CITY UNIVERSITY
LONDON

Temporal-Nasal Asymmetry in Facial Emotion Processing

Farah Hyda

Supervised by: Elliot Freeman   March 2011

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ABSTRACT

Whilst many have argued for a right hemisphere advantage for the processing of emotional stimuli, reflected in a left hemifield bias for attending, researchers have also highlighted the attentional biases of the superior colliculus, which shows an enhanced response to stimuli in the temporal hemifields. This structure has been found to be part of a subcortical network involving the pulvinar and amygdala, activated in response to emotional signals in our environment. The present study was therefore designed to investigate hemispheric lateralisation effects in facial emotion processing, as well as to determine if a temporal-nasal asymmetry in processing could be found for emotional faces, via activation of the colliculo-pulvinar-amygdala pathway. This was attempted using a behavioural choice-reaction time study, whereby participant responses to the location of monocularly presented emotional faces of varying intensities were measured. Based on suggestions of the combined influence of cortical and subcortical systems on spatial attention (Zackon et al, 1997), it was hypothesised that a left hemifield cortical advantage for attending to emotional stimuli would interact with a temporal hemifield subcortical advantage for attending, giving a left temporal hemifield advantage for attending. Data analyses showed that whilst reaction time and accuracy responses significantly improved with greater intensity of facial expression, the hemispheric lateralisation and temporal-nasal asymmetry hypotheses could not be supported. However, patterns in the data which demonstrated these effects, though non-significant, suggested flaws in the current experimental design. It is therefore argued that there is a need for more ecologically valid procedures for these effects to be surfaced. Suggestions are made for future research.

KEY WORDS:	ATTENTION	EMOTIONAL FACES	AMYGDALA	TEMPORAL-NASAL ASYMMETRY	HEMISPHERIC LATERALISATION

INTRODUCTION
The present study aimed to examine hemispheric lateralisation of facial emotion processing, as well as potential interactions with the attentional advantages of the superior colliculus and amygdala when presented with positively and negatively valenced faces, leading to a possible temporal-nasal asymmetry in response to emotional faces.

Hemispheric Lateralisation of Emotion Processing
There is much research to suggest that the left and right hemispheres in the brain process emotional information differently, with some suggesting that the right hemisphere is specialised for the processing of negative emotions whereas the left hemisphere is specialised for the processing of positive emotions (e.g. Canli et al, 1998; Jansari, Tranel & Adolphs, 2000). This widely influential theory is often referred to as the "valence hypothesis" (Canli et al, 1998, pp. 3233).

An fMRI study by Canli et al (1998) provided direct evidence for the valence hypothesis, where positively valenced pictures visually presented to participants resulted in greater activation of the left hemisphere in comparison to the right hemisphere, whilst negative pictures controlled for intensity resulted in greater relative activation of the right hemisphere.

There have also been behavioural studies which have found this hemispheric preference for the processing of either positively or negatively valenced stimuli when presented to their respective hemifields. In a study by Jansari et al (2000) participants were presented with neutral and mildly emotional face stimuli side by side in free field conditions, where they were given no time limit and were free to scan both images. Participants were to determine which of the two faces showed greater emotionality. Jansari et al (2000) found greater accuracy in discriminating negative emotions when these faces were to the left of the neutral face, and greater accuracy for discriminating positive emotional faces when they were to the right of the neutral face. Whilst perhaps the use of free field conditions means it cannot be said that images on one side were processed exclusively by the contralateral hemisphere, Jansari et al (2000) argued that images to the left of the overall image scanning midline would still be processed primarily by the right hemisphere, and vice versa for images on the right. Therefore, the findings are nevertheless highly consistent with the valence hypothesis, with a right hemisphere bias for processing negative emotion and left hemisphere bias for processing positive emotion (Jansari et al, 2000). Studies have also found the right hemisphere to be slightly faster than the left in discriminating pleasant and unpleasant visual face stimuli, as was found in an fMRI investigation by Pizzagalli, Regard and Lehmann (1999).

However, as highlighted by Siman-Tov et al (2008), most research has examined hemispheric differences at the cortical level, but less has been done to examine these differences at the subcortical level. Siman-Tov et al (2008) reported findings in support of a left hemifield bias in subcortical emotion processing when presented with fearful faces. In their study, fMRI scanning showed fearful faces presented to the left visual field resulted in activation of the amygdale in both hemispheres, as well as activation of the superior colliculus and pulvinar, whereas this bilateral representation was not found when the fearful faces were presented to the right hemifield. Interestingly, this study found no significant activation patterns for presentation of happy faces, suggesting that perhaps the networks involved only

show differential activation for fearful or negatively valenced stimuli. These findings are in support of a right hemisphere advantage for the subcortical processing of negative emotionality, and it is also suggested that it may play a more general role in emotion processing (Siman-Tov et al, 2008) since presentation in the right hemifield, projecting to the left hemisphere, yielded no significant patterns of activation. Siman-Tov et al (2008) therefore suggest that perhaps the bihemispheric activation found in this study is a result of communication from the right hemisphere with this general advantage for attending, to the left hemisphere.

Facial emotion processing and the Amygdala

The involvement of the amygdala in the processing of emotion is well recognised in recent literature and has been studied in a number of different neuroimaging studies using both humans and animals (Sato, 2008). Building on the basic picture, this important subcortical brain structure has been found to show a greater preference for emotional faces than for other emotional stimuli such as pictures (Pegna et al, 2005; Sergerie, Chochol & Armony, 2008), and this has been found for negatively valenced or fearful expressions in particular (Sato et al, 2004). However, whilst most research tends to focus on the amygdala response to negatively valenced stimuli, studies have found it is also activated by positively valenced stimuli such as surprised facial expressions, and this may be found under conditions of both conscious and non-conscious perception (Tamietto & De Gelder, 2010).

As suggested by Ohman (2002) perhaps this amygdala preference for emotion in faces, particularly negative emotion, is due to the evolutionary or adaptive significance of this information. For example, perhaps angry or even fearful faces indicate a threat in the environment which must be responded to immediately, stemming either from the person expressing the emotion (angry) or from the surrounding environment (fearful). However, the specific role of the amygdala in this process is still to be established, since there are a number of ways in which this structure could be influencing responses to emotional stimuli (Sato, 2008). For example it is unclear exactly which aspects of the image it responds to, and the mechanisms by which it achieves this biased processing and decoding of emotional stimuli.

Evidence of the basic involvement of the amygdala in emotion has come from animal studies, such as that by Kluver and Bucy (as cited in Sato, 2008) who found monkeys with lesions to the amygdala demonstrated approach behaviour towards snakes rather than the normal avoidance and fear reactions shown in monkeys with intact amygdale. This provides direct evidence for the involvement of the amygdala in evaluating the emotional significance of fearful stimuli.

In order to help identify the mechanisms by which the human amygdala processes and interprets visual information in emotional faces, Sato et al (2004) conducted an fMRI study whereby participants were presented with angry or neutral faces either facing them or looking in a different direction. Here, gaze direction served as a manipulation of the emotional significance of faces, with those facing toward the participant communicating more intense and significant emotion than those facing away (Sato et al, 2004). It was found that faces directed toward the participants, particularly angry faces, resulted in greater amygdala activation than those looking away. Left amygdala activation was also significantly correlated with participant reports of emotion experienced by presentation of the different faces. These findings

therefore indicate that the amygdala is noticeably involved in the coding of the emotional significance of negatively valenced faces as well as the associated emotional experience, and does not simply code by the physical characteristics of the stimulus (Sato et al, 2004).

Such amygdala activation may occur even when the stimuli are not consciously perceived, as is the case with masked stimuli (Ohman, 2002; Liddell et al, 2005) and with cortically blind patients who demonstrate "blindsight" (Pegna et al, 2005). Here, patients with blindness in part of their visual field due to damage to the primary visual areas of the cortex are able to respond at above-chance levels to stimuli presented to their blind regions. In a case study presented by Pegna et al (2005), a 52 year old man suffering cortical blindness in both his right and left visual fields was able to guess which emotion of happy and angry faces was being presented to him, at significantly above-chance levels. When tested with a variety of stimuli this effect was found to be limited to the emotional aspect of faces rather than, for example, gender aspects, and to faces in particular, rather than non-emotional shape stimuli or emotional scenes. Unsurprisingly, fMRI imaging in this study showed activation of the amygdala when making these emotion-based discriminations, though in contrast with the findings of Sato et al (2004), significant activation was found in the right amygdala rather than the left. These findings are also indicative of a subcortical route for the processing of emotional facial stimuli, which bypasses the visual cortex and allows the amygdala to respond prior to conscious awareness and higher level cortical processing (Pegna et al, 2005). This route will be discussed later in more detail.

