

Bangor University

DOCTOR OF PHILOSOPHY

Remembering the prior body states of others : evidence from facial EMG and pupil size

Pawling, Ralph

Award date:
2014

Awarding institution:
Bangor University

[Link to publication](#)

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal ?

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Download date: 12. Mar. 2025

**Remembering the Prior Body States of Others: Evidence From Facial
EMG and Pupil Size**

Ralph Pawling



PRIFYSGOL
BANGOR
UNIVERSITY

This PhD is submitted to the School of Psychology, Bangor University Wales, in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

Declaration and Consent

Details of the Work

I hereby agree to deposit the following item in the digital repository maintained by Bangor University and/or in any other repository authorized for use by Bangor University.

Author Name: Ralph Pawling

Title: Remembering the Prior Body States of Others: Evidence From Facial EMG and Pupil Size

Supervisor/Department: Professor Steve Tipper

Qualification/Degree obtained: Doctor of Philosophy

This item is a product of my own research endeavours and is covered by the agreement below in which the item is referred to as “the Work”. It is identical in content to that deposited in the Library, subject to point 4 below.

Non-exclusive Rights

Rights granted to the digital repository through this agreement are entirely non-exclusive. I am free to publish the Work in its present version or future versions elsewhere.

I agree that Bangor University may electronically store, copy or translate the Work to any approved medium or format for the purpose of future preservation and accessibility.

Bangor University is not under any obligation to reproduce or display the Work in the same formats or resolutions in which it was originally deposited.

Bangor University Digital Repository

I understand that work deposited in the digital repository will be accessible to a wide variety of people and institutions, including automated agents and search engines via the World Wide Web.

I understand that once the Work is deposited, the item and its metadata may be incorporated into public access catalogues or services, national databases of electronic theses and dissertations such as the British Library’s EThOS or any service provided by the National Library of Wales.

I understand that the Work may be made available via the National Library of Wales Online Electronic Theses Service under the declared terms and conditions of use (<http://www.llgc.org.uk/index.php?id=4676>). I agree that as part of this service the National Library of Wales may electronically store, copy or convert the Work to any approved medium or format for the purpose of future preservation and accessibility. The National Library of Wales is not under any obligation to reproduce or display the Work in the same formats or resolutions in which it was originally deposited.

Statement 1:

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree unless as agreed by the University for approved dual awards.

Signed (candidate)

Date

Statement 2:

This thesis is the result of my own investigations, except where otherwise stated. Where correction services have been used, the extent and nature of the correction is clearly marked in a footnote(s).

All other sources are acknowledged by footnotes and/or a bibliography.

Signed (candidate)

Date

Statement 3:

I hereby give consent for my thesis, if accepted, to be available for photocopying, for inter-library loan and for electronic repositories, and for the title and summary to be made available to outside organisations.

Signed (candidate)

Date

Statement 4:

Choose **one** of the following options

a) I agree to deposit an electronic copy of my thesis (the Work) in the Bangor University (BU) Institutional Digital Repository, the British Library ETHOS system, and/or in any other repository authorized for use by Bangor University and where necessary have gained the required permissions for the use of third party material.	
b) I agree to deposit an electronic copy of my thesis (the Work) in the Bangor University (BU) Institutional Digital Repository, the British Library ETHOS system, and/or in any other repository authorized for use by Bangor University when the approved bar on access has been lifted.	
c) I agree to submit my thesis (the Work) electronically via Bangor University's e-submission system, however I opt-out of the electronic deposit to the Bangor University (BU) Institutional Digital Repository, the British Library ETHOS system, and/or in any other repository authorized	

for use by Bangor University, due to lack of permissions for use of third party material.	
---	--

Options B should only be used if a bar on access has been approved by the University.

In addition to the above I also agree to the following:

1. That I am the author or have the authority of the author(s) to make this agreement and do hereby give Bangor University the right to make available the Work in the way described above.
2. That the electronic copy of the Work deposited in the digital repository and covered by this agreement, is identical in content to the paper copy of the Work deposited in the Bangor University Library, subject to point 4 below.
3. That I have exercised reasonable care to ensure that the Work is original and, to the best of my knowledge, does not breach any laws – including those relating to defamation, libel and copyright.
4. That I have, in instances where the intellectual property of other authors or copyright holders is included in the Work, and where appropriate, gained explicit permission for the inclusion of that material in the Work, and in the electronic form of the Work as accessed through the open access digital repository, *or* that I have identified and removed that material for which adequate and appropriate permission has not been obtained and which will be inaccessible via the digital repository.
5. That Bangor University does not hold any obligation to take legal action on behalf of the Depositor, or other rights holders, in the event of a breach of intellectual property rights, or any other right, in the material deposited.
6. That I will indemnify and keep indemnified Bangor University and the National Library of Wales from and against any loss, liability, claim or damage, including without limitation any related legal fees and court costs (on a full indemnity bases), related to any breach by myself of any term of this agreement.

Signature: Date :

Acknowledgements

I would like to thank Professor Steve Tipper who has been my supervisor. I feel incredibly lucky to have worked for someone who is so insightful and who has had so much to teach me over the last few years. I came into Steve's lab with very little research experience and a feeling that I was very lucky to be there. I still have the latter, but I'm leaving with a much richer knowledge and many more skills and that is thanks to Steve and the time he has put into working with me. He has also been a great friend and example of how to be a good colleague as well as a good academic.

I would like to thank Amy Hayes for her very useful insights and ideas that have helped drive the current work, and also for her cheeriness, and calmness, which have been continual in every meeting we've had. Thank you to John Parkinson for being my chair, but also a great friend and running partner.

There are many people in the department to whom I owe a debt of thanks. In particular though I would like to thank the IT technicians who have always gone above and beyond to help keep things running in the lab.

I would not have been able to complete this thesis without the brilliant support of my friends in Bangor. Particularly Thandiwe who has been with me every step of the way since we came to Bangor to study for our MSc degrees, and my lab-mate Wendy, who shared, and help make, the brilliant experience that has been life in the Tipper lab. Both of you have been the most wonderful friends over many years now. I also owe a big , big thank you to my family who have never stopped being supportive and gratifyingly baffled by my endeavours. Finally I would like to thank Naomi for daring to date someone doing a PhD (and even pretending to be interested at times), but mostly for putting up with me over the last couple of years and always being there for me.

