$, $SEM = .206$, $p = .812$ for old adults).

Lexical frequency. The log HAL lexical frequency values remained non-significant between negative and positive valence conditions for young adults ($M = 9.03$, $SD = 1.59$ for negative; $M = 9.20$, $SD = 1.50$ for positive; $t(23) = .371$, $SEM = .463$, $p = .714$) and for old adults ($M = 8.82$, $SD = 1.46$ for negative words; $M = 9.12$, $SD = 1.33$ for positive words; $t(23) = .606$, $SEM = .501$, $p = .551$). Further, there were no age differences in lexical frequency for negative ($t(46) = .473$, $SEM = .441$, $p = .639$) or positive words ($t(46) = .187$, $SEM = .410$, $p = .852$).

Word length. As before, mean word length did not differ between negative and positive conditions for young adults (M word length = 5.13 for negative valence; 5.27 for positive valence; $t(23) = .307$, $SEM = .454$, $p = .762$) or old adults (M word length = 5.21 for negative valence; 5.16 for positive valence; $t(23) = .124$, $SEM = .434$, $p = .902$). Further, there were no age differences in the length of negative (*t*(46) = .173, *SEM* = .460, p = .864) or positive words (*t*(46) = .256, *SEM* = .444, p = .799).

Note that even after excluding words in order to equate conditions and age groups, there were still 50 negative, 51 positive and 172 neutral words remaining for the young adults and 50 negative, 49 positive and 172 neutral words for the old adults.

Letter search

Two-way mixed model ANOVAs were conducted on mean search task RTs and mean search error rates (see Table 4.2) with perceptual load (low or high) as a within-subject factor and age (young or old) as a between-subject factor. Both analyses revealed a main effect of load ($F(1, 46) = 167.465$, $MSE = 5327.5$, $p < .01$, $\eta_p^2 = .785$ for RTs; $F(1, 46) = 131.060$, $MSE = 18.6$, $p < .01$, $\eta_p^2 = .740$ for error rates): RTs were slower (*M* = 1073 ms) and error rates were larger (*M* = 28%) in the high compared to low load condition (*M* RT= 880 ms; *M* error rate = 18%), confirming that the load manipulation was effective. As in Chapter 2, older adults were slower (*M* = 1063 ms) and made more errors (*M* = 27%) than young adults (*M* RT = 891 ms; *M* error rate = 20%), as indicated by a main effect of age ($F(1, 46) = 26.047$, $MSE = 27135.6$, $p < .01$, $\eta_p^2 = .362$ for RTs and $F(1, 46) = 10.448$, $MSE = 130.6$, $p < .01$, $\eta_p^2 = .185$ for error rate). Also similar to Chapter 2 was the significant interaction between load and age for RTs ($F(1, 46) = 5.064$, $MSE = 5327.5$, $p = .029$, $\eta_p^2 = .099$) and error rates ($F(1, 46) = 4.532$, $MSE = 18.6$, $p = .039$, $\eta_p^2 = .090$): load increased RTs and error rates more for old (226 ms slower and 12% less accurate in high *vs* low load) compared to young adults (160 ms slower and 9% less accurate in high *vs* low load). These findings are as expected from previous research and are consistent with Chapter 2.

Table 4.2 Search task performance for old and young adults in Experiment 4.

	Old adults				Young adults			
	Low load		High load		Low load		High load	
Search task	Mean	*(SD)*	Mean	*(SD)*	Mean	*(SD)*	Mean	*(SD)*
RTs (ms)	950	*(116)*	1176	*(119)*	811	*(106)*	971	*(161)*
Error rate (%)	21	*(8)*	33	*(9)*	15	*(15)*	24	*(9)*

Emotional categorisation task

Correctly categorising word valence (as either emotional or neutral) was defined as a 'hit,' and was used to calculate percentage hit rates for each participant. Together with the false alarm rate (percentage of neutral words misclassified as emotional), the percentage hit rate was used to calculate *d′* values. The results are presented in Table 4.3.

Table 4.3 Mean (*SD* in brackets) percentage hit rate, *d'* scores, beta values and confidence ratings for young and old adults in Experiment 4.

	Low load				High load			
	Negative		Positive		Negative		Positive	
	Mean	*(SD)*	Mean	*(SD)*	Mean	*(SD)*	Mean	*(SD)*
Young adults								
Hit Rate (%)	67	*(20)*	49	*(21)*	50	*(23)*	42	*(22)*
d'	1.95	*(.77)*	1.34	*(.69)*	1.06	*(.93)*	0.87	*(.89)*
Beta	2.93	*(2.65)*	2.96	*(2.47)*	2.49	*(3.10)*	2.53	*(2.70)*
Confidence ratings	3.22	*(.53)*	2.90	*(.34)*	2.47	*(.45)*	2.42	*(.69)*
Old adults								
Hit Rate (%)	72	*(19)*	64	*(18)*	43	*(22)*	42	*(24)*
d'	2.02	*(.92)*	1.75	*(.83)*	0.93	*.(84)*	0.93	*(.80)*
Beta	2.25	*(1.81)*	2.34	*(1.43)*	1.89	*(1.11)*	1.91	*(1.17)*
Confidence ratings	3.17	*(.46)*	2.95	*(.30)*	2.24	*(.45)*	2.02	*(.55)*

Percentage hit rates and *d'* scores were entered into mixed model ANOVAs with load (high or low) and valence (negative or positive) as within-subjects factors and age (old or young) as a between-subjects factor. Hit rates and *d'* were reduced in the high (*M* hit rate = 44%; *M d'* = .95) compared to low load condition (*M* hit rate = 63%; *M d'* = 1.77; $F(1, 46) = 93.898$, $MSE = 179.9$, $p < .01$, $\eta p^2 = .671$ for hit rates and $F(1, 46) = 148.754$, $MSE = .2$, $p < .01$, $\eta p^2 = .764$ for *d*') and there was an advantage for negative (*M* hit rate = 58%; *M d'* = 1.49) over positive stimuli (*M* hit rate = 49%; *M d'* = 1.22; $F(1, 46) = 24.438$, $MSE = 147.2$, $p < .01$, $\eta p^2 = .347$ for hit rates; $F(1, 46) = 35.779$, $MSE = .1$, $p < .01$, $\eta p^2 = .438$ for *d'* scores).

There was an interaction between load and valence both for hit rates ($F(1, 46) = 9.241$, $MSE = 87.9$, $p < .01$, $\eta p^2 = .167$) and *d'* values ($F(1, 46) = 19.826$, *MSE* = .1, $p < .01$, $\eta p^2 = .301$). The reduced advantage for negative compared to positive valence under high (*M* difference between negative and positive valence for hit rates = 5%; for $d' = .10$) compared to low load (*M* difference between negative and positive valence for hit rates = 13%; for $d' = .44$) is consistent with studies that have found a load modulation of negative valence (Eimer et al., 2003; Erthal et al., 2005; Holmes et al., 2003; Pessoa et al., 2005; Pessoa et al., 2002).

There was no main effect of age for hit rates or d' scores (both $F < 1$), but this is likely to be the result of matching mean hit rates between young and old adults in the low load neutral condition that would have diluted any differences in other conditions. More importantly however, age interacted with valence both for hit rates ($F(1, 46) = 6.758$, $MSE = 147.2$, $p = .013$, $\eta p^2 = .128$) and d' scores ($F(1, 46) = 7.674$, $MSE = .1$, $p < .01$, $\eta p^2 = .143$). Closer inspection of Table 4.3 indicates that the overall advantage for negative (compared to positive) valence was smaller for old (*M* negative valence advantage = 4% for hit rates; .14 for *d*') compared to young adults (*M* negative valence advantage = 13% for hit rates; .40 for *d*'). Age also interacted with load ($F(1, 46) = 10.596$, $MSE = 179.9$, $p < .01$, $\eta p^2 = .187$ for hit rates; $F(1, 46) = 4.255$, $MSE = .2$, $p = .045$, $\eta p^2 = .085$ for d' scores): load modulated hit rates and sensitivity more for old (*M* reduction from low to high load = 25% for hit rates; .96 for d' scores) compared to young adults (*M* reduction from low to high load = 12% for hit rates; .68 for d' scores). The three-way interaction between load, valence and age was not significant for hit rates or detection sensitivity (both $F < 1$). As shown in Figure 4.2, load reduced the negative advantage both for young and old adults.

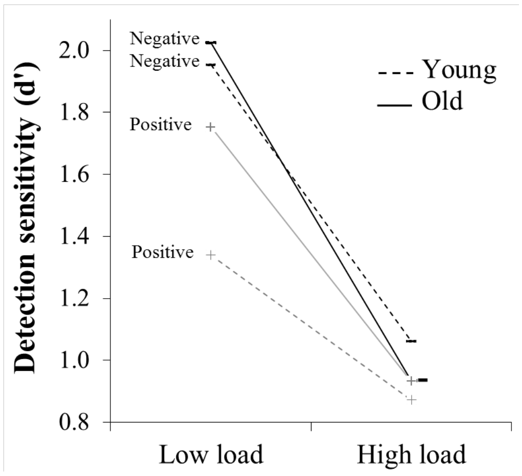

Figure 4.2 Mean d′ for negative and positive valence under high and low load for young and old adults in Experiment 4.

Response criterion tended to be higher in the low compared to high load condition (although this effect was only marginally significant; $F(1, 46) = 3.693$, $MSE = 2.2$, $p = .061$, $\eta p^2 = .074$). There was no main effect of valence ($F < 1$), no main effect of age ($F < 1$) and no interaction between age and valence; age and load; load and valence; or age, load and valence (all $F < 1$).

4.3 Chapter Conclusions

Chapter 4 investigated whether lexical valence detection sensitivity advantages depend on the availability of attentional resources. In the low load condition, a negative valence detection advantage was found for both age groups. Consistent with load theory (Lavie, 1995, 2005), detection sensitivity was reduced under high (relative to low) perceptual load conditions for both age groups, but the load effect was greater for old compared to young adults. The findings were obtained using stimuli that were not subject to visual differences or age-differences in valence or arousal attribution.