Despite convincing findings it has been found that neuroimaging studies on the amygdala often return with some mixed results, and in a meta-analysis by Sergerie et al (2008) it was demonstrated that effects may also occur in the opposite direction as to what is intuitively expected. For example, whilst Sergerie et al (2008) demonstrated that the amygdala does appear to show greater activation effects for faces than for other emotionally significant stimuli; it was found that positive faces tended to produce larger effect sizes than negative faces, contrary to normal assumptions, and no overall significant valence-dependent lateralisation effects were observed. In contrast to some of the previously mentioned findings this therefore suggests that the amygdala responds to emotionally significant facial signals, regardless of valence, and both right and left amygdale are involved in this process.

Temporal-Nasal Asymmetry and the Superior Colliculus
The potential influence of the Superior Colliculus on visual processing and attention has also been an important, and potentially associated, source of interest to researchers. As part of a subcortical pathway involving the pulvinar and amygdala which mediates attentional processes (Liddell et al, 2005; Morris, Ohman & Dolan, 1999; Tamietto & De Gelder, 2010), the Superior Colliculus has been found to show an asymmetry in response to stimuli presented to the temporal and nasal hemifields, with a greater response to stimuli in the temporal hemifield. There is evidence for this as a general attentional advantage (Sylvester et al, 2007; Zackon et al, 1997) and it has also been found specifically for face stimuli (Simion et al, 1998; Tomalski, Johnson &Cisbra, 2009).

In an fMRI study by Sylvester et al (2007) using an eye patching technique to stimulate the temporal and nasal hemifields of each eye separately, an asymmetry in

activation was found for the superior colliculus, but not for the lateral geniculate nucleus (LGN) or cortical visual areas. Here, the superior colliculus showed an enhanced activation response for visual stimuli presented in the temporal hemifield but not for those presented in the nasal hemifield. These findings also therefore indicate the presence of a subcortical visual pathway involving the superior colliculus which bypasses the LGN and the primary visual cortex (retinotectal pathway), separate to the conscious geniculostriate pathway which does run through these regions (Sylvester et al, 2007).

The temporal-nasal asymmetry demonstrated by the superior colliculus has also been found to occur particularly in response to faces as opposed to non-face-like stimuli (Simion et al, 1998; Tomalski et al, 2009). In a study by Tomalski et al (2009) it was found that participants made significantly faster saccadic eye movements to schematic face stimuli presented to the temporal hemifield of each eye than to those presented to the nasal hemifield, and these latencies were significantly faster for upright face configurations than inverted ones.

This particular hypothesis is supported by studies which have found a temporal-nasal asymmetry in visual orienting to face-like stimuli in newborns, demonstrating that these processes occur throughout the lifespan (Tomalski et al, 2009). For example, similar findings were presented in a study by Simion et al (1998), whereby it was found that newborn infants showed greater orienting to schematic face-like stimuli monocularly presented in their temporal hemifields than to those presented in their nasal hemifields, and there was greater orienting to upright rather than inverted patterns only in the temporal hemifields. This indicates that even newborn infants may employ these primarily subcortical mechanisms producing a spacial bias when processing socially relevant stimuli such as faces in their visual environment.

An investigation by Zackon et al (1997) demonstrated how this temporal-nasal asymmetry in response shown by the superior colliculus midbrain structure may interact with a cortical right hemisphere advantage for attending, by comparing monocular and binocular viewing conditions. A "split priming motion induction paradigm" (Zackon et al, 1997, pp. 364) was utilised, whereby the perceived motion of a stationary horizontal bar towards a centre point is shifted to one side depending on asymmetric attention to priming cues presented on either side of fixation. Based on the assumption that visual information from the temporal hemifield goes preferentially through subcortical midbrain structures, Zackon et al (1997) predicted that greater attention to cues in the temporal hemifield would result in an indicative shift in the position of the collision point created by the perceived movement of the bar in monocular viewing conditions. Results of the study showed that whilst such an effect was found for cues initially appearing on the left (and so in the left hemifield) it was not found for cues on the right. Also, a greater effect was found for cues in the temporal hemifield of the left eye, than the temporal or nasal hemifields of the right eye and nasal hemifield of the left eye. Therefore the temporal-nasal asymmetry effect was found only for cues presented to the left eye, whilst the right eye yielded results which simply reflected those of binocular viewing conditions (Zackon et al, 1997).

According to Zackon et al (1997) such results may only be explained by a combination of both cortical and subcortical influences on spacial attention. Whilst the right hemisphere provides a cortical attentional advantage for the left visual field, the superior colliculus provides a subcortical advantage for the temporal hemifields.

Zackon et al (1997) explains that it would therefore follow that the temporal hemifield of the left eye would be processed preferentially by both cortical and subcortical attentional systems since both the superior colliculus and right hemisphere would show an enhanced attentional response to a stimulus on the left. However the visual field of the right eye would face conflicting preferences of cortical and subcortical regions, with the right hemisphere showing a greater attentional response to a stimulus on the left (in the nasal hemifield), and the superior colliculus showing a greater response to a stimulus on the right (in the temporal hemifield) (Zackon et al, 1997).

Neural links between the Superior Colliculus and the Amygdala – A subcortical attentional pathway

The amygdala and superior colliculus midbrain structures discussed here have been shown to be connected in a subcortical network rapidly activated in response to even non-conscious emotional signals in the visual environment such as fearful faces (Liddell et al, 2005; Morris, Ohman & Dolan, 1999; Tamietto & De Gelder, 2010). For example as previously mentioned, the presence of this subcortical route bypassing the primary visual cortex has been indicated in findings from blindsight patients who are able to detect emotional stimuli in their cortically blind regions (Pegna et al, 2005), and by fMRI studies (e.g. Sylvester et al, 2007). According to Tamietto & De Gelder (2010) this subsystem in place for processing non-conscious emotional visual stimuli involves the superior colliculus, pulvinar and amygdala, as well as other subcortical structures such as the substantia innominata and nucleus accumbens.

The presence of such a pathway is supported in a study by Liddell et al (2005) where BOLD signal analyses showed that the amygdala and brainstem structures including the superior colliculus, pulvinar, and the locus coeruleus were activated in response to unseen (masked) fearful faces. Results also showed that these subcortical areas may project to areas of the temporal and frontal cortices to form a network activated in response to undetected environmental signals of fear, and this early detection system is suggested to enable the directing of attention towards these emotionally significant signals (Liddell et al, 2005). These findings also support the important role of the amygdala in detecting sources of fearful emotion or danger in the environment at the very earliest stages.

The involvement of the amygdala may be particularly important in this process, communicating with both subcortical and cortical structures to mediate responses to both seen and unseen emotional stimuli (Tamietto & De Gelder, 2010). This is supported in a study by Morris, Ohman and Dolan (1999), where amygdala responses to masked and unmasked angry and neutral faces and a fear conditioned angry face was measured. Morris, Ohman and Dolan (1999) found that whilst the right amygdala showed correlated activity with the superior colliculus and pulvinar during presentation of the masked fear conditioned angry face stimuli, this was not found for the same stimuli when they were seen. By contrast, the left amygdala was active for both seen and unseen faces and did not show a difference in its connectivity with the superior colliculus and pulvinar under these two conditions. Seen fearful stimuli appeared to activate more cortical regions, such as areas of the cortex in the right temporal lobe and fusiform gyrus, as well as the subcortical regions (Morris, Ohman & Dolan, 1999), and the faces also seem to have activated a

greater number of structures in the right hemisphere than those on the left. The findings suggest that whilst more cortical areas may be active for stimuli which are consciously perceived, responses to unseen stimuli may be limited to the subcortical regions, particularly the colliculo-pulvinar-amygdala pathway for fearful and fear conditioned faces (Morris, Ohman & Dolan, 1999). Such a pattern of findings also appears to be consistent with the predictions and conclusions drawn by Zackon et al (1997), where an emphasis on the contributions of both cortical and subcortical influences on perception and attention was made.

The present study

The present study aimed to investigate hemispheric lateralisation of emotion processing and attention, and whether such cortical attentional influences would interact with the attentional preferences of the superior colliculus and amygdala subcortical structures. Therefore, similarly to the aims and predictions of Zackon et al (1997) this study tested the temporal-nasal hypothesis, and whether this would interact with a right hemisphere advantage for attending to the left hemifield. Building on the work of Zackon et al (1997), the present study incorporated the role of emotions, looking at responses to positively and negatively valenced face stimuli, and considering a right hemisphere advantage for the visual processing of negative emotions in particular as predicted by the valence hypothesis. This was tested in a behavioural study employing a choice reaction time method of assessment. Whilst Zackon et al (1997) focussed on attentional influences on perception (Zackon et al, 1997) the present study looked at both perception (of emotion in faces) and motor choice reaction time responses.