Contents

Title Page	i
Declaration	ii
Acknowledgments	v
Contents	vi
Thesis Summary	1
1. Embodiment of other's emotion and retrieval of this embodiment	3
1.1 Summary	3
1.2 Introduction	3
1.2.1 Embodied cognition and perception	4
1.2.2 Embodiment of other people and their actions	8
1.2.3 Embodying other's emotions	11
1.2.4 Emotional expressions and facial mimicry effects	14
1.2.5 Reactivation of simulations during recall	19
1.2.6 Conclusions	23
2. The role of task relevance and repeated exposures in the production and reactivation of facial mimicry	25
2.1 Summary	25
2.2 Experiment 1: The facial mimicry effect	26
2.2.1 Facial EMG techniques	27
2.2.2 Methods	35
2.2.3 Results	38
2.2.4 Conclusions	39
2.3 Experiments 2 and 3: Reactivation of facial mimicry and	

the effects of multiple exposures and task relevance.	39
2.3.1 Methods	42
2.3.2 Results	47
2.3.3 Conclusions	55
2.4 Discussion	56
3. Dynamic facial expression tasks: Predictive activation and Retrieval of facial mimicry.	62
3.1 Summary	62
3.2 Introduction	62
3.3 Experiments 4, 5, 6 and 7: Dynamic expressions tasks	66
3.3.1 Methods	66
3.3.2 Results	74
3.3.3 Conclusions	85
3.4 Discussion	86
4. Retrieval of rapid facial responses to valenced non-facial stimuli	91
4.1 Summary	91
4.2 Introduction	91
4.3 Experiments 8 and 9: Non-facial expression stimuli	96
4.3.1 Methods	96
4.3.2 Results	100
4.3.3 Conclusions	108
4.4 Discussion	109
5. Incidental encoding of other's pupil size	113
5.1 Summary	113
5.2 Introduction	113
5.3 Experiment 10: The effects of pupil size change on long-term person perceptions	126
5.3.1 Methods	126

5.3.2 Results	131
5.3.3 Discussion	133
5.4 Experiment 11: The effects of high and low trustworthiness on pupil size induced changes in long-term person perceptions	134
5.4.1 Method	134
5.4.2 Results	135
5.4.3 Discussion	136
5.5 Experiments 12 and 13: Effects of encoded pupil size in male participants	138
5.5.1 Methods	138
5.5.2 Results	139
5.5.3 Discussion	142
6. Activation of the sympathetic nervous system during pupil size Encoding and retrieval, and the direction of the pupil size effect	144
6.1 Summary	144
6.2 Introduction	145
6.3 Experiment 14: Activation of the sympathetic nervous system during the encoding and retrieval of pupil size changes	148
6.3.1 Methods	148
6.3.2 Results	154
6.3.3 Discussion	159
6.4 Experiment 15: The direction of the pupil effect	163
6.4.1 Methods	165
6.4.2 Results	168
6.4.3 Discussion	173
7. Remembering the prior body states of others: Evidence from facial EMG and pupil size	176
7.1 Summary	176

7.2 Facial mimicry effects	177
7.3 Reactivation of facial mimicry	179
7.4 Long-term effects of pupil size on person perception	182
7.5 Limitations and future directions	186
7.6 Conclusions	188
8. References	190

Thesis Summary

Other people's internal emotional states can sometimes be perceived through the physical responses they cause. These responses are mimicked, or embodied, by viewers, and this process is believed to aid prediction of other people's feelings and future actions. We propose that when other people's emotional expressions are embodied through facial mimicry, these embodiments are reactivated during later encounters, even when the person who was previously emotional now shows no emotional state. These embodied retrieval processes might underpin the ability to act predictively of someone's future state. We also propose that even subtle cues, that are not knowingly perceived, cause long-term changes in the way we represent individuals.

In the first half of this thesis the reinstatement of facial mimicry effects was investigated. In a series of experiments participants viewed faces that became consistently happy or angry, and later viewed the same faces with neutral expressions. Facial mimicry effects elicited by the faces were shown to be activated predictively of the forthcoming emotion, and in the later task reactivated in response to the neutral faces. These effects only occurred in those participants who first embodied the emotions they saw on the faces, and were shown not to occur for emotional, but non-facial stimuli.

In the second half of the thesis, we investigated the potential encoding of pupil size, a very subtle cue to arousal state. We showed that women, but not men, demonstrated encoding and retrieval of other people's pupil size changes that affected later perceptions of those individuals. This effect was shown even though the

participants were unaware of observing pupil size changes, and was shown to be modulated by static traits of the faces, and to possibly be underpinned by reinstated physiological responses.

Together the experiments in this thesis provide evidence that observers not only embody the physical cues of the emotional states of others, and detect these cues when they are very subtle, but that this embodiment and perception at the time of an interaction can be encoded and later recalled, causing lasting changes in the way the observer perceives or responds to an individual.

Chapter 1

Embodiment of other's emotion and retrieval of this embodiment

1.1 Summary

Evidence from behavioural and neuroimaging studies supports the idea that the brain represents both objects and other people in the world in terms of sensory-motor activations. These embodied theories also claim that sensory-motor representations are reactivated during memory retrieval. In this chapter the central hypothesis of this thesis is discussed. We propose that mimicry of other people's emotional states, which is thought to underpin emotion comprehension, may be reactivated during retrieval of another person's identity from memory, and may act to guide an observer's future actions.

1.2 Introduction

Human beings are remarkably adept at understanding and predicting the inner, unobservable states of other humans. It has been suggested that this social cognitive ability is underpinned by "simulation" (Barsalou, 2008; Niedenthal, 2007), whereby entering into the same physical state by mimicking the action or emotion of a viewed person, allows us to represent their inner emotional state, goals, intentions, and importantly likely future emotions and actions. The experiments in this thesis investigate the hypothesis that mimicry of other's emotions may be reactivated during later encounters with the same individuals, as part of retrieving from memory who they

Chapter 1

are. The re-entering of the same state of embodied emotion that was created when we first mimicked the individual, may act as a guide in predicting how they are likely to behave, allowing us to be predictive and not just reactive. Chapter 1 is going to briefly examine the embodied approach to explaining cognition, discuss evidence for the way that our interactions with objects and people may be guided by embodied processes, and look at the embodiment of other people's emotions and why we hypothesise that this embodiment should be retrieved during later re-exposure.