The negative valence detection advantage for both age groups in the low load condition is in line with the short duration condition in Chapter 3 and with previous ageing research showing a bias for negative (vs neutral and positive) stimuli under divided attention conditions (Knight et al., 2007; Mather & Knight, 2005, but see Allard & Isaacowitz, 2008). The load modulation is in line with previous behavioural (Cartwright-Finch & Lavie, 2006; Lavie, 1995; Lavie & Cox, 1997; Macdonald & Lavie, 2008) and neuroimaging studies on young adults using neutral stimuli (Bahrami et al., 2007; O'Connor et al., 2002; Pessoa et al., 2002; Pinsk et al., 2003; Rees et al., 1997; Schwartz et al., 2005; Yi et al., 2004). The load modulation in old adults is also in line with a number of ageing studies that have used other manipulations of attention, for example the spatial cuing study by Brassen et al. (2011). Old adults showed an interference effect from positive (vs neutral) faces on trials that had no spatial manipulation of attention, but when attention was cued to a location away from the face, the interference effect was no longer apparent. It is also consistent with an object-based attention study on young adults by Erthal et al. (2005) that required a line discrimination response (parallel or not under high or low load conditions) while task-irrelevant emotional images were presented. Under low load, there was a greater interference effect from task-irrelevant unpleasant (vs neutral) images, but the distractor interference effects from unpleasant images was eliminated in the high load condition (unpleasant and neutral images were equally distracting).

The greater load modulation in old (vs young) adults brings together load theory and previous research showing that there is an age-related decline in perceptual capacity (Ball et al., 1988; Humphrey & Kramer, 1997; Lunsman et al., 2008; Maylor & Lavie, 1998; Scialfa et al., 1987; Scialfa et al., 1994; Sekuler & Ball, 1986). The results indicate that as load increases, old adults' detection sensitivity reduces more rapidly than young adults, presumably due to running out of available resources at lower levels of load, as a result of their reduced perceptual capacity.

Chapter 5:

The effect of perceptual load on emotional distraction

5.1 Chapter Introduction

In Chapter 4, load modulated valence detection sensitivity advantages for both young and old adults. However, the modulation was greater for old compared to young adults. It follows then that distraction from emotion should be modulated to a greater extent by load in old compared to young adults, and this was the purpose of Chapter 5. In this chapter I assess whether a high load could have the positive consequence of reducing task-irrelevant emotional distraction to a greater extent for old compared to young adults.

As reviewed in the General Introduction, previous ageing studies looking at distraction from emotion have tended to find that old adults show a reduced distractor interference effect relative to young adults (Ashley & Swick, 2009; Hahn et al., 2006; Lamonica et al., 2010; Thomas & Hasher, 2006). Note that two previous studies failed to find age differences in distraction from emotion (Monti et al., 2010; Samanez-larkin et al., 2009), but these two studies did not match positive and negative stimuli on subjective arousal or valence. Therefore age differences in arousal or valence attribution may have distorted the results. For example, old adults may have found the words more intense and arousing than young adults, and this could have masked the age-related reduction in emotional distraction (see Wurm et al., 2004, for an ageing study on the effect of arousal on emotional distraction).

There are further methodological issues with previous studies that have found an age-related reduction in emotional distraction. Hahn et al. (2006) used schematic faces to show that old adults were better able to ignore task-irrelevant angry stimuli compared to young adults, but it is unclear whether the interference was caused by the emotion of the schematic face, or the geometrical forms that were used to portray the expressions. In addition, schematic faces tend to rely on a single facial feature that often do not correspond with what is considered to be an attribute of the intended expression (e.g. a frowning mouth to portray an angry face; Ekman & Friesen, 1976). Previous studies using emotional word stimuli have not been subject to the same issues as schematic faces, but valence and arousal ratings tended to be obtained from published databases based on young adult data (Ashley & Swick, 2009; Lamonica et al., 2010; Samanez-larkin et al., 2009; Thomas & Hasher, 2006). It is possible that these values do not generalise equally well to young and old adults and so the results could be confounded by age differences in valence or arousal attribution. For example, old adults may have found the emotional stimuli to be more intense and arousing, inflating distractor interference effects (Wurm et al., 2004) and thus masking any age-related reduction in distraction from emotion.

To address previous methodological issues, I collected subjective valence and arousal ratings for all participants in Chapter 5, allowing stimuli to be equated between age groups and emotional conditions (both positive and negative). While attempting to ignore task-irrelevant words (positive, negative or neutral) presented at fixation, participants were asked to indicate whether two peripheral lines (presented either above or below the word) were parallel (or not). Perceptual load was manipulated by varying the angular difference of non-parallel lines so that the task was either low load (90° angular difference between lines on non-parallel trials) or high load (12° angular difference between lines on non-parallel trials).

Based on a study using a similar paradigm that used IAPS images (instead of words) and only tested young (not old) adults (Erthal et al., 2005) and load theory (Lavie, 1995, 2005), I expected responses to be slower and less accurate in the high compared to low load condition, and task-irrelevant emotional stimuli to produce greater interference than task-irrelevant neutral stimuli. With regards to the age effects, given that old adults showed a greater load modulation compared to young adults in Chapters 2 and 4, together with evidence for an age-related reduction in perceptual capacity (Ball et al., 1988; Humphrey & Kramer, 1997; Maylor & Lavie, 1998; Scialfa et al., 1987; Scialfa et al., 1994; Sekuler & Ball, 1986), I predicted that load would modulate interference from emotional stimuli to a greater degree for old compared to young adults.

5.2 Experiment 5

Method

Participants

Old adults. Fifteen new adults were recruited from the University of the Third Age community in London. One participant was removed due to a mean accuracy on the search task lower than 50%. The age range of the old adults included in the final analysis was 65 to 81 years (*M* age = 70.93, *SD* = 4.63; 4 males).

Young adults. Sixteen new young adults were recruited from the UCL Department of Psychology subject pool. The age range of young adults was 19 to 27 years (M age = 22.38, SD = 2.55; 9 males).

Screening

As in previous chapters, participants were tested on a battery of cognitive and visual tasks (see Table 5.1 for results). Independent samples t-tests indicated that young and old adults did not significantly differ on any cognitive or visual test (all p-values > .19).

Table 5.1 Participant characteristics and screening results for old and young adults in Experiment 5.

	Old adults		Young adults	
	Mean	*(SD)*	*Mean*	*(SD)*
Age*	70.93	*(4.63)*	22.38	*(2.55)*
Years in education	16.36	*(3.08)*	15.19	*(1.60)*
IQ (raw score from Mill Hill Vocabulary Scale)	67.07	*(4.95)*	65.06	*(3.45)*
Mini Mental State Questionaire Score	29.79	*(.43)*	29.56	*(.51)*
Foveal visual acuity (Snellen decimal)	1.10	*(.07)*	1.16	*(.08)*

*Asterisks highlight significant differences between age groups.

Stimuli and procedure

The experiment was programmed and run using E-Prime 1 (Psychological Software Tools) on a PC with a 15" display. A fixed viewing distance of 57 cm was maintained using a chinrest. All stimuli were presented in white on a black background. Each trial began with a white fixation dot presented for 1500 ms, followed immediately by the presentation of a target display for 150 ms that consisted of two white lines (each 2.0° by $.2^{\circ}$; see Figure 5.1). The lines were presented either 5.5° above or 5.5° below fixation; and one of the lines was positioned 2.5° to the left and the other 2.5° to the right of centre. On low load trials there was a 90° angular difference between lines on non-parallel trials (lines were either horizontal or vertical) and on high load trials there was a 12° angular difference between lines (14 possible combinations starting from vertical; i.e. O° and 12°, 12° and 24°, 24° and 36° and so on). The horizontal and vertical lines (or most-horizontal and most-vertical lines in the case of high load trials) were equally likely to be presented on the left and right hand side of the screen, and this was counterbalanced across load and valence conditions.

On all trials, a task-irrelevant distractor word was presented at fixation simultaneously with the line task. Eighty-eight of the 176 neutral words used in the previous chapter were randomly selected (*M* rating = 4.00, *SD* = .12, range = 3.75 - 4.19; Handbook of Semantic Word Norms, Toglia & Battig, 1978) and positive and negative words were exactly the same as those in the previous chapter. Word stimuli were equally likely to be positive, negative or neutral and were presented in lower-case, size 48, Arial font. Word length ranged between 3° and 12°, and the height ranged between 1.7° and 2.7°. Following the stimuli offset, a mask was displayed until a response was made (or 3 s elapsed). Participants were instructed to ignore the task-irrelevant word and indicate as quickly as possible, whilst maintaining accuracy, whether the lines were parallel (by pressing ‘0’ on the keypad) or not (by pressing ‘2’ on the keypad). Auditory feedback (a short ‘beep’) was given if an incorrect response was made.

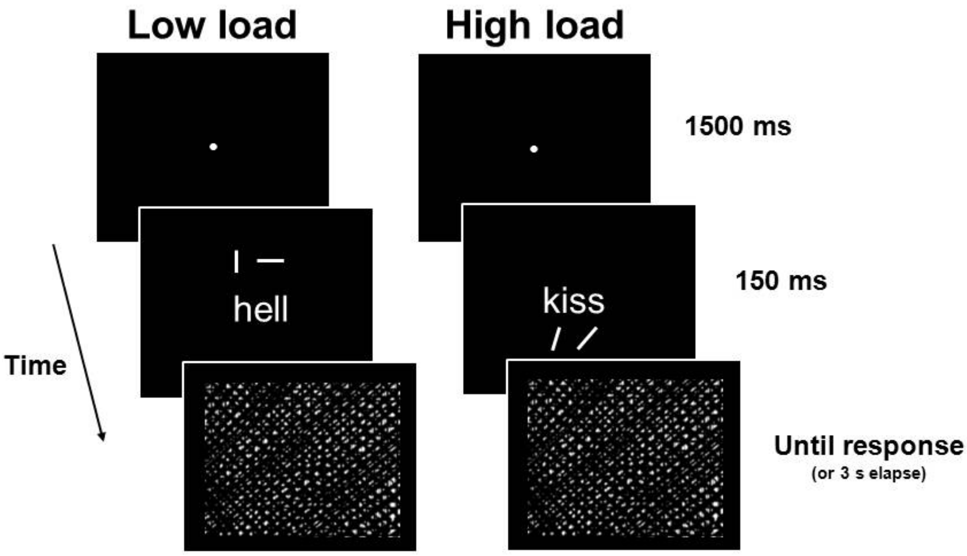

Figure 5.1 Examples of a trial sequence from Experiment 5. Each trial began with a fixation point, followed by the line-orientation task (parallel/non-parallel; non-parallel example shown). A task-irrelevant distractor word (equally likely to be negative, positive or neutral valence) was presented at fixation simultaneously on all trials. Diagram not to scale.