As recommended by Zackon et al (1997) a monocular viewing method was employed in the present study in order to accurately discriminate between the temporal and nasal hemifields, and rapid presentation of stimuli with a fixation point in the centre meant that the study improved on the limitations of the free field conditions employed by Jansari et al (1998) and so stimuli presented in the right and left hemifields would be more likely to have been processed by the left and right hemispheres, respectively.

Based on a review of previous research, the present study used face stimuli in order to maximise the chances of activating the colliculo-pulvinar-amygdala subcortical pathway. These were also presented only very briefly, in order to minimise opportunity for eye movement away from fixation and to activate both subcortical and cortical attentional mechanisms. As both a neutral and an emotional face appeared on-screen under these conditions participants were to respond as quickly and accurately as they could with an indication of which side they thought the emotional (happy or angry) face was on. Since previous findings have found that undetected signals such as that used by Liddell et al (2005) are too fast to activate visual cortical regions, the stimuli presented to participants in the present study were consciously perceived.

The present study was based on three main assumptions, drawn from the research presented and tested together for the first time within a single study. Firstly, it was assumed that a stimulus presented within the temporal hemifield will be processed preferentially by the superior colliculus. Secondly, a threatening or emotionally significant stimulus such as an angry face was assumed to stimulate the colliculo-pulvinar-amygdala pathway more effectively than a non-threatening stimulus.

Thirdly, a general right hemisphere advantage for attending was assumed. Based on these assumptions a number of predictions could be made about the amount of attentional advantage received by angry face stimuli presented in particular hemifield locations. The predictions of the proposed model are displayed in the table below.

Table 1
Proposed attentional advantage for angry faces in each of the four hemifield locations

Assumption	Left visual field, Temporal hemifield	Left visual field, Nasal hemifield	Right visual field, Temporal hemifield	Right visual field, Nasal hemifield
1	*	--	*	--
2	*	n/a	*	n/a
3	*	*	--	--

Legend
* = Advantage based on assumption

-- = No advantage based on assumption

n/a = Lack of advantage due to not having met Assumption 1

By summing up the advantages from the table above, it can be seen that the greatest predicted advantage would be received by an angry face in the left temporal hemifield (in the left location viewed through the left eye), with the least attentional advantage in the nasal hemifield of the right visual field (in the right location viewed through the left eye). The proposed attentional advantage for neutral faces would be lower for each location due to reduced stimulation of the colliculo-pulvinar-amygdala pathway (Assumption 2). The proposed assumptions predict a left hemifield bias for attending to angry faces, though this is explained in terms of a combination of cortical and subcortical influences; with an enhanced leftward bias in the left visual field due to the locational preferences of the superior colliculus.

Based on previous findings the present study therefore tested a number of experimental hypotheses. Firstly, it was hypothesised that there would be some evidence of lateralised processing of the facial emotions, with better reaction time and accuracy scores for emotional faces presented in the left hemifield, and more so for angry faces than for happy faces. Better reaction time and accuracy performances were also expected for emotional stimuli in the temporal rather than the nasal hemifields. As an interaction between these two factors, and based on the findings of Zackon et al (1997) a left hemifield reaction time and accuracy advantage was expected for angry faces in the temporal hemifields, with less of a left visual field advantage in the nasal hemifields. It was also expected that higher intensities of emotion would lead to better accuracy and response times, and that any other main effects would vary as a function of such intensity.

METHOD

Participants
Twenty participants were tested in the present study, all of which were undergraduate students studying Psychology at City University London. Participants

were either recruited via an internal online sign-up system, or were approached randomly by the experimenter. Four participants were male and 16 were female, and all were aged between 18 and 25 years old.

As a requirement, all participants were right handed and had normal or corrected-to-normal vision in both eyes. This meant that the sample was as homogenous as possible in any criteria which may have acted as confounds to the experiment.

Apparatus and Stimuli

Practice and experimental trials were conducted on a single computer in an experimental laboratory in the City University Social Sciences building. A fixed chinrest was used to position the head of the participant at a set distance from the screen, and a piece of card fixed to the chinrest apparatus was used to block the view of the screen from one eye. Once seated, participants were able to adjust the height of the chair until they felt comfortable. Participants pressed the right and left arrow keys on a standard computer keyboard to record their responses. E-prime experimental software was used to run the experiment, and response times and accuracy were recorded automatically by the program. Standardised Ekman faces based on stimuli used in a study by Calder et al (1997) were presented to participants and were comprised of five male and five female happy and angry faces varying in intensity, ranging from 1-5. The intensity manipulation was achieved by comparing each original emotional face with the same face showing a neutral expression in order to identify reference points associated with the emotionality. These points could then be used to exaggerate or dampen the original emotional expression by 25% each time to give different levels of intensity. Both the emotional and neutral face presented on each trial was of the same person, so the only comparison to be made between the two would be that of emotional expression.

Figure 1: Examples of happy (left), neutral (middle) and angry (right) faces used in the present study. Happy and angry faces are shown at intensity 4, the original emotional expression, with the original neutral expression.

Design

The present study employed a 2x2x2x5 repeated measures design, whereby each participant was presented with visual stimuli for all conditions of the experiment in a randomised order. Put simply, each participant viewed positively and negatively valenced faces appear on-screen, either on the left or right of fixation, with a neutral

face appearing on the other side of fixation. There were four Independent Variables (IVs), three of which had two levels and one of which had five levels. The first IV was that of the hemifield. Emotional faces could either be in the left hemifield (to the left of fixation) or in the right hemifield (to the right of fixation). The second manipulated variable was whether the faces appeared in the temporal or nasal hemifields. The monocular viewing method enabled manipulation of this variable, which meant that a face in the left location would be in the temporal hemifield if viewed through the left eye and nasal hemifield if viewed through the right eye, and vice versa for a face on the right. The third variable was the emotional valence of the faces, which could either be happy or angry, and the fourth was the intensity of the emotional expressions. This ranged from 1 (close to neutral) to 5 (more intense/obvious emotion). Participant reaction times and accuracy served as the two dependent variables and were recorded automatically by the program.

The main advantage of employing a repeated measured design in this experiment was that conditions could be compared and analysed without being limited by consideration of the possible confound of individual differences.

Presentation order for all conditions was randomised, which avoided any order or practice effects which may have biased responses towards a particular condition.

Procedure

As each participant arrived at the testing session they were handed an information sheet which described the main aims and procedures of the study (see Appendix A). The experimenter also provided a verbal explanation of what was provided on the sheet. Before the experiment began participants were informed of the hemispheric lateralisation of emotion processing research background to the study, but remained uninformed about the more specific interest in the amygdala and temporal/nasal asymmetry. This was to minimise any bias in responses caused by explicit knowledge of the aims and hypotheses of the study. The experimenter then explained what would be expected of participants, informed them that the lights would be switched off during the practice and test trials, and that stimulus presentation would be quite rapid so it would be important that they concentrate throughout the study. Most importantly, they were also instructed to ensure they were fixating in the centre point during all trials (though no eye tracking systems were used). All participants were also informed that there would be opportunity to take short breaks between blocks of trials, and a slightly longer break between the first 5 and last 5 blocks. Finally, participants were informed that some of the emotional faces may be more obvious than others, but to nevertheless respond as best they can, and signed a consent form (see Appendix B) to say they were happy to participate in the study and understood they had a right to withdraw at any time. They were also given the opportunity to ask any questions about the procedure at this point.

Participants could adjust the height of the chair until they felt comfortable with the positioning of their head on the chin rest. They were then asked to close the uncovered eye only and report back if they could see any part of the computer screen. This was to ensure that the covered eye received no visual input and viewing conditions would be truly monocular. The experimental program was then started and the lights switched off. Participants could read the on-screen instructions before pressing the spacebar to begin the practice block of 40 trials. If after the

practice block participants had any questions to ask they had the opportunity to do so, or if the experimenter could see they did not fully understand the procedure these issues could be addressed before moving onto the test trials.