1.2.1 Embodied cognition and perception

During social interactions it is vital that we understand how another person is feeling, and what their actions mean for our immediate situation. For example, do they seem pleased to see us or angry? Does their advancing hand mean a forthcoming handshake or a possible blow? It is also very important that we are predictive and not just reactive. It is better to pre-empt a blow, and more socially acceptable to pre-empt a handshake, than to wait until the other person has acted before making our own response. One theory of how this is achieved is that our understanding and prediction of other people's actions is based on simulating their current state (see Barsalou 2003; Frith and Frith, 2006; Gallese & Goldman, 1998). That is, when we see another person's actions, we represent these actions with matching states in our brains and bodies. This representation, or simulation, aids our ability to understand what that person is doing, or how they are feeling, and through association of that state with goals and outcomes, allows us to be predictive about what they are going to do next. This theory represents an embodied account of social cognition.

Chapter 1

Embodied accounts of cognition suggest that knowledge in general is represented through sensory-motor simulations (Barsalou, 1999; 2008;). A *disembodied* account of cognition suggests that our initial experiences of objects and concepts occur through sensory input and our motor actions, but that the mental representation of these inputs is amodal. This means it is abstracted from its original sensory-motor form, so the neural coding for the sight and taste of an apple for example, would take the same form. In contrast, embodied accounts put sensory-motor systems right at the centre of knowledge (Barsalou, 1999, 2008; Damasio, 1989). When an experience occurs, it is multisensory, including perception of our own actions and internal physical states. This sensory-motor information is stored to form memories, and when memories are retrieved, whether during conscious recollection or rapid implicit retrieval, these sensory-motor states are partially reactivated and substantiate the representations that make up the memory (Barsalou, 1999; Danker & Anderson, 2010). The reactivation of sensory-motor states forms a simulation, with multiple simulations of prior states from different modalities activated together to form the basis of conceptual knowledge. This process is termed a “simulator” (Barsalou, 1999). So the simulator of an apple, which would become active if we saw an apple, imagined an apple, or read the word ‘apple’ would involve reactivation of neural states involved in encoding the taste of apple, the sound of it’s crunch, the feel of it in our hands, it’s colour and so on. It is important to say that embodied theorists suggest that shallow levels of processing of concepts might occur at a linguistic level (i.e symbolic but amodal representations, not rooted in embodied states), but that deep processing of concepts involves simulation (e.g. Barsalou, Santos, Simmons and Wilson, 2008).

Chapter 1

There is evidence to support the claims that cognition is embodied, in the way the body and brain behave when we see objects that we have acted upon in the past. This evidence is also in line with the concept that the brain is principally there to control the actions of the body, and that it represents the world around it in terms of the potential for action (e.g., Gibson, 1979; Tipper, 2010), something which can be applied to perceptions of other people as well as of objects. Seeing a commonly grasped object like a knife or door-handle, aligned so its handle is oriented toward one of our hands, speeds responses with that hand even if the graspable nature of the object is not relevant to the hand response (Tipper, Paul & Hayes, 2006; Tucker & Ellis, 1998). This apparently automatic preparation of the brain for action upon the object is even sensitive to the necessary grip for a particular object, readying that grip specifically (Tucker & Ellis, 2001), suggesting a finely tuned system for action readiness.

Evidence that this automatic action priming is caused by reactivation of the same cortical regions that are active when these objects are actually manipulated comes from neuroimaging studies. Participants viewing and naming pictures of tools and other graspable objects showed cortical activation in pre-motor areas that would also become active if they were to actually act on the tools, despite not subsequently moving their hands (Chao & Martin, 2000; Grafton, Fadiga, Arbib & Rizzolatti, 1997). The argument that these activations support cognition is strengthened further by evidence that cortical regions which encode sensory information become active when participants mentally represent a stimulus, with different sensory regions being activated dependent on the aspect of the stimulus that requires representation (for review see Barsalou, 2008). However, it must be considered that neuroimaging data only provides a correlation between the mental activity the participant is supposed to be undertaking

Chapter 1

and the cortical activations recorded, and from this data cannot on its own be taken as evidence that simulation is *necessary* for mental representation, just that mental representation causes sensory-motor regions to become active.

These results could be interpreted as the brain simply readying the body for potential action, which in itself is relevant to the current experiments, but there is also evidence that the representations of action are involved in the retrieval of the concepts of objects. For example, if images of objects are oriented so that they cause a motor simulation, (as in Tucker and Ellis (1998,2001) and Tipper, Paul and Hayes (2006)), this improves participant's performance in naming them (Helbig, Graf & Kiefer, 2006). The reinstatement of the motor action associated with the object appears to prime retrieval of what the object is. Conversely, when participants are asked to make circular or square movements with their hands, these are interfered with by consideration of the non-shape properties of square or round objects. Although the shape of the object is not being considered, just thinking about a square object makes circular movements squarer, and thinking about a round object makes square movements more rounded (Bach, Griffiths, Weigelt & Tipper, 2010).

Therefore in this latter example it seems the concept of the object appears to be partly grounded in physical representations of its shape. Or at least that retrieving one aspect of the object from memory also activates a physical embodiment of the object. This embodiment is powerful enough to alter the physical state of the participant, in this case the trajectory of their movements. It is possible to theorise that similar embodiments might also alter other physical states, were they measurable at the time. For example the taste of something currently being eaten might be altered if the concept of another food item was to be accessed, even if the taste of that item was not the

specific feature being evaluated. This is important for the current body of work, because it supports the idea that retrieving information about a person from memory might also trigger embodiment of other properties associated with that person, which in turn could affect our physical and perhaps emotional state.

1.2.2 Embodiment of other people and their actions

There is increasing evidence that our understanding of others may also be grounded in embodiment of their states and actions, certainly that this embodiment occurs. This has commonly been attributed to the action of so called “mirror systems”. Single cell recordings made in macaque monkeys uncovered populations of neurons that fired not only when the monkey performed an action, but also when it watched the experimenter performing the same action (Di Pellegrino, Fadiga, Fogassi, Gallese & Rizzolatti, 1992). These were termed mirror neurons. Later discovered properties of these neurons, such as the fact that they appeared to strongly encode the goal of an observed action, and were in some cases action specific (see Fogassi et al., 2005; Rizzolatti & Craighero, 2004), made them a very attractive proposition for a neuronal underpinning of the embodied understanding and prediction of other’s actions.

Multiple modes of research have been used to investigate the possibility that humans also have mirror neurons. The idea is controversial (see Heyes, 2010), but this thesis is not intended to shed further light on the existence of human mirror neurons. Instead, it is interested in the evidence gleaned during the search for human mirror neurons that suggests when we view other’ actions, and emotional states, we enter a shared state of neural activity, the same regions of our brains becoming active as can be assumed to be active in the person we are viewing. These activations appear to support

Chapter 1

the idea of simulation as a means of understanding the actions and inner states of other people.