Before the experiment, each participant completed two practice blocks of 12 trials containing neutral words that were not used in the main experiment. Participants then completed eight experimental blocks of 33 trials. Valence was intermixed within blocks; there were 11 positive, 11 negative and 11 neutral trials per block, in randomised order. The lines were parallel on half the trials and non-parallel on the remaining half, in randomised order. Load was ordered in an ABBAABBA manner, with A and B representing either low or high load, counterbalanced across participants.

As in previous chapters, upon completion of the experiment, each participant provided subjective valence and arousal ratings for the words presented in the experiment. These values were used to ensure that positive and negative valence was equally distributed at each extreme and mean arousal ratings were matched between conditions and age groups. Lexical frequency and word length were also matched.

Results

Initial word sets

Valence. For young adults, valence ratings were initially 1.82 (*SD* = .37) for negative, 5.85 (*SD* = .35) for positive and 3.97 (*SD* = .35) for neutral words. For old adults, initial ratings were 1.91 (*SD* = .35) for negative, 5.97 (*SD* = .38) for positive and 4.06 (*SD* = .31) for neutral words. Independent samples t-tests revealed that there were no significant age differences in the initial ratings for negative ($t(46) = .884$, *SEM* = .104, $p = .381$) positive ($t(46) = 1.172$, *SEM* = .106, $p = .247$) or neutral words ($t(46) = 1.044$, *SEM* = .095, $p = .302$).

Arousal. For young adults, arousal ratings were initially 5.34 (*SD* = .84) for negative, 5.07 (*SD* = .83) for positive and 4.42 (*SD* = .82) for neutral words. For old adults, initial ratings were 5.23 (*SD* = 1.05) for negative, 5.35 (*SD* =

1.02) for positive and 4.26 (*SD* = .87) for neutral words. Independent samples t-tests revealed that there were no significant age differences in the initial arousal ratings for negative ($t(46) = .428$, $SEM = .274$, $p = .671$), positive ($t(46) = 1.075$, $SEM = .272$, $p = .288$) or neutral arousal ratings ($t(46) = .646$, $SEM = .244$, $p = .521$).

Lexical frequency. Log HAL lexical frequency values were initially 8.50 (*SD* = 1.68) for negative words, 9.48 (*SD* = 1.58) for positive words and 9.26 (*SD* = 1.64) for neutral words. Note that word sets were the same for young and old adults, so lexical frequency scores were identical across age groups.

Word length. The mean word length of stimuli was initially 5.43 (*SD* = 1.39) for negative words, 5.28 (*SD* = 1.49) for positive words and 5.32 (*SD* = 1.27) for neutral words. Note that word sets were identical for both age groups (so lengths did not differ between young and old adults).

Word sets following matching

Valence. As was the case prior to matching, subsequent ratings did not significantly differ between young ($M = 1.99$, $SD = .36$) and old adults ($M = 1.98$, $SD = .30$) for negative words ($t(46) = .070$, $SEM = .095$, $p = .944$); and there were also no rating differences between young ($M = 6.02$, $SD = .36$) and old adults ($M = 5.99$, $SD = .44$) for positive words ($t(46) = .247$, $SEM = .116$, $p = .806$). Within each age group, there was no difference in the distribution of ratings from the scale midpoint between positive and negative conditions ($t(23) = .095$, $SEM = .096$, $p = .925$ for young adults; $t(23) = .235$, $SEM = .112$, $p = .816$ for old adults).

Arousal. As before, arousal ratings did not significantly differ between young (*M* = 5.21, *SD* = .43) and old adults (*M* = 5.26 *SD* = .79) for negative words ($t(46) = .263$, *SEM* = .184, $p = .794$); and there were also no rating differences between young (*M* = 5.25, *SD* = .52) and old adults (*M* = 5.23, *SD* = .83) for positive words ($t(46) = .108$, *SEM* = .200, $p = .914$). Within each age group, arousal ratings did not differ between positive and negative conditions ($t(23) = .284$, *SEM* = .144, $p = .779$ for young adults; $t(23) = .290$, *SEM* = .101, $p = .775$ for old adults).

Lexical frequency. Log HAL lexical frequency values still did not differ between negative and positive valence conditions for young adults (*M* = 9.06, *SD* = 1.57 for negative; *M* = 9.38, *SD* = 1.33 for positive; $t(15) = .685$, *SEM* = .459, $p = .504$) or for old adults (*M* = 9.06, *SD* = 1.18 for negative words; *M* = 9.33, *SD* = 1.23 for positive words; $t(13) = .699$, *SEM* = .378, $p = .497$). Further, there were no age differences in lexical frequency for negative ($t(28) = .004$, *SEM* = .513, $p = .996$) or positive words ($t(28) = .102$, *SEM* = .471, $p = .920$).

Word length. The difference in mean word length remained non-significant between negative and positive conditions for young adults (*M* word length = 5.16 for negative valence; 5.23 for positive valence; $t(15) = .124$, *SEM* = .550, $p = .903$) or old adults (*M* word length = 5.49 for negative valence; 5.28 for positive valence; $t(13) = .349$, *SEM* = .593, $p = .773$). Further, there were no age differences in the length of negative ($t(28) = .538$, *SEM* = .622, $p = .786$) or positive words ($t(28) = .110$, *SEM* = .539, $p = .395$).

Note that even after excluding these additional words, there were still 51 negative, 52 positive and 88 neutral words remaining for the young adults and 50 negative, 51 positive and 88 neutral words for the old adults.

Line task

Trials on which RTs on the line task were over two standard deviations from the participants' overall mean were removed from further analysis. Mean percentage RTs were calculated for all trials that had a correct response on the line task. These values, together with standard error rates, are presented in Table 5.2.

Table 5.2 Line task performance for young and old adults in Experiment 5.

	Low load						High load					
	Negative		Positive		Neutral		Negative		Positive		Neutral	
	Mean	*(Stderr)*	Mean	*(Stderr)*	Mean	*(Stderr)*	Mean	*(Stderr)*	Mean	*(Stderr)*	Mean	*(Stderr)*
Young adults												
RT (ms)	544	*(11)*	549	*(11)*	527	*(11)*	666	*(20)*	670	*(21)*	660	*(21)*
Error rate (%)	7	*(1)*	7	*(1)*	5	*(1)*	17	*(1)*	18	*(2)*	17	*(1)*
Old adults												
RT (ms)	725	*(17)*	730	*(18)*	689	*(19)*	889	*(22)*	885	*(21)*	886	*(23)*
Error rate (%)	12	*(1)*	11	*(1)*	8	*(1)*	26	*(2)*	26	*(3)*	27	*(2)*

RT. A mixed model ANOVA with a Greenhouse-Geisser correction (due to a larger RT variance for old compared to young adults; Greenhouse & Geisser, 1958) was performed on mean RTs, with perceptual load (high or low) and valence (positive, negative or neutral) as within-subject factors and age (young or old) as a between-subjects factor. There was a main effect of load ($F(1, 28) = 175.151$, $MSE = 5649.0$, $p < .01$, $\eta_p^2 = .862$): RTs were slower in the high ($M = 769$ ms) compared to low load condition ($M = 622$ ms), confirming that the load manipulation was successful. There was also a main effect of valence ($F(1, 28) = 61.797$, $MSE = 91.4$, $p < .01$, $\eta_p^2 = .688$), indicating that RTs in the positive ($M = 702$ ms) and negative ($M = 699$ ms) valence conditions were slowed relative to RTs in the neutral condition ($M = 684$ ms). This establishes an effect of interference by emotion, as anticipated on the basis of previous research that demonstrates greater interference from task-irrelevant emotional (vs neutral) distractor words on the flanker task (Samanez-larkin et al., 2009; Thomas & Hasher, 2006) and slower RTs on the emotional Stroop task for emotional compared to neutral words (Ashley & Swick, 2009; Lamonica et al., 2010). Further, there was an interaction between load and valence ($F(1, 28) = 45.954$, $MSE = 71.0$, $p < .01$, $\eta_p^2 = .621$): neutral words were modulated by load to a greater extent (*M* difference from high to low load = 163 ms) than negative words (*M* difference from high to low load = 141 ms) and positive words (*M* difference from high to low load = 137 ms). This was also expected based on research showing that emotional stimuli are prioritised over neutral stimuli irrespective of attention (Anderson et al., 2003; Attar & Muller, 2012).

As is typical in ageing literature, older adults were slower ($M = 801$ ms) than young adults ($M = 603$ ms), as indicated by a main effect of age ($F(1, 28) = 66.867$, $MSE = 26332.1$, $p < .01$, $\eta_p^2 = .705$). The interaction between age and valence was not significant ($F(2, 56) = 3.199$, $MSE = 182.8$, $p = .085$, $\eta_p^2 = .103$), but there was an interaction between age and load ($F(1, 28) = 4.382$, $MSE = 5649.0$, $p = .045$, $\eta_p^2 = .135$): load slowed RTs more for old (172 ms slower under high vs low load) compared to young adults (125 ms slower under high vs low load). Note that the line task produced a smaller load effect for the old adults in this chapter compared to the letter search task in previous chapters (256 ms in Chapter 1 and 226 ms in Chapter 4); the same was true for young adults (166 ms in Chapter 1 and 160 ms in Chapter 4).