Participants undertook two sets of 5 blocks of 150 trials each. On each trial, two faces would appear on screen (one on either side of fixation), one neutral and one emotional, and participants were to press a key to record which side they thought the emotional face was on as quickly and accurately as they could. Visual feedback was provided after each trial (green circle for a correct answer, red cross for an incorrect answer, blue question mark if they did not respond in the required time) before the next stimulus would appear.   After the first five blocks of trials the lights were switched on and participants had a short break as the eye patch was moved to cover the other eye and checked for accurate positioning. The experimenter remained in the room with the participant throughout the experiment.

Once all trials were completed, participants were handed a debrief form (see Appendix C). This provided further information about the aims of the study which was also explained verbally by the experimenter, and participants had the chance to ask any questions. Participants were thanked for their participation at the end of the experiment.

RESULTS

Reaction time

Table 2
Mean Reaction Times and Standard Error values for the Temporal-Nasal, Valence and Hemifield conditions.

| Temp_nas	Valence	Hemifield	Mean	Std. Error
Temporal	Angry	Left	510.279	14.504
		Right	523.073	12.799
	Happy	Left	505.703	14.196
		Right	510.54	11.86
Nasal	Angry	Left	520.911	11.499
		Right	521.451	17.76
	Happy	Left	514.151	11.298
		Right	511.306	18.416

Table 2 presents means and standard deviations for reaction times in the four hemifield locations. For ease of exposition, data summarised here has been collapsed across the intensity factor, data of which will be referred to later. Data was submitted to a 4-way ANOVA (see Appendix D). Table 2 showed that reaction times were faster for the temporal hemifield (M = 512.4) than for the nasal hemifield (M = 516.96) though this main effect was non-significant [$F(1,19) = 2.04$ (n.s)]. They also seemed to be faster for the left hemifield (M = 512.76) than for the right hemifield (M = 516.59) though this main effect was also non-significant [$F(1,19) = .48$ (n.s)]. Of

the four hemifields reaction times therefore appeared to be fastest for the left temporal hemifield (M = 507.99), illustrated in Figure 2 below.
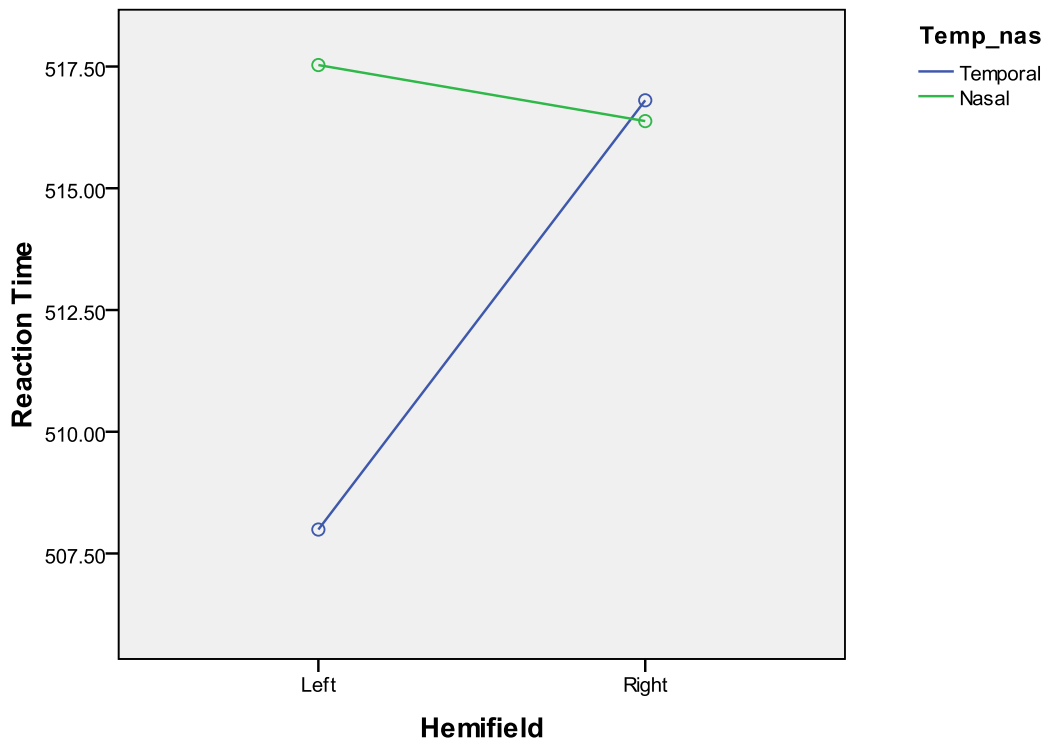

Figure 2: Reaction times for the temporal and nasal left and right hemifields. Blue line represents reaction times for the temporal hemifield, green line represents reaction times for the nasal hemifield.

Figure 2 illustrates the apparent interaction, with a greater observable difference in reaction times for the temporal and nasal hemifields in the left hemifield than in the right hemifield. There appears to have been an advantage for the left temporal hemifield, with little difference between the remaining three hemifield locations. However against prior predictions this interaction was non-significant [$F(1,19) = .29$ (n.s)] and so these location effects do not seem to have had a significant influence.
Participants responded significantly faster to happy faces (M = 510.43) than to angry faces (M = 518.93) [$F(1,19) = 7.89, p < .05$], and overall reaction times decreased significantly with greater intensity [$F(4,16) = 18.23, p < .001$] (see Figure 3). These main effects were still significant after the Greenhouse-Geisser correction was applied to adjust for violations of sphericity. There also appeared to be the greatest difference in mean reaction times for temporal and nasal conditions at intensities 3 and 4, with mean reaction times at intensity 3 of 497.53 in the temporal hemifield, and 507.74 in the nasal hemifield, whereas there was less of a difference at higher and lower intensities. This effect is illustrated in Figure 3 below. However, this interaction was non-significant [$F(4, 76) = .64$ (n.s)].
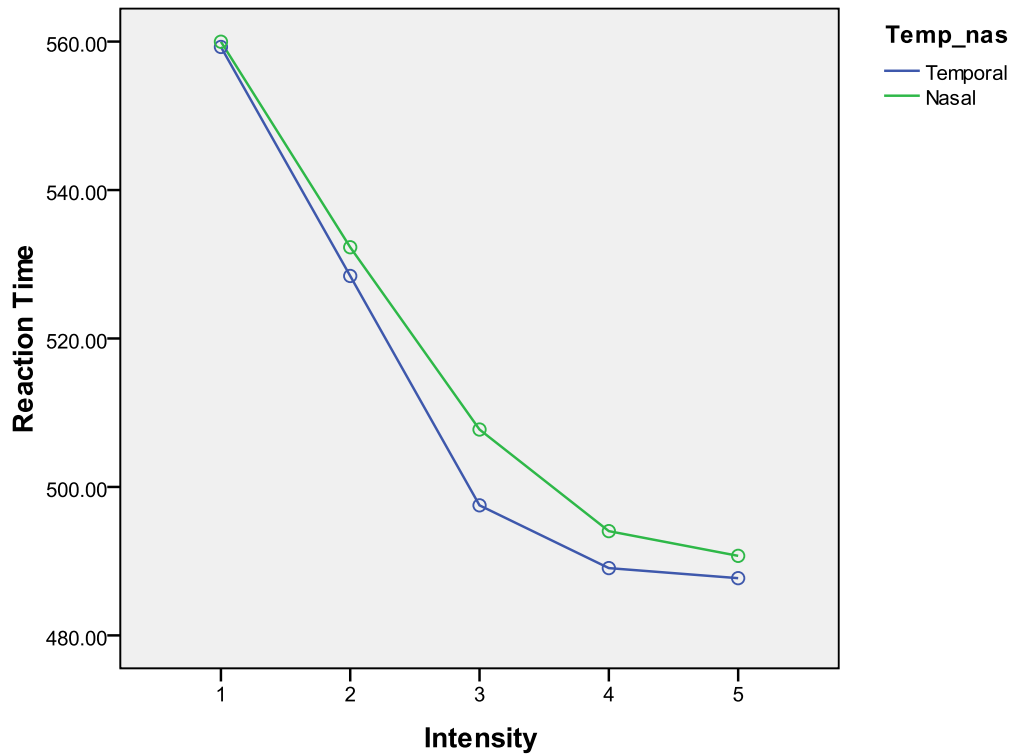
Figure 3: Reaction times for the temporal and nasal hemifields at each of the 5 levels of intensity. Blue line represents reaction times for the temporal hemifield, green line represents reaction times for the nasal hemifield.
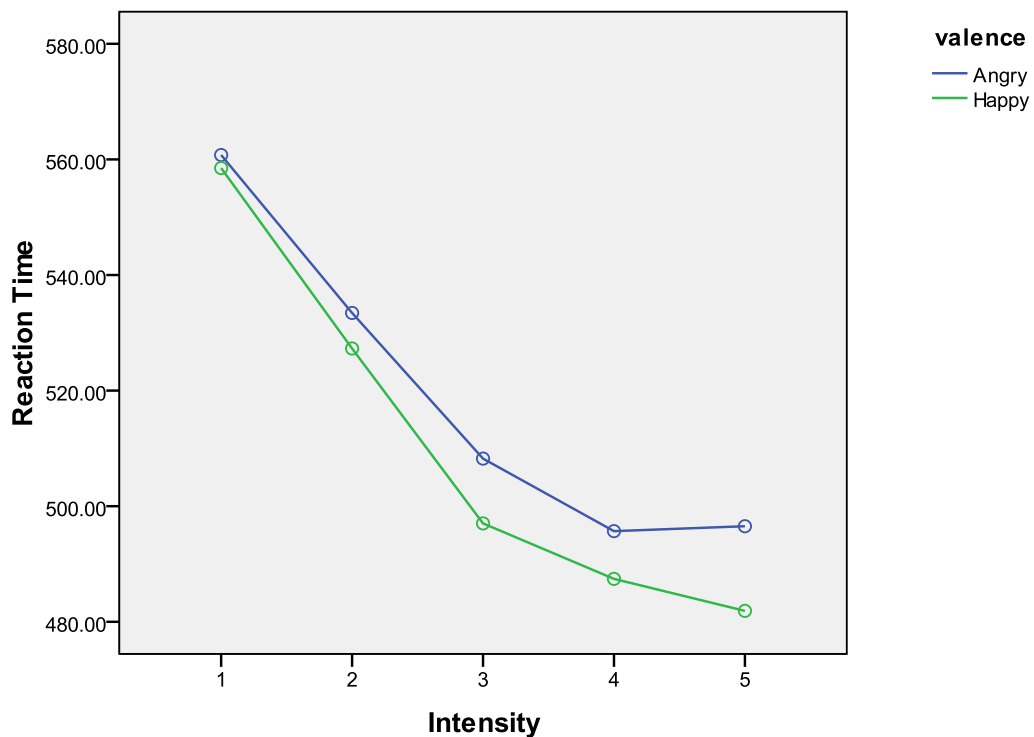
Figure 4: Reaction times for happy and angry faces at the 5 levels of intensity. Blue line represents reaction times for angry faces, green line represents reaction times for happy faces.