Viewing another person perform a hand action has been shown to cause activity in areas of the parietal cortex that are also active when we perform the same action ourselves (e.g., Oosterhof, Tipper & Downing, 2012; Oosterhof, Wiggett, Diedrichsen, Tipper & Downing, 2010). Similarly, observing other people's actions has been shown to increase nerve impulses sent to muscles that are active when participants perform the same actions themselves (Fadiga, Fogassi, Pavesi & Rizzolatti, 1995). These studies suggest that other people's actions may be represented in the motor-cortex of the viewer, which can be evidenced as activations of non-cortical systems, in this case the musculature. Watching someone tap their finger can speed reactions with the same finger in an observer, but interfere with actions made with different fingers (Brass, Bekkering & Prinz, 2001; Brass, Bekkering, Wohlschlagel & Prinz, 2000), which suggests a very specific and automatic representation of other's body parts. Watching more complex actions like kicking or typing also seems to prime activation of the matching motor states, evidenced by faster foot and hand responses respectively (Bach, Peatfield & Tipper, 2007), and seemingly quite automatically. Even if participants attended to a colour patch placed over an actor's limb and not to the limb itself, the same activation priming occurred. In this way simulation of other people's actions seems to occur more robustly than simulation of the actions an object affords, where similar attention manipulations can extinguish simulation (Paul, Hayes & Tipper, 2006).

Simulations of other's actions also seem to occur predictively, and not just reactively. Participant's watching videos of actor's hands grasping objects showed matching patterns of electrical brain potentials in the moments before the hands moved

Chapter 1

to make a grasp, as they did in the moments before making their own grasps of actual objects (Kilner, Vargas, Duval, Blakemore & Sirigu, 2004). Watching someone gaze towards an object activates similar motor regions to those active when viewing someone's actual action upon an object (Ramsey, Cross & Hamilton, 2012), indicating that the brain is running a simulation of the expected forthcoming action. It has been suggested that action understanding is underpinned by these predictive simulations, integrated with information about context, including who the actor is, so that simulations of the same forthcoming action can hold different meanings from one actor and one situation to the next (Kilner, Friston & Frith, 2007).

Action simulations appear to underpin our concepts of who people are. Seeing a person's face causes simulation of the actions they are associated with, without those actions needing to be seen. Famous tennis player's faces were shown to speed hand responses, whilst famous footballer's faces sped foot responses (Bach & Tipper, 2006). This suggests that person concepts are also stored in an embodied manner and driven in part by our associations between a person and their actions. In a similar vein, other research has shown that physical embodiments underlie representations of other people's traits. For example representations of the concept of 'elderly' through slow movements (Bargh, Chen and Burrows, 1996), although of course this could be interpreted as a priming effect whereby representing mentally the concept of an elderly person causes a change in the physical action of the thinker. Either way, it appears that cognitive processing of concepts involves or trigger physical embodiments. If processing triggers embodiments, it seems logical that these embodiments would play some purpose, perhaps in strengthening representations. Perception of traits can also be cemented by simulation. Bach & Tipper (2007) and Tipper & Bach (2008) showed

that motor fluency induced by another person's sporty or academic action caused participants to become biased in associating person and trait. If an unknown actor is seen playing football and typing on a computer, but the participant only shares one of these motor states with the actor in a fluent manner because during a task they always identify them with foot press for example, they become biased after multiple exposures to consider the actor as more sporty and less academic. This is an important finding in the light of the current set of experiments. It suggests that changes in person perception and predictions of future behaviour are perhaps driven by reinstatement of embodied responses. In this case the motor fluency induced by watching another person's action is attributed to the individual. In the case of the experiments we propose, the emotional state elicited by mimicking an individual might be associated with that person.

1.2.3 Embodying other's emotions

There is evidence that as well as simulation of other people's overt actions, we also simulate other people's internal states, such as their emotions, their state of attention, or their current intentions, by sharing representations of the outward signs of these states. This process is thought to be critical to social cognition and the way the remarkable social abilities of humans (Bastiaansen, Thioux & Keysers, 2009; Niedenthal, Barsalou, Winkielman, Krauth-Gruber & Ric, 2005). Although this thesis doesn't enter into the debate about whether mirror neurons underpin these processes, it's worth mentioning that there are contrasting accounts of how the brain might carry out these social cognitive operations. Both of these accounts are in line with our hypotheses

Chapter 1

about the simulation and reinstatement of simulations of other people's facial expressions.

The first account suggests that humans are born with populations of neurons that code for their own actions and the actions of others, and that these neurons are there to provide information about the states of other people (Rizzolatti & Craighero, 2004; Iacoboni, 2009). This theory would explain why infants less than three weeks old already appear to simulate other people's facial expressions with their own facial muscle responses, through obvious mimicry (see Meltzoff & Decety, 2003). Another view is that simulations of other people's actions occur through associative learning (Heyes, 2010; Keysers & Perrett, 2004). This account suggests that bonds between cortical regions are strengthened by repeated pairings of sensory inputs with outcomes and goals, which are also represented in a sensory-motor manner. In time, perceiving another person's action, say a grasp, is enough to trigger cascades of activity through the network of sensory regions that are now strongly associated with this visual input after seeing our own grasps so many times. This is how simulations of other people's actions and intentions are formed through observing them. This account explains simulations of emotional states through simulation of expressions in a different way. Instead of neurons in the brain coding specifically for other people's facial actions causing early mimicry effects in infants, infant mimicry is driven by associative learning when adults mimic their offspring. So when a new born opens its mouth and its parent playfully mimics this action, the brain of the new born is forming a neural bond between the motor activation behind its own open mouth, the visual representation of the parent's open mouth, and whatever autonomic state the infant is currently in. Both these accounts work in terms of the hypotheses of the current experiments.

Chapter 1

Neuroimaging studies provide evidence that humans do indeed simulate the inner emotional states of other humans. Seeing or knowing another person is in pain, particularly if they are significant to us, causes activation in the same regions of the brain that are active when we experience pain ourselves, namely anterior cingulate cortex and anterior insular cortex (Jackson, Meltzoff & Decety, 2005; Morrison, Peelen & Downing, 2007; Singer et al., 2004). Seeing an actor expressing disgust activates the same cortical areas as smelling a disgusting odour (Wicker et al., 2003). These studies evidence the idea that understanding another person's emotion involves simulating their physical state.