Further, there was a significant three-way interaction between age, load and valence ($F(1, 28) = 12.092$, $MSE = 71.0$, $p < .01$, $\eta_p^2 = .302$). Closer inspection of Figure 5.2 indicates that the effect of load on valence was larger in the old adults compared to young adults. In the low load condition, young and old adults showed a significant effect of valence ($F(2, 30) = 29.939$, $MSE = 72.0$, $p < .01$, $\eta_p^2 = .666$ for young adults; $F(2, 26) = 74.190$, $MSE = 97.0$, $p < .01$, $\eta_p^2 = .851$ for old adults), though the valence effect was larger for old (*M* difference between negative and neutral = 36 ms; *M* difference between positive and neutral = 41 ms) compared to young adults (*M* difference between negative and neutral = 17 ms; *M* difference between positive and neutral = 22 ms) both for negative ($t(28) = 3.316$, $SEM = 5.931$, $p < .01$) and positive valence ($t(28) = 4.191$, $SEM = 4.529$, $p < .01$). However, as illustrated in Figure 5.2, high load completely eliminated the valence effect for old adults ($F(2, 26) = 1.105$, $MSE = 61.4$, $p = .346$, $\eta_p^2 = .078$), but not for young adults ($F(2, 30) = 3.483$, $MSE = 93.9$, $p = .044$, $\eta_p^2 = .188$).

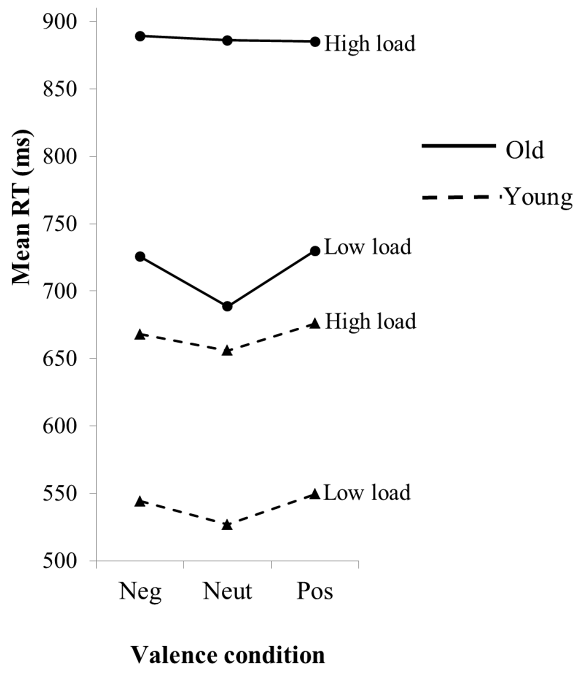

Figure 5.2 Mean RTs for negative, neutral and positive valence conditions under high and low load for the young and old adults in Experiment 5.

To examine the possibility that the age differences could be accounted for in terms of generalised slowing, valence effects were calculated as proportions of each participants' baseline RT, that is: (valence condition RT - neutral RT)/neutral RT. Given that this analysis now considers valence effects (i.e. the proportional difference between the valence and neutral condition), a two-way interaction between age and load is predicted if the differential effects of load on distraction occur regardless of the overall RT differences between young and old adults. Proportional scores were entered into a mixed model ANOVA with perceptual load (high or low) and valence (positive or negative) as within-subject factors, and age (young or old) as a between-subjects factor. There was a significant effect of load ($F(1, 28) = 79.209$, $MSE = .0$, $p < .01$, $\eta_p^2 = .739$): proportional RT scores were reduced from low to high load across all participants (*M* reduction in proportional RT from low to high load = .038 % for negative valence; .045% for positive valence). Crucially, there was an interaction between age and load ($F(1, 28) = 10.440$, $MSE = .0$, $p = .003$, $\eta_p^2 = .272$): load reduced proportional RT scores more for old (*M* reduction = .051 for negative; .062 for positive) compared to young adults (*M* reduction = .024 for negative; .029 for positive), as shown in Figure 5.3. Thus, the generalised slowing hypothesis (Brinley, 1965) cannot account for the greater effect of load on valence for old compared to young adults in the present chapter.

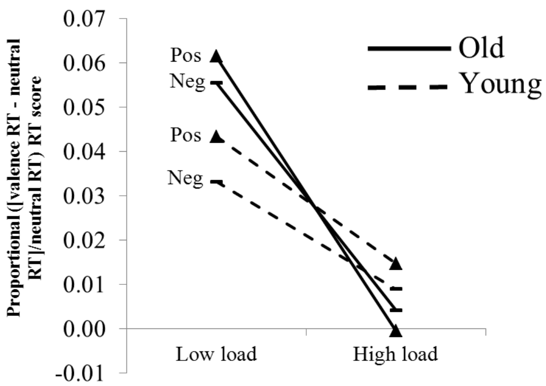

Figure 5.3 Proportional RT scores for negative and positive valence for young and old age groups.

Error rate. A mixed model ANOVA was performed on mean error rates, with perceptual load (high or low) and valence (positive, negative or neutral) as within-subject factors and age (young or old) as a between-subjects factor. There was a significant effect of valence ($F(1, 28) = 3.490$, $MSE = 12.7$, $p = .037$, $\eta_p^2 = .111$), which interacted with load ($F(1, 28) = 3.973$, $MSE = 9.5$, $p = .024$, $\eta_p^2 = .124$). Thus, error rates were higher in the valence conditions compared to neutral condition for low load (*M* difference from neutral to valence conditions = 2.8%) but not for high load (*M* difference from neutral to valence conditions = .2%). There were also significant effects of age ($F(1, 28) = 15.594$, $MSE = 125.1$, $p < .01$, $\eta_p^2 = .358$) and load ($F(1, 28) = 131.339$, $MSE = 64.0$, $p < .01$, $\eta_p^2 = .824$), with an interaction between them ($F(1, 28) = 4.943$, $MSE = 64.0$, $p = .034$, $\eta_p^2 = .150$): the decrease in accuracy from low to high load was greater for old (*M* difference from high to low load = 15%) compared to young adults (*M* difference from high to low load = 11%). The interaction between age and valence and the three-way interaction between age, load and valence were not significant (*F*-values < 1). Although less sensitive, the accuracy analysis generally supported the RT data and indicated no evidence of any trade-off between speed and accuracy.

5.3 Chapter Conclusions

Chapter 5 investigated whether age differences in the effect of load on emotional perception could have the positive consequence of old adults being less susceptible to distraction from emotional lexical stimuli under high load conditions. Distractor interference effects from emotion were reduced under high (relative to low) perceptual load conditions for both age groups. Whereas old adults showed a greater distractor interference effect from emotion in the low load condition (vs young adults), they were less susceptible to distractor interference effects from emotion under high load conditions (vs young adults). Note that age-related slowing was ruled out, and the stimuli were not subject to visual differences or age differences in valence and arousal attribution.

The load modulation of the emotional distractor effect is in line with load theory (Lavie, 1995, 2005) and with Erthal et al. (2005) that found that the distractor interference effect from unpleasant (vs neutral) stimuli was no longer apparent under high (vs low) load. The larger distractor interference effect from emotion in the low load condition can be explained by the theoretical framework developed by Hasher and Zack (1988) which states that failures to ignore task-irrelevant information are attributable to an age-related decline in the efficiency of inhibitory processes. Thus, when perceptual resources were available under low load, old adults were less able to inhibit task-irrelevant distractors compared to young adults. This interpretation would also fit with findings obtained by Maylor and Lavie's (1998), which found that interference effects from task-irrelevant incompatible distractors was greater for old compared to young adults under low perceptual load conditions.

The greater load modulation in old relative to young adults can be explained by the age-related reduction in perceptual capacity (Ball et al., 1988; Humphrey & Kramer, 1997; Maylor & Lavie, 1998; Scialfa et al., 1987; Scialfa et al., 1994; Sekuler & Ball, 1986). Proportionally less attentional resources are available in old (vs young) adults as load increases, meaning that task-irrelevant information can be more effectively ignored. Thus, the effect of age and load on perception seems to involve two components: an age-related reduction in the active inhibition mechanism and a reduced processing capacity that leads to improved selectivity in old (vs young) adults with smaller increases of load. I discuss the implications of the present chapter in the General Discussion.

Chapter 6:

General Discussion

6.1 Overview of findings

The research reported in this thesis demonstrates the effects of age and load on the perception of emotion. The results established that under conditions of divided attention involving low perceptual load (Chapters 2 and 4), and of full attention and short exposure durations (Chapter 3), old adults retain the negative valence detection advantage (both as compared to neutral and as compared to positive valence) that is typically found for young adults (e.g. Nasrallah et al., 2009). The negative valence detection advantage was established both for peripheral and parafoveal stimuli (Chapter 2). Increased perceptual load in the attended task modulated the negative valence detection advantage to a greater extent for old compared to young adults (Chapter 4). These findings were reflected in perceptual sensitivity measures, typically not accompanied by any effects on response bias. Distractor interference effects were greater for both negative and positive compared to neutral words. Under low load conditions old adults showed a larger distractor interference effect from emotion compared to young adults, whereas in the high load condition distractor interference effects from emotion were eliminated for old adults but young adults still showed heightened interference from emotion. Alternative accounts in terms of visual confounds, and differences in IQ and visual acuity between the age groups were ruled out. Also note that the findings were established in cases where idiosyncratic valence and arousal ratings were matched between age groups. Next I discuss the implications of the present findings to the understanding of the effects of ageing on attention to emotion.

6.2 Effects of age on emotional perception

The present thesis establishes that, at least under some circumstances, old adults retain the negative valence detection advantage that is typically found in young adults. This conclusion adds to previous research showing that old (and young) adults show a bias for negative words on the valence categorisation task (Keightley et al., 2006) and show a greater interference effect from negative (vs positive) words on a response competition task (Sammerz-Larkin et al., 2009). It is also consistent with findings that old adults show a bias for sad (vs neutral) schematic faces (Isaacowitz et al., 2006) and angry (vs neutral) facial expressions (presented subliminally; Lee & Knight, 2009) on the dot probe task, and a bias for detecting angry (vs happy and neutral) schematic faces (Hahn et al., 2006; Mather & Knight, 2006) and negative (vs positive or neutral) objects (e.g. a grenade; Leclerc & Kensinger, 2008) on visual search tasks. In addition to these previous studies the research in the present thesis directly demonstrates effects on perceptual sensitivity, free from any age differences in response biases, for lexical stimuli that were not subject to visual confounds.