In addition to this, the intensity effect appears to have been greater for happy faces, with a larger difference in reaction times between the two types of stimuli at higher intensities (see Figure 4 above) though this interaction was non-significant [F(4,76) = 1.18 (n.s)].
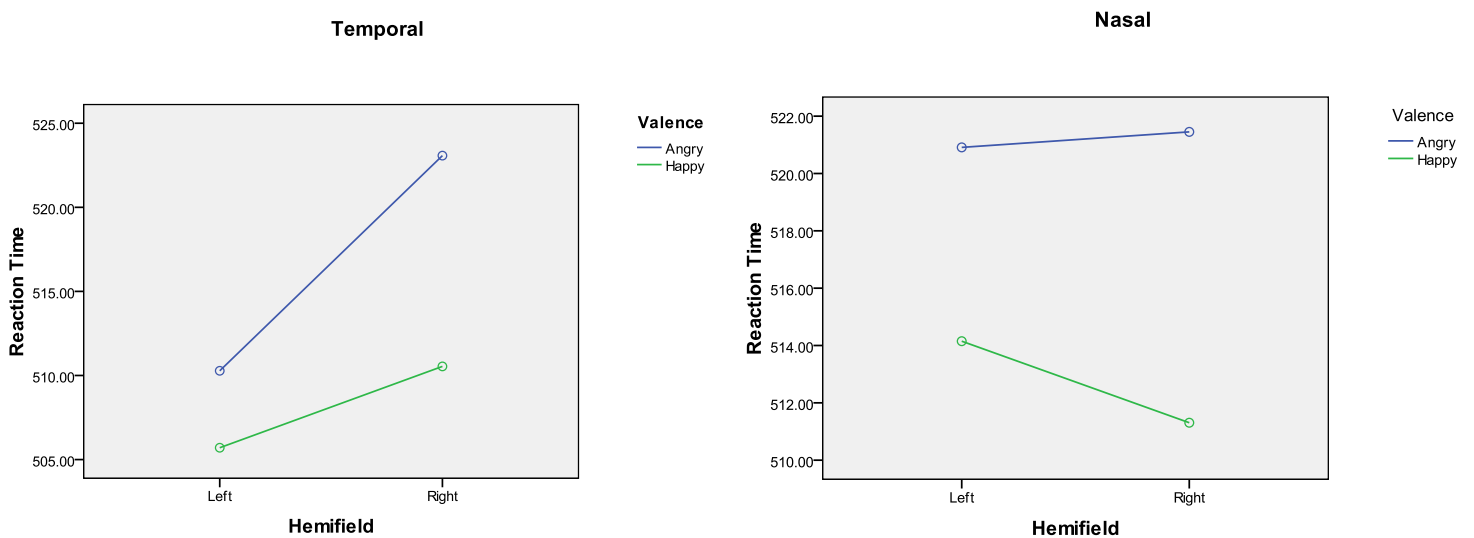
Figure 5a (above, Left): Reaction times for angry and happy faces presented in the right and left temporal hemifields.

Figure 5b (above, right): Reaction times for angry and happy faces presented in the right and left nasal hemifields. In both graphs above the blue line represents response times to angry faces and the green line represents response times to happy faces.

As shown in Figures 5a and 5b, reaction times were faster in response to happy faces than to angry faces in all four hemifield conditions. There were faster reaction times in the left temporal hemifield than in the right temporal hemifield for angry faces, with no difference in responses to stimuli in the right and left nasal hemifields. For happy faces the interaction differed from that for angry faces, with faster reaction times for the temporal left hemifield than for the right and faster reaction times in the nasal right hemifield than the left, though these differences appear to be small. However this 3-way interaction was non-significant [F(1,19) = .32 (n.s)]. For both happy and angry faces there appeared to be a greater difference between temporal and nasal hemifields in the left hemifield, and little or no difference in the right hemifield. There did not appear to be any clear valence-specific hemispheric lateralisation of emotion processing [F(1,19) = 2.19 (n.s)]. All other main effects and interactions were non-significant, judged at an alpha value of p > .05.
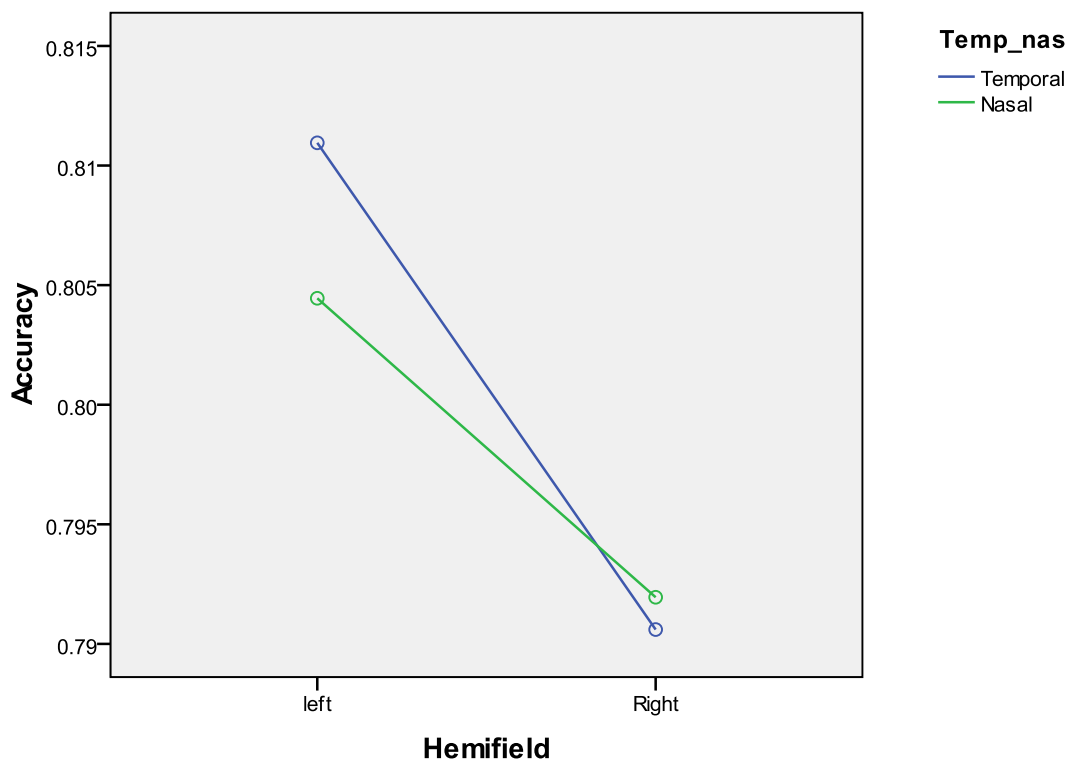
Accuracy

Table 3
Mean Accuracy scores and Standard Error values for Temporal-Nasal, Valence and Hemifield conditions.