Simulation also appears to transfer to us other people's perspectives on the world. For example, if we shared a direction of gaze with another person, thus simulating the orientation of their attention, and they happen to be smiling at the object of that attention, we like that object more. Without that shared body state though, their expression has no effect on our liking for the object (Bayliss, Frischen, Fenske & Tipper, 2007; Bayliss et al., 2013). Just as evidence from non-social action observation suggests simulations are integrated with contextual knowledge to support the understanding of other's actions (Kilner et al., 2007), neuroimaging evidence also suggests that when we view other people's emotional body language, our understanding of its meaning is created through non-conscious simulation. Watching silent movie clips where actors appear expressing emotional body language activates motor regions in the brains of participants lying still in the scanner. This occurs even when participants do not explicitly attend to the body movements of the actors and instead try to imagine what the actor is feeling (Spunt & Lieberman, 2012). Here apparent simulations in motor regions occur alongside activity in regions that are associated with mentalising (Saxe &

Kanswisher, 2003), making judgements about other people's internal states. The findings suggest that when viewing other's outward emotional actions, like the facial expressions of disgust portrayed by the actors in Wicker et al., (2003), motor simulations play a role in passing a representation of the other person's current state, to regions that integrate this embodied state with contextual information to facilitate understanding.

1.2.4 Emotional expressions and facial mimicry effects

Facial expressions offer the most salient and dynamic cue to another person's internal emotional state (Frith & Frith, 2009), and this information is critical in guiding social interactions, and in order for one person to pass information to another about the state of the environment, for example the presence of danger. Facial expressions can be seen as part of a general physical response to a change in the environment (Scherer, Mortillaro & Mehu, 2013), which ready our body for action and communicate this readiness to others. So being wide eyed and open mouthed during fear not only signals to others that we are afraid, but also maximises visual input, and allows more air to pass to our lungs as we get ready for possible flight. This response occurs alongside the other autonomic responses to fearful stimuli, such as increased heart rate and sweating.

We appear to be predisposed to detect changes in facial expression from a very early age (Vieillard & Guidetti, 2009). Facial expressions are understood to reflect the same internal states regardless of the cultural background of the viewer (Ekman & Friesen, 1971), and certain facial expressions, most notably fear, are salient enough to bypass conscious visual processing and cause neural activation in emotion processing

Chapter 1

regions of the brain without the need for explicit processing (Whalen et al., 2004; Williams, Morris, McGlone, Abbot & Mattingley, 2004).

Whether through an innate set of neurons that are responsive to other's expressions, or associative learning, other people's facial expressions appear to exert a powerful influence on our own faces, reflecting the hypothesised simulation/mimicry processes thought to underpin social cognition (Barsalou, 2003). This has led to the theory that our understanding of others emotional states may be partly supported by physical simulation of their expression (Niedenthal, Barsalou, Winkielman, Ric & Krauth-Gruber, 2005; Niedenthal, Mermillod, Maringer & Hess, 2010), through a process of facial feedback (McIntosh, 2006)

Activity of the zygomaticus major, the muscle that lifts the corners of the mouth during smiling, and the corrugator supercilii, the muscle that draws down the brow during frowning, has been shown to be linearly related to states of positive and negative emotion (Codispoti, Bradley & Lang, 2001; Larsen, Norris & Cacioppo, 2003). Importantly, activity in these sites during emotional reactions co-occurs with other responses indicative of autonomic arousal, such as heart rate and sweat responses (Bradley et al., 2001; Dimberg, 1982; Dimberg, Hansson & Thunberg, 1998), and can be induced through exposure to emotional images such as facial expressions, fear inducing animals such as snakes and arousal scenes. Activity of the facial muscles also appears to influence affective perception even if applied artificially. Gently forcing participants to assume facial muscle activations associated with particular mood states, such as holding a pen between the teeth which activates the zygomaticus as when smiling (Strack, Martin & Stepper, 1988), or drawing golf tees on the brow together to activate the corrugator (Larsen, Kasimatis & Frey, 1992), changes the way they perceive emotional

Chapter 1

stimuli. For example, holding a pen between the teeth makes a funny cartoon seem more humorous, and drawing together golf tees on the brow makes sad images seem sadder. The fact that even this very basic, forced, embodiment of an emotional state can actually influence perception lends support to the idea that simulation of other people's expressions might similarly change an observer's emotional state, garnering an insight into the state of the person they are observing; the so called facial feedback hypothesis (McIntosh, 1996).

Facial electromyography (EMG), which measures muscle activation via electrodes placed on the skin above muscle sites, has been used to provide evidence that when we see the emotional expressions of another person, we do indeed embody them with our own facial muscles, in what have been termed "rapid facial reactions" and "facial mimicry" (Dimberg & Thunberg, 1998). Seeing another person smile for example, causes slight activations of the observer's own zygomaticus major and relaxation or a lack of response in the corrugator. Viewing another person's frown causes activation of the corrugator and no activation, or relaxation of the zygomaticus (Dimberg, 1982). These simulations have been shown to occur very rapidly, within 300 - 500 ms (Dimberg & Thunberg, 1998; Dimberg, Thunberg & Elmehed, 2000) and to show the hallmarks of automaticity, in that they are not only rapid, but cannot be consciously controlled, occur spontaneously and without conscious attention or awareness of the face stimulus evoking them (Dimberg, Thunberg & Grunedal, 2002; Dimberg et al., 2000).

The fact that these mimicry responses covary with other autonomic states supports the idea that they represent more of a preparatory response, than a communicative facial expression. Further supporting this is the fact that they are

Chapter 1

evoked most distinctly by stimuli such as facial expressions and snakes (Dimberg & Karlsson, 1997), that humans are thought to be biologically predisposed to react to (Seligman, 1971). However, evidence that they play a role in comprehending emotion as well as preparing for its consequences is needed if facial mimicry responses are to be considered simulations that play a role in understanding others, and not just simulations that place us in the correct autonomic state to react to another person's emotional state.

Several approaches have been used to address the question of whether facial mimicry represents simulation of another person's emotion that aids us in comprehending how they are feeling. Hess & Blairy (2001) found no evidence that facial mimicry of video stimuli lead to better decoding of the emotions displayed in the videos, using regression analyses. However, participants who had the upper or lower halves of their faces held in a state of tonic contraction, using a technique similar to those used in Larsen et al., 1992 and Strack et al., 1988, were poorer in identifying cropped images of emotional expressions (Ponari, Conson, D'Amico, Grossi & Trojano, 2012). Similarly, Neal and Chartrand (2011), showed that in a sample of participants who had had their brow muscles denervated through the use of cosmetic botulinum-toxin-a (BTX) injection, emotion identification of similar cropped facial images was poorer than in control subjects, whilst taping the facial muscles to increase afferent feedback improved emotion identification in normal controls.