The finding of a negative valence detection advantage appear at odds with the claim that there is an age-related positivity bias. There are a number of possible explanations. The first is by referring to the nature of the stimuli: face stimuli have been used in much of the previous research that has found a positivity bias (Calder et al., 2003; Isaacowitz et al., 2007; Keightley et al., 2006; Lee & Knight, 2009; Mather & Carstensen, 2003; McDowell et al., 1994; Moreno et al., 1993). It is therefore possible that old adults are more biased to positive (vs negative and vs neutral) faces, but when it comes to emotion represented by spiders (Chapter 2) and words (e.g. murder, cancer, rape; Chapters 3 and 4), old adults appear more sensitive to negative (vs positive and neutral) stimuli. Secondly, whereas here the effects are found on perceptual sensitivity for emotional stimuli, previous studies have tended to look at other forms of processes, for example RT or eye movement biases. Therefore the negative valence detection advantage established in this thesis may be confined to perceptual sensitivity and not be reflected these other processes. Indeed there was typically no effects on response bias in the present thesis. A third possibility is that the previous studies that used photographs of facial expressions (Calder et al., 2003; Isaacowitz et al., 2007; Keightley et al., 2006; Lee & Knight, 2009; Mather & Carstensen, 2003; McDowell et al., 1994; Moreno et al., 1993) that were not matched for low level visual differences, meaning that the stimuli could have contained visual confounds (e.g. happy facial expressions contained open mouths showing white teeth compared to other facial expressions with closed mouths) that masked perceptual sensitivity differences. The pictorial and lexical stimuli used in the present thesis however, meant that the results were not subject to visual confounds. In line with this interpretation, two other studies using lexical stimuli found that old adults retain the negative valence detection advantage in the emotional categorisation (Isaacowitz et al., 2007) and emotional blink tasks (Langley et al., 2008).

There was an exception in the present thesis regarding the negative valence detection advantage in old adults: when stimuli received full attention for a longer duration. The negative valence detection advantage was no longer apparent under these conditions (Chapter 3). One explanation for this finding comes from the socioemotional selectivity theory (e.g. Carstensen, 1993) that posits that with age, individuals become increasingly selective with regards to the information they process, investing greater resources in positive information and less to negative information (see reviews by Carstensen, Mikels & Mather, 2006; Mather & Carstensen, 2005). Since there would have been a greater strategic opportunity to adapt attention processing to be consistent with these emotional goals (i.e. old adults allocating proportionately more resources to positive information) in the longer duration condition of Chapter 3, this could have led to a positive strategy counteracting the negative bias. In other words, the negative bias appears to have been concealed by an additional positive strategic bias (possibly in later stages of processing) in the long duration condition, and so no advantage was found for either positive or negative valence. However, in the short duration condition old adults would not have had a sufficient opportunity to bias positive information (thus allowing the negative valence detection advantage to surface).

Indeed support for a positivity strategy is found in previous studies using long exposure durations, for example in dot probe studies using facial expressions presented for over 1000 ms (Isaacowitz et al., 2006; Mather & Carstensen, 2003). Old adults were faster to detect dot probes that appeared in the location of positive (vs neutral) facial expressions and slower to detect targets in the location of negative (vs neutral) faces, indicating an orientation preference towards positive and away from negative facial expressions.

This interpretation also fits with Lee and Knight's (2009) study where old adults were faster to detect dot probes that appeared in the location of subliminally presented angry (vs neutral) facial expressions, but slower to detect targets that appeared in the location of supraliminally presented angry (vs neutral) faces. The subliminal condition is consistent with the findings in the short duration condition and the supraliminal condition is in line with the long duration condition in the present thesis. That said, whereas Lee and Knight (2009) used faces and their RT measure does not address perceptual sensitivity, I found the negative advantage in detection sensitivity under short exposure durations using words.

6.3 Effects of load on age differences in information perception and distraction

The findings reported in this thesis was as predicted from load theory (Lavie, 1995, 2005) and from the assumption that there is a reduced perceptual capacity with age (e.g. Salthouse, 1991, 1992). Detection sensitivity and distractor interference were reduced under high (relative to low) perceptual load conditions for both age groups, in line with previous behavioural (Cartwright-Finch & Lavie, 2006; Lavie, 1995; Lavie & Cox, 1997; Macdonald & Lavie, 2008) and neuroimaging (Bahrami et al., 2007; O'Connor et al., 2002; Pessoa et al., 2002; Pinsk et al., 2003; Rees et al., 1997; Schwartz et al., 2005; Yi et al., 2004) studies on young adults that support load theory. The finding of a greater load modulation of the detection sensitivity and distractor interference effects for old compared to young adults (Chapters 2, 4 and 5) brings together load theory and previous research showing that there is an age-related decline in perceptual capacity (Ball et al., 1988; Humphrey & Kramer, 1997; Lunsman et al., 2008; Maylor & Lavie, 1998; Scialfa et al., 1987; Scialfa et al., 1994; Sekuler & Ball, 1986). The reduced perceptual capacity in old adults meant that as load increased, the detection of additional stimuli in old adults reduces more rapidly than young adults, presumably due to running out of available resources at lower levels of load. This had the consequence of old adults benefiting more from increases in the level of perceptual load in the case of selective attention (the distractor interference effect was entirely eliminated under high load) compared to young adults (distractor interference was reduced but not eliminated under high load).

Note that old adults were more prone to emotional distraction than young adults under low perceptual load conditions (Chapter 5). This effect was greater than expected on the basis of generalised slowing, as revealed by response compatibility effects expressed as a proportion of baseline RT. These results can be explained using the theoretical framework developed by Hasher and Zack (1988) which states that failures to ignore task-irrelevant information are attributable to an age-related decline in the efficiency of inhibitory processes. Thus under low load, when perceptual resources are available, participants are less able to inhibit task-irrelevant distractors. This interpretation would also fit with findings obtained by Maylor and Lavie's (1998), which found that interference from task-irrelevant incompatible distractors was greater for old compared to young adults under low perceptual load conditions. Thus, the effect of age and load on perception seems to involve two components. The first is the age-related reduction in the active inhibition mechanism that leads to a reduced suppression of potent distractors (explaining the greater distractor interference under low load). The second is a reduced processing capacity that, by contrast, leads to improved selectivity in old (vs young) adults with smaller increases of load.

The present thesis indicates that conscious detection of and interference from emotional stimuli, at least to some extent, require attentional resources. By manipulating the allocation of attention through a manipulation of perceptual load, the negative valence detection advantage (Chapter 4) and interference effect from emotional distractors (Chapter 5) under low load was reduced (Chapter 5 young adults) or eliminated (Chapter 4; Chapter 5 old adults) under high load. This is in line with some previous attention studies using other manipulations of attention, for example the spatial cuing study by Brassen et al. (2011) who found that old adults showed an interference effect from positive (vs neutral) faces on trials that had no spatial manipulation of attention, but when attention was cued to a location away from the face the interference effect was no longer apparent. It is also consistent with an object-based attention study on young adults by Erthal et al. (2005) that required a line discrimination response (parallel or not under high or low load conditions) while task-irrelevant emotional images were presented. Under low load, there was a greater interference effect from unpleasant compared to neutral images, but the enhanced distractor interference effect from emotion was eliminated under high load (unpleasant and neutral images were equally distracting). This suggests that processing emotional images is dependent on attentional resources.

One result in the present thesis the would appear inconsistent with load theory is the finding that detection sensitivity for threat is not modulated by load for young adults (Chapter 2). This would seem all the more surprising given that there was a load modulation of detection sensitivity for negative words in the young adults (Chapter 4). One potential explanation is that the threat image in Chapter 2 had a greater socio-biological evaluative strength (Matthews et al., 1997) compared to the word stimuli in Chapter 4. Indeed the threat stimulus in Chapter 2 is known to elicit consistent emotional responses even in non-arachnophobic individuals (Arrindell et al., 1991; Kindt et al., 1997). Thus, although some of the words in Chapter 4 indicated biological threat (e.g. murder, anger, cancer, deface, rape) the stimuli were likely to have had less affective strength at conveying biological threat compared to the image stimulus. In other words, the physical form of a spider is more likely to convey a genuine threat to participants in the real world than the word 'spider,' accounting for why only highly socio-biologically relevant stimuli were able to evade the effects of perceptual load.

The present thesis can accommodate previous discrepancies in ageing literature regarding the effect of attention on emotional perception. In the divided attention conditions of two previous studies, a bias for negative information was found (Knight et al., 2007; Mather & Knight, 2005), but a bias for positive information was found in a different study (Allard & Isaacowitz, 2008). The study that found a positive bias under divided attention conditions placed minimal demands on attentional resources and the exposure duration was long (participants were asked to simply view images presented for 2 s and engage in a brief auditory word/non-word discrimination task at the start of the trial). It is therefore possible that the divided attention condition in this study was more analogous to the full attention long duration condition in Chapter 3. Old adults would have had sufficient capacity to employ a positivity bias strategy (vs short duration or divided attention conditions) in line with the socioemotional selectivity theory (e.g. Carstensen, 1993). In the two other studies that did find a negativity bias under divided attention conditions (Knight et al., 2007; Mather & Knight, 2005), the more demanding secondary task may have precluded the use of a conscious positivity strategy. Note that the divided attention condition in these studies was not likely to have involved a high perceptual load and so are comparable to the low load condition in Chapter 4 in the present thesis (where a negative bias was found for old adults). As none of these previous studies assessed the effects of manipulating visual informational load on emotional perception, it is impossible to make any further inferences about the effects of perceptual load.

Positive and negative stimuli were equally distracting (vs neutral stimuli) for young and old adults in the low load condition of Chapter 5. This is a different pattern to the detection chapters (Chapters 3-4) that showed a negative (vs positive) detection advantage for the same set of word stimuli. One explanation is that distractor processing may reflect a different mechanism to perceptual sensitivity. For instance, distraction may be sensitive to both positive and negative information whereas perceptual sensitivity, a different process, may reflect an earlier processing stage that may be more attuned to negative valence. Valence detection advantages have previously been suggested to reflect a faster speed of information accrual in short duration conditions (Nasrallah et al., 2009). Conversely, stimuli presented for longer durations may no longer be affected by differences in speed of accrual, and may instead be more sensitive to the effect of the positivity bias (given the longer duration to produce conscious strategic biases). This can explain studies that find a positivity bias in long durations (presented for over 1000 ms; Isaacowitz et al., 2006; Mather & Carstensen, 2003). Indeed the negative valence detection advantages in the present thesis were found under shorter exposure durations than the distraction word exposure duration (whereas distractors were presented for 150 ms for both young and old adults, the conditions that showed a negative valence detection advantage presented stimuli for 22 ms and 33 ms for young adults, and 55 ms and 99 ms for old adults).