Temp/Nas	Valence	Hemifield	Mean	Std. Error
Temporal	Angry	Left	0.795	0.023
		Right	0.775	0.021
	Happy	Left	0.827	0.016
		Right	0.807	0.02
Nasal	Angry	Left	0.798	0.022
		Right	0.779	0.022
	Happy	Left	0.811	0.017
		Right	0.805	0.019

Table 3 presents means and standard deviations for accuracy in the four hemifield locations. Data summarised here has again been collapsed across the intensity factor for ease of interpretation. Data was submitted to a 4-way ANOVA (see Appendix E). As shown in Table 3, accuracy was greatest for happy faces presented in the left temporal hemifield (M = 0.81) and poorest for angry faces presented in the right temporal hemifield (M = 0.78) (see Figures 8a & 8b). Accuracy was greater for happy faces in general (M = .813) than for angry faces (M = .786) and this main effect of valence was significant [$F(1, 19) = 7.47, p < .05$]. Accuracy also appeared to be greater for the left hemifield (M = .808) than for the right hemifield (M = .791) though this was non-significant [$F(1,19) = .51$ (n.s)]. There was little overall difference in accuracy for temporal versus nasal hemifields [$F(1,19) = .07$ (n.s)]. Hemifield differences can be observed in Figure 6 shown below.
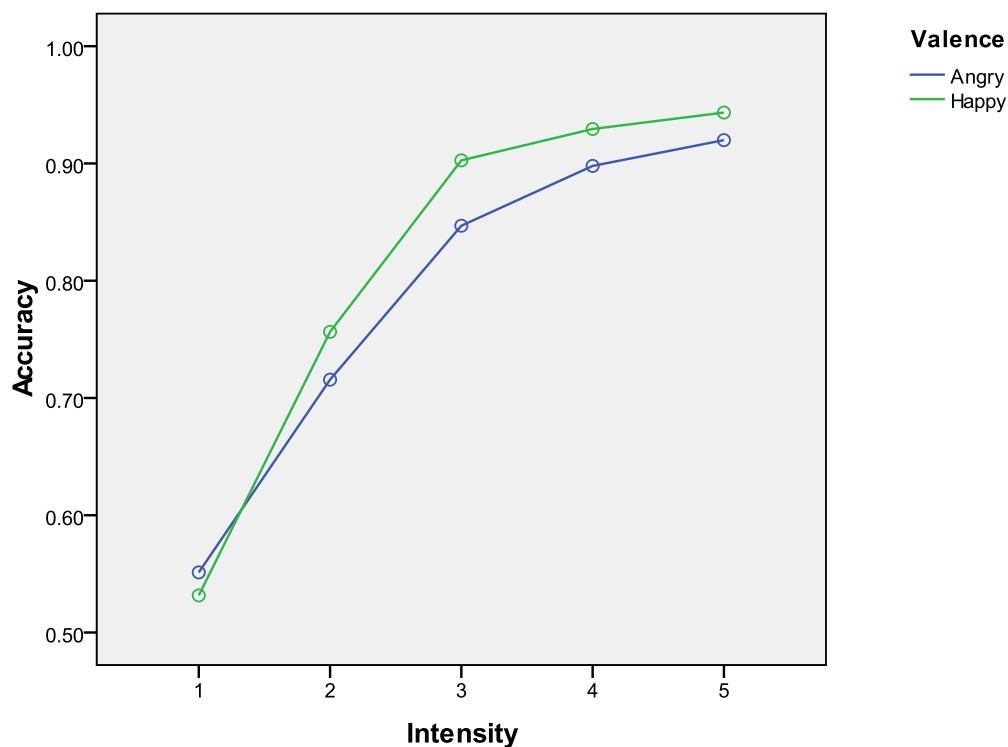
Figure 6: Accuracy scores for the temporal and nasal left and right hemifields. Blue line represents accuracy scores in the temporal hemifield whereas green line represents accuracy scores in the nasal hemifield.

As illustrated in Figure 6, overall accuracy scores were greater in the left hemifield than in the right hemifield. There was little difference in accuracy scores for temporal and nasal hemifields, though any small difference between the two was greater in the left hemifield. This interaction was non-significant $[F(1,19) = .22$ (n.s)].

It was also observed that accuracy scores increased between intensity 1 (M = .541) and intensity 5 (M = .932). This main effect was significant $[F(4, 76) = 393.36, p < .001]$ and can be viewed in Figure 7 (below), shown separately for happy and angry faces. Differences between happy and angry faces also appear to have varied by intensity, with greater differences being observed in the mid-range intensities than for very high or low intensities and with happy faces showing a larger intensity effect than angry faces (see Figure 7). This interaction effect was significant $[F(4, 76) = 6.18, p < .001]$.

Figure 7: Accuracy scores for angry and happy faces at each level of intensity. Blue line represents accuracy scores for angry faces and green line represents accuracy scores for happy faces.

Interaction graphs drawn for right versus left hemifields and happy versus angry faces for the temporal and nasal hemifields (see Figures 8a and 8b below) show that there was no 3-way interaction effect between the valence, hemifield and temporal-nasal factors [F(1,19) = .49 (n.s)]. This is in contrast to greater observable effects for reaction time data. No other significant main or interaction effects were found.
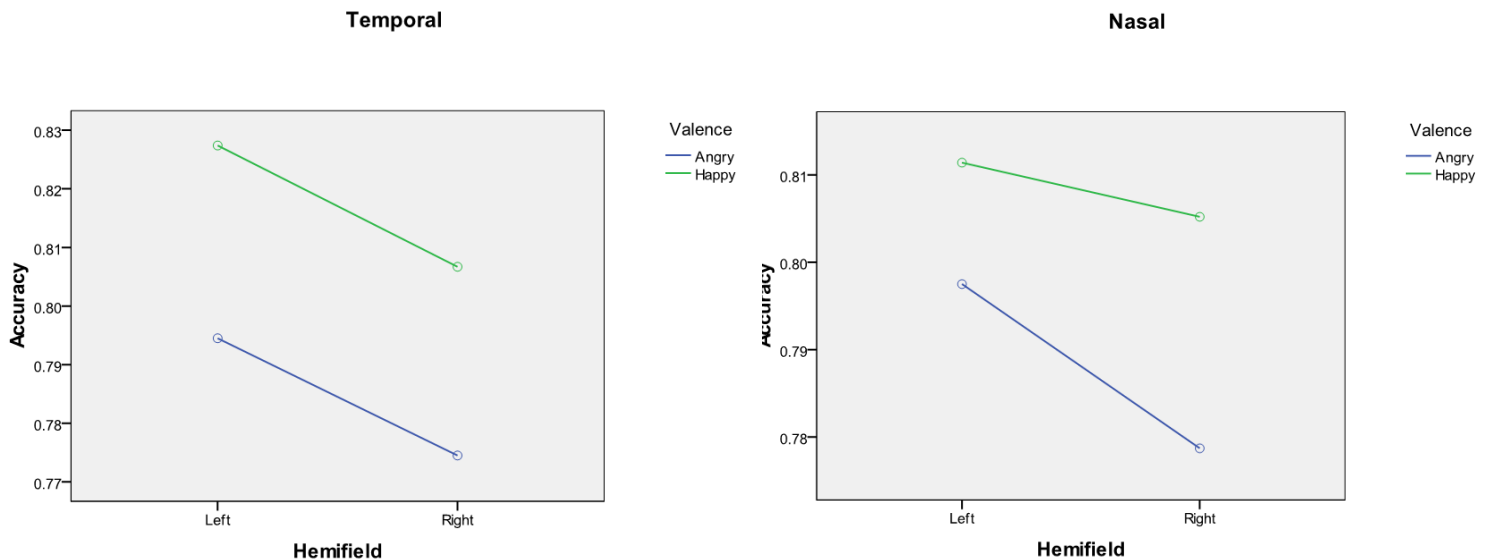

Figure 8a (above, Left): Accuracy scores for angry and happy faces presented in the right and left temporal hemifields.