Further evidence that facial mimicry facilitates emotion comprehension comes from studies that link facial EMG responses with empathy. Participants with low scores for empathetic traits showed reduced facial mimicry in comparison to those who showed greater empathy (Sonnby-Borgstrom, 2002) and administration of testosterone,

Chapter 1

a neurotransmitter associated with decreased empathy, was shown to reduce facial mimicry in female participants. Individuals with autism, a condition known to be associated with difficulties in understanding the internal states of others, also show reduced facial mimicry (McIntosh, Reichmann-Decker, Winkielman & Wilbarger, 2006). However, echoing the results of Hess and Blairy (2001), some evidence does suggest that feedback from facial mimicry may not be necessary for understanding the meaning of facial expressions. Whilst mirror-touch synesthetics, who show heightened sensory-motor simulation of others, show better emotion recognition than controls (Banissy et al., 2011), people with congenital facial paralysis were shown to be as good at identifying facial expressions of affect as controls (Bogart & Matsumoto, 2009).

Neuroimaging evidence has come from studies of BTX users who viewed negative emotions whilst undergoing fMRI (Hennelotter et al., 2009), purposefully mimicked the facial expressions of others (Lee, Josephs, Dolan & Critchley, 2006), or demonstrated unconscious facial mimicry with (Likowski et al., 2012) or without (Schilbach, Eickhoff, Mojzisch & Vogely, 2008) facial EMG measures. The data from across these studies indicates that increased facial mimicry is associated not only with increased activation of facial motor regions, and areas implemented in motor simulation of others, such as the inferior fusiform gyrus, but also increased activation of emotion processing regions such as the amygdala, insular, anterior cingulate cortex, and regions that would play a role in bringing an observer into an aligned autonomic nervous system state with the person whose emotion they are viewing, such as the dorsal pons.

Collectively, the evidence suggests that simulation of other's emotions, through facial mimicry, may well play a role in understanding other's emotional states, although it may not always be necessary. This is reflected in recent theories that place

Chapter 1

embodiment of expressions at the centre of emotion comprehension, such as the Simulation of Smiles Model (Niedenthal et al., 2010), but allow for simulations being inhibited without the loss of emotion comprehension. For example, because social context means it would be risky for someone to spot our simulation of their expression (Bourgeois & Hess, 2008; Weyers, Muhlberger, Kund & Pauli, 2006), or because expressions are very predictable, i.e during blocks design studies (Hess, Philpott & Blairy, 1998). Simulation though is assumed to play a key role in our understanding other's and their internal emotional states. However, simulation of a facial expression corresponds to a reaction to another person, and as mentioned at the start of this introduction, the current experiments explore the possibility that simulations might underpin our ability to be *predictive* of others.

1.2.5 Reactivation of simulations during recall

Theories of embodied cognition place simulations at the centre of both explicit and implicit memory (Barsalou, 1999, 2008; Buckner & Wheeler, 2001; Damasio, 1989; Danker & Anderson, 2010). Evidence exists that sensory regions of the brain that are active during the encoding of a memory, are also active when it is recalled, which supports the idea of explicit memory as “mental time travel”, with memories supported by the reactivation of sensory representations (Tulving, 1985). For example, learning words alongside associated pictures or sounds, leads to reactivation of sensory-specific areas for sound or vision upon recall of the words (see Danker & Anderson, 2010, pp. 90). Similarly emotion processing regions such as the amygdala and insular, active when words are learned in an emotional context, are also activated during recall in a neutral context (Smith, Henson, Dolan & Rugg, 2004). Analysis of the specific patterns

Chapter 1

of cortical activity during encoding of images of famous faces, places and well known objects, showed that patterns upon encoding, predicted patterns that occurred when participants freely recalled the names of the stimuli they had seen (Polyn, Natu, Cohen & Norman, 2005). These activations occurred not only in category specific regions (i.e fusiform face area for faces), but were more wide spread across the cortex.

Implicit memories are also thought to rely upon simulations (Barsalou, 2008; Wilson, 2002), with embodied representations building up over time and providing a platform for automatic recall, and reactivation of internal states influencing decisions without conscious awareness. For example, patients with frontal lobe damage who do not show unconscious autonomic responses to punishment when choosing the wrong card deck in a gambling task, also do not show reactivation of these responses when considering picking the same deck at a later stage, and show poor learning of deck contingencies. Normal controls generate autonomic reactions to picking the wrong deck and these reactions begin to pre-empt their picking the wrong deck again, which they begin to do less and less as the task goes on (Bechara, Damasio, Tranel & Damasio, 1997). Topolinski (2011) demonstrated in a series of experiments that implicit memory effects including mere exposure, repetition priming and familiarity effects, could be interfered with by preventing sensory simulations of the items during encoding.

Humans have been shown to learn rapidly about the potential actions of other humans and this process is thought to be driven by both explicit and implicit processes (see Frith & Frith, 2006). Neuroimaging studies have shown that social learning about the behaviour of others recruits reward regions in the brain that fire both when we learn, and when we are re-exposed to individuals, either in further interaction (Smith-

Chapter 1

Collins et al., 2012) or later passive viewing (Singer et al., 2004). Facial expressions have been shown to carry value equitable to financial value (Shore & Heerey, 2011), which can drive learning (Heerey & Crossley, 2013). However, little is known about whether learning about another person occurs through simulation of their emotional state, and whether, as with reactivation of reward systems during learning of behaviour, simulations are also reactivated when we meet a person again, after initially simulating them.

Embodied theories of social cognition and memory would suggest that such a process should occur (e.g Neidenthal, 2007). That, as with perceptions of others actions (e.g Kilner et al., 2007, see also Wholpert, Doya & Kawato, 2003), visual input should trigger the simulation of expected action. So if we meet a person who smiles at us we simulate their smile through facial mimicry, as we learn to expect this smile, which may occur without our explicit awareness, the visual input of their *neutral* face is enough for our brain to simulate the predicted oncoming expression. Reactivation of this simulation brings us into alignment with what is *expected* to be the forthcoming state of that individual. Such matching of physical state is thought to benefit social interactions (see Chartrand & Bargh, 1999; Niedenthal et al., 2005), promoting liking between partners, but also, and more saliently when negative affect is expected, it may cause a cascade of autonomic reactions associated with the facial expression being reinstated, which would be adaptive in preparing us for the possible consequences of the other's upcoming actions.