6.4 Implications for future research

The findings of the present thesis lead to interesting and potentially important directions for future research.

6.4.1 Age difference in the unconscious processing of emotional valence

The short exposure duration condition in Chapter 3 restricted conscious perception (relative to the long duration condition), but could not be considered subliminal. Indeed confidence ratings were above pure guess level. Future research could assess the effects of age and load on unconscious perception of emotion. The results obtained in the short duration condition of Chapter 3 would lead to the expectation that young and old adults would both show a similar bias for unconsciously presented negative (vs positive) information. To test this, a semantic priming task (similar to Dehaene et al., 1998) could be employed. Individuals could be asked to categorise centrally located words as either emotional or neutral, which are preceded by either a congruent or incongruent word primes presented unconsciously (masked and short exposure durations such that confidence ratings were reliably pure guess).

Previous semantic priming studies on young adults using emotional stimuli have produced mixed findings (see Rossell & Nobre, 2004). Matthews and Southall (1991) found that young adults showed a similar magnitude of priming for positive, negative and neutral prime–target pairs. Matthews, Pitcaithly and Mann (1995) demonstrated that young adults showed greater priming when negative stimuli were used in comparison to neutral or positive pairs. In contrast, Rossell, Shapleske and David (2000) found that young adults exhibit less priming to pairs of negative valence compared to both neutral and positive valence. However, they do establish that the affective valence of the prime–target pair has an impact on the degree of priming reported. Nevertheless, the stimuli in each condition of valence in these studies were not matched on subjective arousal; primes were presented above the conscious threshold (all three studies presented the prime for over 120 ms, providing the opportunity for conscious strategic biases to confound the results); and only young adults were tested. Thus, the effects of age and load on the unconscious perception of emotion remains untested and would be a worthwhile avenue for further research.

6.4.2 Modality

This thesis studied age difference in the effect of load on perceptual sensitivity and distractor interference effects from emotion in the visual domain. In light of evidence suggesting that attentional resources are shared between modalities (Santangelo, Belardinelli & Spence, 2007; Sinnett, Costa & Soto-Faraco, 2006; see Spence, 2001, for review), it would be of theoretical interest to ask whether the age differences in emotional distraction and perceptual sensitivity in the present thesis would also be found in the auditory domain. Words could be presented in audition and cross modal effects, for example using the visual letter search task (as in Chapters 2 and 4 in the present thesis) could be assessed. Alternatively, within modal effects could be studied, for example using an auditory word discrimination task while assessing detection or interference from positive (e.g. a laugh) or negative (e.g. a scream) audio clips. Detection sensitivity or distraction paradigms could be conducted to see if the same effects of age and load on emotional perception are found in the auditory domain.

6.4.3 Different manipulations of load and type of stimuli

In this thesis I used search tasks of similar items or subtle line discrimination tasks to manipulate load. Future research could seek to generalise the effects of age and load on emotion perception over a variety of different perceptual load tasks. For example, perceptual load could be manipulated using the cross task devised by Cartwright-Finch and Lavie (2007), in which participants are asked either to determine which cross-arm is longer (high load) or which cross-arm is blue (low load). Alternatively, an RSVP stream could be used on which a single feature (low load) or conjunction of features (high load) search task can be performed (e.g. Schwartz et al., 2005).

It is also possible that the findings reported in the present thesis are, to some extent, specific to the type of stimuli that were used. To test this claim, other types of emotional stimuli could be used to see whether the reported effects apply to other stimulus modalities. For example, computer morphed face stimuli could be used that lie on a valence continuum. Participants would be asked to rate the faces on the continuum for valence intensity and arousal before the experiment. A replication of the findings in the present thesis with either a different stimulus modality or an alternative load manipulation would demonstrate the generality of the effect of age and load on emotional perception.

6.5 Implications for daily life

Although the conclusions of the present thesis are derived from measures obtained from laboratory settings, the findings have interesting implications for daily life. For instance, for navigating the world (e.g. while driving) and social interactions. The finding that old adults maintain the negative valence detection advantage under conditions of divided attention involving low perceptual load

(Chapters 2 and 4), and of full attention and short exposure durations (Chapter 3), is important as it suggests that old adults remain able to prioritise emotionally salient items and respond appropriately to avoid negative outcomes. The greater modulation by load of threat (Chapter 2) and negative valence (Chapter 4) in old (vs young) adults means that old adults are at greater risk from negative, potentially threatening, stimuli under conditions of high load (vs young adults). For example, old adults may not notice hazard signals, or may come across as offensive in social interactions if they appear to ignore angry spoken words. In addition, the greater distraction from emotion in old (vs young) adults under low load conditions (Chapter 5) suggests that old adults should be more cautious in situations of low load. The present thesis further suggests that under certain circumstances it may even be beneficial for old adults to engage in a high load task in order to prevent distraction in situations where noticing the emotional distractor would be undesirable.

6.6 Conclusions

In summary, the present thesis contributes to our understanding of the role of ageing and perceptual load in the perception of emotion. The results established that old adults retain the negative valence detection advantage under conditions of full attention and short durations, and of divided attention involving low perceptual load. This advantage was reflected in enhanced perceptual sensitivity, typically not accompanied by any response bias, as shown by signal detection analysis. A high perceptual load modulated the negative valence detection advantage for both age groups, but to a greater extent for old (vs young) adults. This gave rise to the finding that old adults were less prone to emotional distraction under high perceptual load conditions. The findings demonstrate the importance of considering age and perceptual load in determining the perception of emotion, and have implications for applied settings as well as interesting avenues for further research.

References

Allard, E., & Isaacowitz, D. (2008). Are preferences in emotional processing affected by distraction? Examining the age-related positivity effect in visual fixation within a dual-task paradigm. *Aging, Neuropsychology, and Cognition. 15*, 725–743.

Anderson, A.K., Christoff, K., Panitz, D., De Rosa, E., & Gabrieli, J.D. (2003). Neural correlates of the automatic processing of threat facial signals. *Journal of Neuroscience*, *23*, 5627–5633.

Anstis, S.M. (1974). A chart demonstrating variations in acuity with retinal position. *Vision Research, 14*, 589-592.

Arrindell, W.A., Pickersgill, M.J., Merckelbach, H., Ardon, A.M., & Cornet, F.C. (1991). Phobic dimensions: III. Factor analytic approaches to the study of common phobic fears; an updated review of findings obtained with adult subjects. *Advances in behaviour research and therapy*, *13*(2), 73-130.

Arrindell, W.A., Pickersgill, M.J., Merckelbach, H., Ardon, M.A., & Cornet, F.C. (1991). Phobic dimensions: III. Factor analytic approaches to the study of common phobic fears: An updated review of findings obtained with adult subjects. *Advances in Behaviour Research and Therapy, 13*, 73-130.

Ashley, V., & Swick, D. (2009). Consequences of emotional stimuli: age differences on pure and mixed blocks of the emotional Stroop. *Behavioral and Brain Functions. 5*, 14.

Attar, C.H., & Müller, M.M. (2012). Selective Attention to Task-Irrelevant Emotional Distractors Is Unaffected by the Perceptual Load Associated with a Foreground Task. *PloS one*, *7*(5), e37186.

Bach, M. (1996). The “Freiburg Visual Acuity Test” – Automatic measurement of visual acuity. *Optometry and Vision Science, 73*, 49–53.

Bahrami, B., Lavie, N., & Rees, G. (2007). Attentional load modulates responses of human primary visual cortex to invisible stimuli. *Current Biology, 17*, 509-513.

Ball, K., Beard, B.L., Roenker, D.L., Miller, R.L., & Griggs, D.S. (1988). Age and visual search: expanding the useful field of view. *Journal of the Optical Society of America A*, *5*, 2210-2219.

Becic, E., Kramer, A.F., & Boot, W.R. (2007). Age-related differences in visual search in dynamic displays. *Psychology and Aging*, 22, 67-74.

Brassen, S., Gamer, M., & Büchel, C. (2011). Anterior cingulate activation is related to a positivity bias and emotional stability in successful aging. *Biological psychiatry*, *70*(2), 131-137.

Brinley, J. F. (1965). Cognitive sets, speed and accuracy of performance in the elderly. In A. T. Welford & J. E. Birren (Eds.), *Behavior, aging and the nervous system* (pp. 114–149). Springfield, IL: Charles C Thomas.

Calder, A.J., Keane, J., Manly, T., Sprengelmeyer, R., Scott, S., Nimmo-Smith, I., & Young, A.W. (2003). Facial expression recognition across the adult life span. *Neuropsychologia*, *41*(2), 195-202.

Carstensen, L.L. (1993). Motivation for social contact across the life span: A theory of socioemotional selectivity. In J. E. Jacobs (Ed.), *Nebraska symposium on motivation: 1992, developmental perspectives on motivation* (Vol. 40, pp. 209–254). Lincoln: University of Nebraska Press.

Carstensen, L.L., Mikels, J.A., & Mather, M. (2006). Aging and the intersection of cognition, motivation, and emotion. *Handbook of the psychology of aging*, *6*, 343-362.

Cartwright-Finch, U., & Lavie, N. (2006). The role of perceptual load in inattentional blindness. *Cognition, 102*, 321–340.

Cohen, J.A. (1960). A coefficient of agreement for nominal scales. *Educational and Psychological Measurement*, *20*, 213–220.

Daniel, P.M., & Whitteridge, D. (1961). The representation of the visual field on the cerebral cortex in monkeys. *The Journal of Physiology*, *159*(2), 203-221.