Figure 8b (above, right): Accuracy scores for angry and happy faces presented in the right and left nasal hemifields. In both graphs above, blue line represents response times to angry faces and green line represents response times to happy faces

Angry Faces
In further investigation of the data, analyses were run on angry faces alone in order to explicitly test the assumptions of the present study which predicted patterns of responses for these faces in particular. Two 3-way ANOVAs were run, with temporal-nasal as a factor with two levels, intensity as a factor with 5 levels, and hemifield as a factor with two levels. The first ANOVA was run for reaction time data (see Appendix F) whilst the second ANOVA was run for accuracy data (see Appendix G).

Reaction time and accuracy patterns for angry faces at the different levels of intensity can be viewed in Figures 4 and 7 respectively. Significant main effects were found for the intensity factor for both reaction time data [F(4,76) = 35.59, p < .001] and accuracy [F(4,76) = 186.63, p < .001]. Both effects were still significant after the Greenhouse-Geisser correction was applied following violations of sphericity. Therefore, both accuracy and reaction times improved with increased intensity. Reaction time patterns for the left and right temporal and nasal hemifields can be viewed in Figure 9 below.
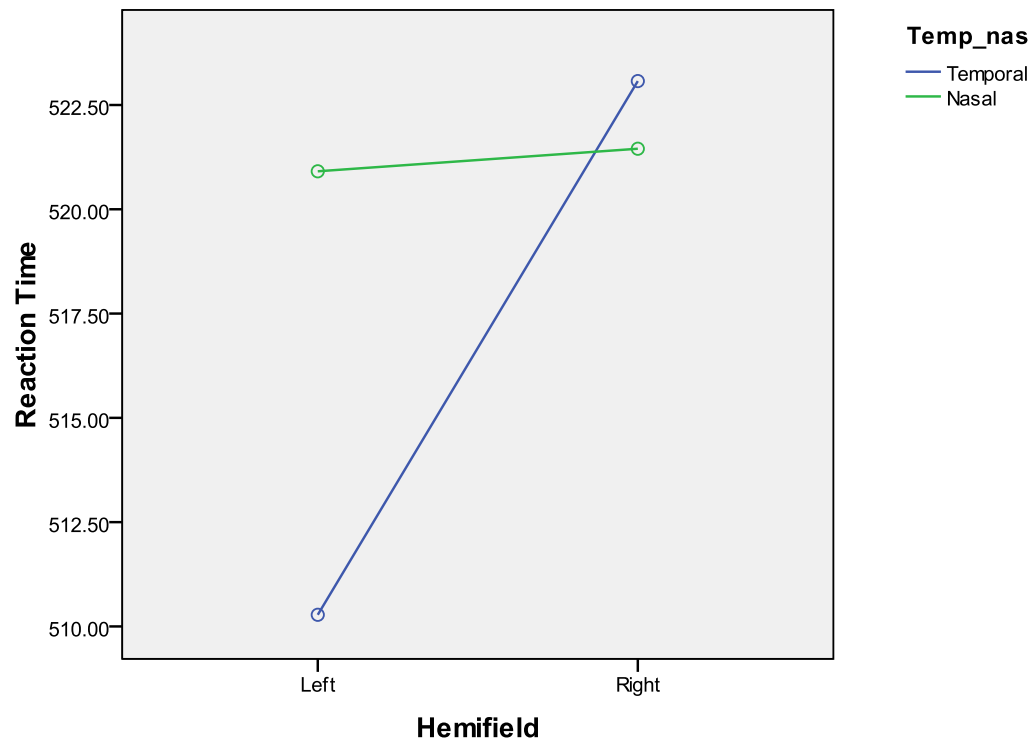
Figure 9: Reaction times for temporal and nasal right and left hemifields for angry faces only. Blue line represents reaction times for temporal hemifield, green line represents reaction times for nasal hemifield.

As shown in Figure 9, reaction time data for angry faces appear to support the hemifield hypotheses, with a clear advantage being seen for the left temporal hemifield. There also appears to be an increase between left and right temporal hemifields but no such difference between left and right nasal hemifields. However this interaction was non-significant [$F(1,19) = .51$ (n.s)]. No other significant main or interaction effects were found.

DISCUSSION

The present study aimed to test the right hemisphere advantage for attending to negatively valenced faces in particular, as well as to investigate whether the temporal-nasal asymmetry in attention to emotional face stimuli stemming from the colliculo-pulvinar-amygdala pathway would interact with this cortical advantage for attending to the left hemifield, to give a left temporal hemifield advantage for attending.

Whilst much of the data demonstrated trends in expected directions, statistical analyses demonstrated that only intensity and valence effects were significant, with a significant interaction between these two factors for accuracy only. Statistical analyses failed to support the hemispheric lateralisation of emotion processing hypothesis as well as predictions of better reaction time and accuracy performances in the temporal rather than nasal hemifields. Whilst further statistical analyses were conducted for angry faces alone, these also yielded significant effects for the intensity factor only. Therefore, though angry faces appeared to show greater

location effects than happy faces, these were still non-significant when considered in isolation. However, since the full data set as well as that for angry faces alone demonstrated some of the expected trends, perhaps their lack of significance could be attributed to experimental set-up rather than theoretical factors. These issues will be discussed.

The significant effects found for valence showed faster response times and greater accuracy when responding to happy rather than angry faces. These results, as well as the significantly greater effect of intensity on accuracy scores for happy faces in particular were consistent with the findings of Sergerie et al (2008). Here, a meta-analysis of brain imaging studies involving the amygdala showed that the structure is activated in response to both happy and negatively valenced faces; and positive stimuli tended to show larger effect sizes than negative stimuli. However, such results are in contrast with the assumptions of Sato et al (2004), Pegna et al (2005) and Ohman (2002) who focussed on the importance of the amygdala in showing an enhanced response to negatively valenced faces. Therefore, the current study contradicted theories of an enhanced amygdala involvement for presentation of threatening stimuli in the environment as was theorised by researchers such as Ohman (2002) and Liddell et al (2005), which would lead us to expect faster response times to angry faces as this structure and its attentional networks were activated.

In an attempt to explain why happy faces often lead to faster response times than negatively valenced faces, a study by Leppanen and Hietanen (2004) suggested that this advantage may be based on holistic processing of happy faces, rather than centred on basic processing of simple features. However, whilst this may help inform us of the way in which the faces are processed visually, it contributes little to helping us understand the reason why this advantage is present. Perhaps a further explanation may be that prominent features such as white teeth may be more visible in happy faces, acting as salient cues to rapid recognition. Contradictions in research such as those demonstrated above highlight the need for further investigation into the processes involved in human response to facial emotion.

As previously mentioned, and as demonstrated in the descriptives and interaction graph (Figure 2), reaction time data demonstrated trends in the predicted directions for location factors. For example, reaction times appeared to be faster in the left hemifield than the right hemifield; consistent with the findings of Pizzagalli et al (1999), where a facial discrimination task showed the right hemisphere responds slightly faster than the left. Accuracy also appeared to be better in the left hemifield, and reaction times were faster in the temporal hemifield than in the nasal hemifield, though this advantage was not shown for accuracy. The temporal-nasal trend shown for reaction time data appears to be consistent with studies which have found this temporal hemifield advantage for faces (e.g. Simion et al, 1998; Tomalski et al, 2009), and is also therefore indicative of the involvement of the superior colliculus in enhancing attention to these locations (Sylvester et al, 2007). The data also appeared to indicate a general advantage for faces presented in the left temporal hemifield, particularly so for angry faces. Taken together, such trends are consistent with the findings of Zackon et al (1997) and the three assumptions of the present study, indicating an interaction between the cortical advantage for the left hemifield and subcortical advantage for the temporal hemifield. However, since these effects were not significant, the present study failed to provide valid empirical evidence for

any of these effects. Without questioning the validity of the suggested hypotheses, the trends which were exposed rather suggest that perhaps a stronger effect would emerge with an improved experimental design.

With lower response times and higher accuracy for happy faces than for angry faces in all locations, a left temporal hemifield advantage for angry faces in particular, as would be expected from the proposed theories, was not found. Therefore, the present study failed to provide support for the neural network suggested by Liddell et al (2005) to be activated in response to even unseen fearful stimuli in the environment, in place to detect and direct attention to these signals of threat at the very earliest stages. Whilst perhaps trends in the data suggested the influence of the superior colliculus, there was little evidence of the involvement of the entire colliculo-pulvinar-amygdala pathway in significantly influencing the direction of responses to negatively valenced emotional faces specifically.