Some past research suggests that this may occur. For example in a social associative learning game (Heerey & Crossley, 2012), participants had to learn face/key associations, and correct responses were followed on most occasions by the faces

Chapter 1

smiling, and on rare occasions by frowns. Participants mimicked the smiling faces, as measured by EMG at the zygomaticus, but also started to show predictive EMG responses to faces they expected to smile. The task used a relatively small number of faces (4) and a high probability of smiles, with smiles rewarding 85% of correct responses, so to some extent it is hard to determine the extent to which predictive activity in the participants represented simulation or reward expectancy associated with making a correct response.

Another study (Halberstadt, Winkielman, Niedenthal & Dalle, 2009), had participants view faces that appeared on the 50/50 point of a continuum between happy and angry expressions, alongside ideographs. All stimuli were paired with written concepts that were either emotional (e.g. happy/angry) or valenced but not emotional (i.e wise/lazy) and the participants imagined why the faces/ideographs matched the concepts. Later participants passively viewed the faces and ideographs again, and using a sliding scale which scrolled through the continuum of expression for each face, tried to match the emotion on each face to the one they saw during exposure. EMG was recorded during exposure and passive viewing and revealed that only when thinking about faces in terms of emotional concepts (happy/angry) did participants show facial mimicry like effects, and that these were reactivated only for this category of stimulus, when they passively viewed the faces without the concepts. Participant's muscle responses predicted their memories for the expressions on the faces, so participant's who reactivated their zygomaticus for example, in response to faces that had been encoded alongside the concept 'happy', choose frames on the face's continuums that were closer to the 100% happy frame as their memory of the face, than participants who did not show zygomaticus reactivations. This study provides good

Chapter 1

evidence that embodiments of emotional concepts encoded alongside faces can influence representations of the physical emotional expression associated with that face. The study is compelling because of the relationship between the embodiment and the later perception shown in the memory task, and for the fact the effects only occurred with emotional concepts and faces, and not ideographs or valenced concepts. However, whilst it supports our hypothesis, the task uses a 20 second exposure to face and concept during encoding, and asks participants to think carefully about the face and the concept. It does not address the question we are asking, which is about rapid reactions to *facial expressions* being encoded alongside identity, in a more naturalistic manner, through repeated exposure, and without the explicit awareness of the participant that the face/ emotion association is important.

1.2.6 Conclusion

There is extensive evidence that we simulate other people's emotional states, in the same way we might simulate actable properties of objects. Facial mimicry is one of the most obvious examples of this embodiment and may represent a process by which we better understand, and come into alignment with the inner state of another person. In the following experiments we investigate whether facial mimicry effects occur only during the time of an interaction, when someone else's facial expressions are being viewed, or whether they are reactivated at a future time when we view an individual again, but without their showing a facial expression. We predict that as we learn about the likely facial action of another person, and repeatedly simulate this action, in future encounters this simulation will be reactivated, in a manner than pre-empts their forthcoming expression, and can occur even when an expression is not expected. We

Chapter 1

also predict that just as emotional expressions might implicitly influence our predictions about other individuals, other more subtle cues might also cause similar lasting changes in person representation.

In chapters two to four we investigate the possibility that facial mimicry responses are reactivated during later exposure to faces we have consistently simulated. We do so whilst also investigating the automaticity of these effects in terms of the need for emotion to be task relevant (chapters two and three), and in terms of the effects of multiple exposures (chapter two). We investigate the prediction that reactivation of mimicry will differ dependent on the extent to which participants show mimicry responses in the first instance (chapter three), and that this retrieval of prior simulation may represent an embodiment of another's prior facial movements, and not just a general affective response to someone we have learnt is pleasant/unpleasant (chapter 4). Finally, in chapters five and six, we look for evidence that pupil size, a much more subtle cue for internal emotional state, might also be similarly encoded alongside identity, to influence later person perceptions.

Chapter 2

The role of task relevance and repeated exposure in the production and reactivation of facial mimicry

2.1 Summary

Embodied accounts of memory predict that sensory-motor states that are active when a stimulus is encoded should be reactivated as part of the retrieval of that stimulus from long-term memory. Therefore, we predicted that if another person's facial expression is simulated by an observer, through partial activations of their own facial muscles (facial mimicry), this motor activity should be reinstated when the same person is seen again, even if their expression is neutral.

The first experiment in this chapter aimed to replicate the facial mimicry effect using the stimuli that would be employed in the later retrieval experiments.

In Experiments 2 and 3, a novel paradigm was employed which required participants to attend either to the emotional expression or sex of faces that consistently smiled or frowned. The same faces also appeared with neutral expressions. By recording the facial muscle activity of the participants over the course of five blocks, we were able to show that facial mimicry effects remain stable over time, and occur even when the emotion a face is displaying is task irrelevant. The pattern of muscle activity seen when participants viewed neutral faces hinted that when the same person appears with both emotional and neutral expressions within a short period of time,

emotional contrast effects may actually cause a counter-mimicry, or rebound effect in the muscle activity of the observer.

2.2 Experiment 1: The facial mimicry effect

Numerous studies have reported that when participants view emotional faces, their own facial muscles become active in a manner that is mimetic of the expression they are seeing (Cannon et al., 2009; Dimberg, 1982; Dimberg & Thunberg, 1998; Dimberg et al., 2000; Hess & Blairy, 2001; Hess et al., 1998). These rapid facial reactions to emotional expressions are known as facial mimicry. In Chapter 1, the possible role of these activations in understanding others internal states was discussed, and we predicted that these mimicry responses should be reinstated when faces that have previously been mimicked are seen at a future time, with neutral expressions.

The muscle activations in facial mimicry are typically very slight and not under the conscious control of the participant (Dimberg et al., 2000). Because they are also often invisible to the naked eye they are most accurately measured with facial electromyography (EMG), which allows the recording of the electrical signatures of muscle activation via electrodes placed on the skin above the muscle sites of interest. All the previously cited studies that demonstrated facial mimicry responses have used this technique.