Dehaene, S., Naccache, L., Le Clec'H, G., Koechlin, E., Mueller, M., Dehaene-Lambertz, G., & Le Bihan, D. (1998). Imaging unconscious semantic priming. *Nature*, *395*(6702), 597-600.

Eastwood, J.D., Smilek, D., & Merikle, P.M. (2001). Differential attentional guidance by unattended faces expressing positive and negative emotion. *Attention, Perception, & Psychophysics*, *63*(6), 1004-1013.

Eimer, M., Holmes, A., & McGlone, F.P. (2003). The role of spatial attention in the processing of facial expression: an ERP study of rapid brain responses to six basic emotions. *Cognitive, Affective, & Behavioral Neuroscience*, *3*, 97–110.

Ekman, P., & Friesen, W.V. (1976). Pictures of facial affect. *Palo Alto, CA: Consulting Psychologists Press*.

Erthal, F.S., De Oliveira, L., Mocaiber, I., Pereira, M.G., Machado-Pinheiro, W., Volchan, E., & Pessoa, L. (2005). Load-dependent modulation of affective picture processing. *Cognitive, Affective, & Behavioral Neuroscience*, *5*(4), 388-395.

Fischer, H., Sandblom, J., Gavazzeni, J., Fransson, P., Wright, C.I., & Bäckman, L. (2005). Age- differential patterns of brain activation during perception of angry faces. Neuroscience letters, 386, 99-104.

Fox, E., Lester, V., Russo, R., Bowles, R.J., Pichler, A., & Dutton, K. (2000). Facial expressions of emotion: Are angry faces detected more efficiently? *Cognition & Emotion*, *14*(1), 61-92.

Goren, D., & Wilson, H.R. (2003). Quantifying recognition abilities for four major emotional expressions based on facial geometry. *Journal of Vision*, *3*(9), 300-300.

Grady, C. (2012). The cognitive neuroscience of ageing. *Nature Reviews Neuroscience*, *13*(7), 491-505.

Grady, C.L. (2008). Cognitive neuroscience of aging. *Annals of the New York Academy of Sciences*, *1124*(1), 127-144.

Greenhouse, S.W., & Geisser, S. (1959). On methods in the analysis of profile data. *Psychometrika*, *24*, 95–112.

Gruhn, D., Scheibe, S. (2008). Age-related differences in valence and arousal ratings of pictures from the International Affective Picture System (IAPS): do ratings become more extreme with age? *Behavior Research Methods, 40*(2), 512–21.

Hahn, S., Carlson, C., Singer, S., & Gronlund, S.D. (2006). Aging and visual search: Automatic and controlled attentional bias to threat faces. *Acta Psychologica, 123, 312*–336.

Hansen, C.H., & Hansen, R.D. (1988). Finding the face in the crowd: an anger superiority effect. *Journal of personality and social psychology*, *54*(6), 917.

Hasher, L. & Zacks, R.T. (1988). Working memory, comprehension, and aging: A review and new view. *Psychology of Learning and Motivation*, *22*, 193-225.

Holmes, A., Vuilleumier, P., & Eimer, M. (2003). The processing of emotional facial expression is gated by spatial attention: evidence from event-related brain potentials. *Cognitive Brain Research*, *16*, 174-184.

Humphrey, D.G., & Kramer, A.F. (1997). Age differences in visual search for feature, conjunction, and triple-conjunction targets. *Psychology and Aging*, *12*(4), 704.

Isaacowitz, D.M., Löckenhoff, C.E., Lane, R.D., Wright, R., Sechrest, L., Riedel, R., & Costa, P.T. (2007). Age differences in recognition of emotion in lexical stimuli and facial expressions. *Psychology and Aging*, *22*(1), 147.

Isaacowitz, D.M., Wadlinger, H.A., Goren, D., & Wilson, H.R. (2006). Selective preference in visual fixation away from negative images in old age? An eye-tracking study. *Psychology and Aging*, *21*(1), 40.

Ishai, A., Pessoa, L., Bikle, P.C., & Ungerleider, L.G. (2004). Repetition suppression of faces is modulated by emotion. *Proceedings - National Academy of Sciences USA, 101,* 9827–9832.

Keightley, M.L., Winocur, G., Burianova, H., Hongwanishkul, D., & Grady, C.L. (2006). Age effects on social cognition: faces tell a different story. *Psychology and Aging*, *21*(3), 558.

Kindt, M., Bierman, D., & Brosschot, J.F. (1997). Cognitive bias in spider fear and control children: Assessment of emotional interference by a card format and a single-trial format of the Stroop task. *Journal of Experimental Child Psychology*, *66*(2), 163-179.

Knight, M., Seymour, T.L., Gaunt, J.T., Baker, C., Nesmith, K., & Mather, M. (2007). Aging and goal-directed emotional attention: distraction reverses emotional biases. *Emotion, 7*, 705-14.

Lamonica, H.M., Keefe, R.S., Harvey, P.D., Gold, J.M., & Goldberg, T.E. (2010). Differential effects of emotional information on interference task performance across the life span. *Frontiers in aging neuroscience*, *2*, 141.

Lang, P. J. (1980). Behavioral treatment and bio-behavioral assessment: Computer applications. In J. B. Sidowski, J. H. Johnson, & T. A. Williams (Eds.), *Technology in mental health care delivery systems* (pp. 119–137). Norwood, NJ: Ablex.

Lang, P.J., Bradley, M.M., & Cuthbert, B.N. (2005). *International Affective Picture System (IAPS): Digitized Photographs, Instruction Manual and Affective Ratings.* Gainesville, FL: University of Florida.

Langley, L.K., Rokke, P.D., Stark, A.C., Saville, A.L., Allen, J.L., & Bagne, A.G. (2008). The Emotional Blink: Adult Age Differences in Visual Attention to Emotional Information. *Psychology and Aging, 23*, 873-885.

Lavie, N. (1995). Perceptual load as a necessary condition for selective attention. *Journal of Experimental Psychology: Human Perception and Performance, 21*, 451–468.

Lavie, N. (2005). Distracted and confused?: selective attention under load. *Trends in Cognitive Sciences, 9,* 75-82.

Lavie, N., & Cox, S. (1997). On the efficiency of attentional selection: Efficient visual search results in inefficient rejection of distraction. *Psychological Science, 8*, 395-398.

Leclerc C.M., & Kensinger E.A. (2008). Effects of age on detection of emotional information. *Psychology and Aging, 23*, 209-215.

Lee, L.O., & Knight, B.G. (2009). Attentional bias for threat in older adults: moderation of the positivity bias by trait anxiety and stimulus modality. *Psychology and Aging*, *24*(3), 741.

Lunsman, M., Edwards, J.D., Andel, R., Small, B.J., Ball, K.K., & Roenker, D.L. (2008). What predicts changes in useful field of view test performance? *Psychology and Aging, 23,* 917-27.

Macdonald, J.S.P., & Lavie, N. (2008). Load induced blindness. *Journal of Experimental Psychology: Human Perception and Performance, 34*, 1078-91.

Madden, D.J., & Langley, L.K. (2003). Age-Related Changes in Selective Attention and Perceptual Load. *Psychology and Aging, 18,* 58-61.

Madden, D.J., Pierce, T.W., & Allen, P.A. (1996). Adult age differences in the use of distractor homogeneity during visual search. *Psychology and Aging*, *11*(3), 454.

Malatesta, C.Z., Izard, C.E., Culver, C., & Nicolich, M. (1987). Emotion communication skills in young, middle-aged, and older women. *Psychology and Aging*, *2*(2), 193.

Mather, M. (2012). The emotion paradox in the aging brain. *Annals of the New York Academy of Sciences*. *1251,* 33–49.

Mather, M., & Carstensen, L.L. (2003). Aging and attentional biases for emotional faces. *Psychological Science*, *14*(5), 409-415.

Mather, M., & Carstensen, L.L. (2005). Aging and motivated cognition: The positivity effect in attention and memory. *Trends in cognitive sciences*, *9*(10), 496-502.

Mather, M., & Knight, M. (2005). Goal-directed memory: the role of cognitive control in older adults' emotional memory. *Psychology and Aging*, *20*(4), 554.

Mather, M., & Knight, M.R. (2006). Angry faces get noticed quickly: threat detection is not impaired among older adults. *The journals of gerontology. Series B, Psychological sciences and social sciences, 61,* 54-57.

Mathews, A., Mackintosh, B., & Fulcher, E.P. (1997). Cognitive biases in anxiety and attention to threat. *Trends in Cognitive Sciences*, *1*(9), 340-345.

Matthews, G., & Southall, A. (1991). Depression and the processing of emotional stimuli: A study of semantic priming. *Cognitive Therapy and Research*, *15*(4), 283-302.

Matthews, G., Pitcaithly, D., & Mann, R.L.E. (1995). Mood, neuroticism, and the encoding of affective words. *Cognitive Therapy and Research, 19,* 563–587.

Maylor, E., & Lavie, N. (1998). The influence of perceptual load on age differences in selective attention. *Psychology and Aging*. *13,* 563-573.

McDowell, C.L., Harrison, D.W., & Demaree, H.A. (1994). Is right hemisphere decline in the perception of emotion a function of aging? *International Journal of Neuroscience*, *79*(1), 1-11.

Monti, J.M., Weintraub, S., & Egner, T. (2010). Differential age-related decline in conflict-driven task-set shielding from emotional versus non-emotional distracters. *Neuropsychologia*, *48*(6), 1697-1706.

Moreno, C., Borod, J.C., Welkowitz, J., & Alpert, M. (1993). The perception of facial emotion across the adult life span. *Developmental Neuropsychology*, *9*(3-4), 305-314.

Murphy, S.T., & Zajonc, R.B. (1993). Affect, cognition, and awareness: Affective priming with optimal and suboptimal stimulus exposures. *Journal of Personality and Social Psychology, 64*(5), 723-739.

Nasrallah, M., Carmel, D., & Lavie, N. (2009). Murder, she wrote: Enhanced sensitivity to negative word valence. *Emotion*, *9*(5), 609.

Neiss, M.B., Leigland, L.A., Carlson, N.E., & Janowsky, J.S. (2009). Age differences in perception and awareness of emotion. *Neurobiology of aging*, *30*(8), 1305-1313.