The lack of significant valence-specific lateralisation effects found in the present study meant that this hypothesis also remained unsupported. The findings remained inconsistent with theories of a right hemisphere advantage for the processing of negative emotion and left hemisphere advantage for the processing of positive emotions (Canli et al, 1998; Jansari et al, 2000; Siman-Tov et al, 2008). However, such an outcome was loosely consistent with the results of the meta-analysis by Sergerie et al (2008) where it was demonstrated that studies often return with mixed conclusions regarding the involvement of the amygdala in particular. As mentioned previously, analysis of studies showed that when findings were pooled together no lateralisation effects were found. Perhaps, therefore, the present findings would seem less surprising when considering the lack of consistency found when analysing across studies with varying methodologies. The suggestion here is that perhaps valence-specific lateralisation effects, and in fact any location-specific attention effects of neural structures, may be more difficult to access empirically than initially thought and more attention should be taken into the conditions under which these mechanisms operate, if at all.

Perhaps experimental conditions must simulate the way in which such stimuli are encountered in real life to a greater extent in order for these mechanisms to fully operate and be demonstrated behaviourally. As an example and in application to the present study, Jansari et al (2000) had found greater accuracy scores for identifying positive emotions in free field conditions only when these were presented in the right hand location, allegedly being processed primarily by the left hemisphere, whilst the present study found greater accuracy for distinguishing positive emotions regardless of location. The procedures used in the present study differed from those of Jansari et al (2000) in that they were perhaps more artificial in a sense. Whilst Jansari et al (2000) allowed participants the opportunity to look at the positive and negative face stimuli, rarely in real life are we exposed to faces flashing on either side of our visual periphery as was the case in the present study. However even the procedures used by Jansari et al (2000) are subject to their own criticism, questioning the study's basis as a valid and strong comparison in itself. For example, as mentioned previously the use of free field conditions reduces any confidence in asserting that a stimulus in a particular location was in fact processed primarily by the contralateral hemisphere (Jansari et al, 2000). Therefore, there is reason to suggest that for lateralisation effects of positively valenced faces to be demonstrated behaviourally, experimental conditions must have a closer approximation to those in real life than

was achieved in the present study, though perhaps in doing so, the internal validity and ability to make valid assertions of hemispheric dominance is compromised in most cases.

The significant increase in accuracy and decrease in response times with greater intensity found in the present study was consistent with previous expectations. This effect could perhaps simply be attributed to the greater ease of identifying more intense emotional faces. Whilst at lower intensities poor accuracy and slower response times could be attributed to difficulty in discriminating the emotional faces from neutral expressions, participants were able to identify and thus respond to high intensity faces much faster and with greater certainty. Here, the Ekman face stimuli at greater intensities displayed more obvious happy and angry emotions, with greater contortions of the face, and with teeth on display particularly for the intensity 5 emotions. However, perhaps it could be argued that such a salient physical characteristic could have acted as a superficial visual cue for emotion, regardless of which particular emotion was being expressed. Perhaps this could help explain why at higher intensities the difference in accuracy scores between happy and angry faces was smaller than at mid-intensities.

The ease of discriminating emotion from lack of emotion (neutral) at high intensities based on superficial cues may have meant that there was less attention paid to valence; whereas at mid-intensities, the absence of this ceiling effect meant the effect of valence on accuracy could be more apparent. Conversely, at low intensities the smaller difference in valence would appear to be due to a floor effect, whereby the difficulty of discriminating emotional faces from neutral expressions would leave little opportunity for a happy face advantage. Though non-significant, intensity also appeared to show a particular trend with the temporal-nasal factor for reaction time, with the greatest difference between faces in the temporal and nasal hemifields being found in intensity 3 only. Perhaps this effect could also be attributed to floor and ceiling effects if it was significant, with faces at high and low intensities being either too easy or too difficult to discriminate and so all response times being similarly high or low at these extremes of the scale. Perhaps further investigation into this possible effect would help identify if stimuli at mid intensities would in fact be more likely to yield temporal-nasal differences than if a wider range is used, as was the case in the present study.

There are a number of possible factors which may have contributed to the absence of significant effects in the present study, a few of which have already been mentioned. Since the data appeared to display predicted patterns corresponding to theories on which the study was based, their non-significance is perhaps more indicative of flaws in the experimental design than in the theoretical frameworks themselves. For example, whilst efforts were made to maintain a controlled testing environment free from distraction, and environmental conditions and procedures were kept constant across all participants, a lack of control over participant eye movements may have contributed to weak temporal-nasal and hemifield effects. Whilst participants were reminded to fixate in the centre, there was no tracking of their saccadic eye movements as the stimuli appeared on screen, and therefore one cannot be certain that all stimuli were in fact presented to the correct location within the visual field of each eye. In addition to this, perhaps the sample was too small for experimental effects not to be masked by error in the data. A larger sample may

yield more encouraging results, since averaging across a larger sample of participant scores would reduce noise found in any data set.

However, perhaps the most significant limitation of the present study, and of the research on which the underlying theory was based, is in the stimuli often used in attempts to surface these attentional mechanisms. It seems sensible to suggest that the neural networks involved are attuned to respond to stimuli and cues likely to be provided in our real-life environment. For example, in real life, facial expressions are seen in context; apart from in a snapshot taken with a camera we are presented with other cues as to what emotion is being expressed, based on the circumstances of the expresser, and those which we are in ourselves. This is a view shared by Russel (1997) who highlights that our ancestors would have been presented with facial emotions in context, rather than judging by expression alone.

The suggestion, therefore, is that perhaps the single facial expressions briefly presented in the present study were insufficient to enable participants to fully process the emotion and activate the attentional neural mechanisms in place to influence their responses. The consideration of context also places a question mark on the validity of behavioural studies within the present field which use such facial stimuli to elicit specific responses, with a lack of contextual information to aid emotional interpretation and processing. However, this view goes against those of many previous researchers, who have asserted that emotional information can be sufficiently judged from facial expression alone, independent of context (e.g. Ekman, cited in Fernandez-Dols & Carroll, 1997) and that there is in fact great value in investigating human judgement of single facial expressions (Izard, 1997) as was done in the present study. As highlighted by Russel (1997) there is a need for further research into the relative importance of facial signals and contextual factors in the judgement and processing of emotion.

Further criticism of the theoretical background of the present study includes the fact that we cannot be sure that stimuli presented in one hemifield would be processed solely by the contralateral hemisphere. For example, as was demonstrated by Siman-Tov et al (2008), face stimuli presented in the left hemifield led to bilateral activation of the amygdala and other subcortical structures. Evidence from neuroimaging studies such as this demonstrate that whilst input from each hemifield will be processed exclusively by the visual cortex and lateral geniculate nucleus of the contralateral hemisphere (Thompson, 2000), processing of the more meaningful features of the visual scene, such as emotionality, may be processed bilaterally. Therefore, perhaps causal attributions of responses to location-specific stimuli, such as those in the present and previously mentioned studies, cannot be isolated to just one hemisphere of the brain; since there are extensive neural links between the two which make this view seem oversimplified. This therefore suggests that even those stimuli which were presented within the correct visual field location in the present study were not processed exclusively by one hemisphere, and perhaps this leads one to question the reliability of such conclusions drawn from purely behavioural studies.

A number of questions have arisen from discussion of the present findings, and it is evidently beyond the scope of the present study to attempt to resolve such issues. Rather, a number of suggestions for future research may be proposed. Firstly, it is suggested that further research could be undertaken to identify why happy faces often lead to better response time performances, despite common assumptions that

neural mechanisms in place for processing emotion have specialised preferences for negatively valenced stimuli. As previously suggested, more research should also be undertaken into the optimal conditions under which attentional mechanisms in the brain may be activated enough to be measured behaviourally in a controlled environment. Perhaps the use of weak stimuli contributes to inconsistent findings, and so ecologically valid procedures which more closely simulate the circumstances within which these systems operate, or have done in our ancestral history, will be more likely to yield stronger results. In doing this, research should also attempt to determine the relative importance of contextual information over facial signals of emotion. Difficulty was also identified in drawing definitive conclusions from behavioural studies. Therefore, whilst studies with improved stimuli may help us identify how these attention mechanisms affect our actions, perhaps neuroimaging such as fMRI would help give a clearer picture of the systems involved. Perhaps Transcranial Magnetic Stimulation (TMS) could also be used to test predictions such as the valence hypothesis, to see if stimulation of the right or left cerebral hemisphere would significantly affect responses to positive and negatively valenced stimuli in different locations.

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