O'Connor, G.H., Fukui, M.M., Pinsk, M.A. & Kastner, S. (2002). Attention modulates responses in the human lateral geniculate nucleus. *Nature Neuroscience, 5*(11), 1203- 1209.

Ohman, A., Lundqvist, D., & Esteves, F. (2001). The face in the crowd revisited: a threat advantage with schematic stimuli. *Journal of personality and social psychology*, *80*(3), 381.

Paulhus, D.L. (1991). Measurement and control of response bias. In J.P. Robinson, P. Shaver, & L.S. Wrightsman (Eds.), *Measures of personality and social psychological attitudes* (pp. 17–59). San Diego, CA: Academic Press.

Pessoa, L., Gutierrez, E., Bandettini, P.A., & Ungerleider, L.G. (2002). Neural correlates of visual working memory: fMRI amplitude predicts task performance. *Neuron, 35*(5), 975-987.

Pessoa, L., Kastner, S., & Ungerleider, L.G. (2002). Attentional control of the processing of neutral and emotional stimuli. *Cognitive Brain*

Research, *15*(1), 31-45.

Pessoa, L., Padmala, S., & Morland, T. (2005). Fate of unattended fearful faces in the amygdala is determined by both attentional resources and cognitive modulation. *Neuroimage*, *28*(1), 249.

Pinsk, M.A., Doniger, G.M. & Kastner, S. (2003). Push-pull mechanism of selective attention in human extrastriate cortex. *Journal of Neurophysiology, 92*, 622-629.

Plude, D.J., & Doussard-Roosevelt, J.A. (1989). Aging, selective attention, and feature integration. *Psychology and Aging*, *4*(1), 98.

Purcell, D.G., Stewart, A.L., & Skov, R.B. (1996). It takes a confounded face to pop out of a crowd. *Perception*, *25*, 1091-1120.

Raven, J. & Rust, J. (2008) *Ravens Educational Standard Progressive Matrices Plus and Mill Hill Vocabulary Scale*. Pearson Assessment, London.

Rees, G., Frith, C.D. & Lavie, N. (1997). Modulating irrelevant motion perception by varying attentional load in an unrelated task. *Science, 278,* 1616-1619.

Rossell, S.L., & Nobre, A.C. (2004). Semantic priming of different affective categories. *Emotion*, *4*(4), 354.

Rossell, S.L., Shapleske, J., & David, A.S. (2000). Direct and indirect semantic priming with neutral and emotional words in schizophrenia: relationship to delusions. *Cognitive Neuropsychiatry*, *5*(4), 271-292.

Rovamo, J., & Virsu, V. (1979). An estimation and application of the human cortical magnification factor. *Experimental Brain Research*, *37*(3), 495-510.

Salthouse, T.A. (1991).Mediation of adult age differences in cognition by reductions in working memory and speed of processing. *Psychological Science, 2*, 179-183.

Salthouse, T.A. (1992). Mechanisms of age, cognition relations in adulthood. Hillsdale, NJ: Erlbaum.

Samanez-Larkin, G.R., Robertson, E.R., Mikels, J.A., Carstensen, L.L., & Gotlib, I.H. (2009). Selective attention to emotion in the aging brain. *Psychology and Aging*, *24*(3), 519.

Santangelo, V., Belardinelli, M.O., & Spence, C. (2007). The suppression of reflexive visual and auditory orienting when attention is otherwise engaged. *Journal of Experimental Psychology: Human Perception and Performance, 33,* 137– 148.

Schwartz, S., Vuilleumier, P., Hutton, C., Maravita, A., Dolan, R.J. & Driver, J. (2005). Attentional load and sensory competition in human vision: modulation of fMRI responses by load at fixation during task-irrelevant stimulation in the peripheral visual field. *Cerebral Cortex, 15*, 770-786.

Scialfa, C.T., Kline, D.W., & Lyman, B.J. (1987). Age differences in target identification as a function of retinal location and noise level: An examination of the useful field of view. *Psychology and Aging, 2*, 14-19.

Scialfa, C.T., Thomas, D.M., & Joffe, K.M (1994). Age differences in the Useful Field Of View: An Eye Movement Analysis. *Optometry and Vision Science, 71*, 736.

Sekuler, A., Bennett, P., & Mamelak. M. (2000). Effects of Aging on the Useful Field of View. *Experimental Aging Research,* 26, 103-120.

Sekuler, R., & Ball, K. (1986). Visual localization: age and practice. *Journal of the Optical Society of America A, 3***,** 864 – 867.

Sinnett, S., Costa, A., & Soto-Faraco, S. (2006). Manipulating inattentional blindness within and across sensory modalities. *The Quarterly Journal of Experimental Psychology, 59,* 1425– 1442.

Snellen Eye Chart. (2002). Snellen Eye Chart. *Health progress (Saint Louis, Mo.)* 70: 54-6.

Schwartz, S., Vuilleumier, P., Hutton, C., Maravita, A., Dolan, R.J. & Driver, J. (2005). Attentional load and sensory competition in human vision: modulation of fMRI responses by load at fixation during task-irrelevant stimulation in the peripheral visual field. *Cerebral Cortex, 15,* 770-786.

Spence, C. (2001) Crossmodal attentional capture: a controversy resolved? In: Folk C, Gibson B (eds) *Attention, distraction and action: multiple perspectives on attentional capture.* Elsevier Science, Amsterdam, pp 231–262.

Thomas, R.C., & Hasher, L. (2006). The influence of emotional valence on age differences in early processing and memory. *Psychology and Aging*, *21*(4), 821.

Toglia, M.P., & Battig, W.F. (1978). *Handbook of semantic word norms.* Hillsdale, NJ: Erlbaum.

van Reekum, C.M., Schaefer, S.M., Lapate, R.C., Norris, C.J., Greischar, L.L., & Davidson, R.J. (2011). Aging is associated with positive responding to neutral information but reduced recovery from negative information. *Social Cognitive and Affective Neuroscience, 6*(2)*,* 177-185.

Virsu, V., & Rovamo, J. (1979). Visual resolution, contrast sensitivity, and the cortical magnification factor. *Experimental Brain Research, 37,* 1–16.

Vuilleumier, P., & Schwartz, S. (2001). Beware and be aware: Capture of spatial attention by fear-related stimuli in neglect. *Neuroreport*, *12*(6), 1119-1122.

Vuilleumier, P., & Schwartz, S. (2001). Emotional facial expressions capture attention. *Neurology, 56*, 153-158.

Wilson, H.R., Loffler, G., & Wilkinson, F. (2002). Synthetic faces, face cubes, and the geometry of face space. *Vision research*, *42*(27), 2909-2923.

Wright, C.I., Wedig, M.M., Williams, D., Rauch , S.L., & Albert, M.S. (2006). Novel fearful faces activate the amygdala in healthy young and elderly adults. *Neurobiology of aging, 27*, 361- 374.

Wurm, L.H., Labouvie-Vief, G., Aycock, J., Rebucal, K.A., & Koch, H.E. (2004). Performance in auditory and emotional Stroop tasks: A comparison of older and younger adults. *Psychology and Aging, 19*, 523–535.

Yi, D.J., Woodman, G.F., Widders, D., Marois, R., & Chun, M.M. (2004). Neural fate of ignored stimuli: dissociable effects of perceptual and working memory load. *Nature Neuroscience, 7*(9), 992-996.

Appendix I

List of negative words

ache
agony
anger
army
ashamed
bad
beg
bitter
bomb
bore
bored
cage
cancer
casket
cheat
coffin
cowardly
crime
cruel
dandruff
dead
death
debt
decay
deface
defeated
degraded
despair
despise
destroy
die
dungeon
fail
failing
flood
fraud
frigid
grave
greedy
guilt
gun
hate
hazard
hell
hostage
hurt
ignore
insult
jail
kill
liar
lice
measles
misery
morbid
morgue
mosquito
murder
nag
nervous
never
offend
perish
perjury
pimple
polio
poor
punish
rancid
rape
rejected
retard
sewer
shot
sick
sickness
slavery
slay
soldier
tragedy
trash
trouble
ugly
unjust
vile
vulgar
weak
wreck

List of positive words

air	mountain
amuse	music
beach	new
beauty	nice
bed	ocean
blossom	passion
calm	peace
cheerful	peaceful
comfort	peach
cottage	pet
country	playing
dance	praise
dawn	pretty
deer	pup
dinner	quilt
dream	rejoice
eagle	rose
fantasy	sail
father	sailboat
feel	sea
flower	sex
forest	shower
free	sing
freedom	ski
friend	sky
fruit	smile
garden	soft
generous	softly
gentle	song
glad	spring
grass	spruce
happy	sun
home	sunset
honesty	sweet
honey	swimming
icecream	tranquil
kiss	travel
lake	tree
laugh	trust
lemonade	truth
lips	wisdom
mermaid	wise
merry	woman
mother	youth

List of neutral words

accord
account
adding
after
age
aim
allow
also
angle
area
author
back
banker
bark
basement
beak
bean
belt
blew
blow
booth
bowl
box
brick
building
business
cable
capsule
card
cellar
center
chart
choral
clove
coach
cockpit
collar
combine
cord
course
crawl
cup
custom
deal
deck
dense
dial
docile
drizzle
duty
ear
eight
engine
exposure
feet
finite
five
foot
form
front
gate
glasses
graph
hairpin
helmet
highway
ignition
imitate
ink
jargon
jump
junction
kettle
lesson
level
lift
load
long
loop
magnet
math
meeting
method
mile
molecule
napkin
nine
nose
note
number
oblique
orderly
ounce
oven
packs
page
paper
pedal
peer
pen
permit
phase
piece
platter
pliers
point
pole
post
pots
pour
powder
prop
pump
quart
ramp
reason
rocket
roll
roof
rope
rural
sack
said
science
seen
sequel
shape
sidewalk
since
slang
slice
slide
some
south
spoke
sponge
stair
stand
state
steel
stone
straight
street
string
suit
sweep
table
tail
tape
theory
thick
thing
thread
three
threw
throw
ticket
tooth
trace
tractor
trailer
tray
trend
triangle
tube
veil
vertical
vest
vote
waist
wash
watts
work
years
zipper
zone