Much of the previous research using EMG to measure facial mimicry has used passive tasks, where participants simply watched emotional expressions while their muscle activity was measured (Dimberg, 1982; Dimberg et al., 2000; Dimberg & Thunberg, 1998; Hess et al., 1998). We intended to use tasks that required participants to make responses to the stimuli, so that attention could be maintained and its

Chapter 2

allocation controlled. Experiment 1 set out to use a paradigm that incorporated the stimuli that would be used in later experiments, and a design that would be carried forward into later tasks, to try and replicate the facial mimicry effect. It was critical to our later studies that this could be achieved with our task design, stimuli and equipment. In Experiment 1, participants responded to emotional faces that appeared on screen, by categorising their emotional expression as happy or angry, while their own facial muscle activity was recorded using facial EMG measures. It was predicted that activity in the participant's zygomaticus major (smile muscle) would be greater when they looked at smiling faces than frowning faces, and the opposite would be true of activity in their corrugator supercilii (frown muscle). This would replicate the classic pattern of facial mimicry, whilst the participants were carrying out a more active task than those used in many previous investigations.

2.2.1 Facial EMG Techniques

EMG Data Collection

The experiments in Chapters 2 to 4 involve the measurement of facial muscle activity, using facial electromyography, known as EMG. In this section, the activity of the body's musculature will be briefly described, and the methods applied in capturing and processing facial EMG will be discussed.

There are numerous reasons why recording the activity of the body's many muscles can provide scientists with valuable data, not only about the workings of the physical body, but also of the mind. The experiments in the first chapters of this thesis concentrate on two of the muscles of the face, which we use to express positive and

Chapter 2

negative emotions; the zygomaticus major, which lifts the corner of the mouth during a smile, and the corrugator supercilii, which draws down the brow during a frown (See Figure 2.1 Panel A). There are over 20 muscles in the human face that can be arranged to form an estimated 6,000 to 7,000 changes of appearance (Izard, 1971, in Tassinari, Cacioppo & Vanman 2007). However, in line with previous research, these two muscle sites were chosen due to the consistency with which they have been found to respond to positive and negative emotional stimuli (e.g., Cacioppo, Bush & Tassinari, 1992; Dimberg, 1982; Larsen, Norris & Cacioppo, 2003).

Like other muscles, facial muscles are formed from bundles of fibres, which at their most microscopic level are made up of protein molecules, which can be electro-chemically induced to slide, causing muscle contraction. The messages that induce this contraction originate from two separate sources, depending on whether the movement is voluntary or automatic. Voluntary movements are caused by activity originating in the motor cortex, with the left motor cortex being critical for the voluntary or controlled expressions of emotion. However, involuntary, automatic activation of the facial muscles is elicited by signals sent through an older brain system, which includes the basal ganglia. Automatic movements of the face can originate in either hemisphere (Gazzaniga & Smylie, 1990). Both routes send signals via the facial nucleus in the brain stem, and the seventh cranial nerve. Signals from one hemisphere are sent to the facial musculature on the contralateral side of the face, and in voluntary expressions, the initial command to activate the muscles is shared with the right hemisphere via the corpus callosum (Gazzaniga & Smylie, 1990).

The fibres of the facial muscles contract in response to the activity of motor-units. Motor-units are the conjunction of individual motor neurons, which carry signal

Chapter 2

from the brain to the muscles, with multiple muscle fibres being innervated by a single motor neuron (Andreassi, 2007). The number of fibres innervated by a motor neuron as part of its motor-unit varies, with motor-units with more connections to muscle fibres playing a role in more gross movements, and those with fewer connections playing a role in faster and more precise movements (Loeb & Ghez, 2000, in Tassinary et al., 2007). Motor units simultaneously cause contraction in as many as 2000 fibres, meaning that the muscle tissue acts in a consistent manner.

The electrochemical activity at the motor-unit, which is caused by the rapid metabolism of the neurotransmitter acetylcholine, causes the bi-directional spread of electrical potentials along the muscles fibres, and the resulting slide of protein molecules, contracting the muscle. As more force is required, more motor-units are recruited, and those already firing increase the rate at which they do so. Therefore the activity of a facial muscle contraction, such as that which would take place during even the smallest micro-movement of the face, results in a change in the electro-magnetic field around the muscle. Some portion of this electromagnetic field passes through the fluid and tissue around the muscle site and can be detected with carefully placed electrodes, which act like radio receivers. This is the basis of facial EMG recording, and the stochastic signal that is collected during this procedure, represents the repeated firing of multiple motor units. The amplitude of this signal, when carefully recorded can inform us of changes in the level of contraction of the facial muscles, with a very precise degree of temporal accuracy.

EMG signal can be collected using either invasive needle electrodes sunk into the muscle tissue, or non-invasive surface electrodes stuck onto the skin of the face. The former method is very spatially accurate and can even be used to measure the activity of

Chapter 2

individual motor-units. However, it is not a pleasant procedure and is not suitable for testing large numbers of undergraduates. The latter procedure lacks the spatial accuracy, but is far more practical. As the EMG signal is made up of a random train of electrical potentials (Fridlund and Cacioppo, 1986), with a wide bandwidth partly caused by differing levels of motor-unit firing synchrony, differing numbers of recruited motor units, or their relative size (Van Boxtel, 2001), it has to be carefully treated during collection and post processing, so the signal is not lost amongst possible causes of electrical noise. Given the relative spatial inaccuracy of surface electrodes, placing electrodes accurately over the correct muscle sites is an important part of ensuring maximal signal. Also, as the facial muscles are very responsive to noise and activity in the environment as well as internal states such as boredom or discomfort, it is important in reducing noise to maintain as well a controlled and comfortable testing environment as possible. The final part of this methods section is therefore a description of how EMG data were collected during the experiments that make up this thesis, and how the advice of several methods papers and texts were applied in insuring the best possible signal to noise ratio.

Fridlund and Cacioppo (1986) make clear that the process of reducing noise in the EMG trace, starts with the lab environment and the experimenter participant relationship. For this reason all our EMG studies took place in a cool, quiet lab space, where the participants, tested individually, were seated in a comfortable padded chair, and during the experimental tasks were separated from the experimenter by a room divider to reduce any risk of performance anxiety effects. The participants sat approximately 500mm from the computer screen, centralised with the screen and the keyboard (see Figure 2.1 Panel B) The participants were fully briefed at the start of the

session, both about the way the electrodes would be attached, and about the tasks themselves. However, a cover story of frontal lobe activity measurement was used, and all the participants included in the datasets were those who were naïve to the true purpose of the recordings. This was ascertained before debriefing, using a brief triangulated interview process.

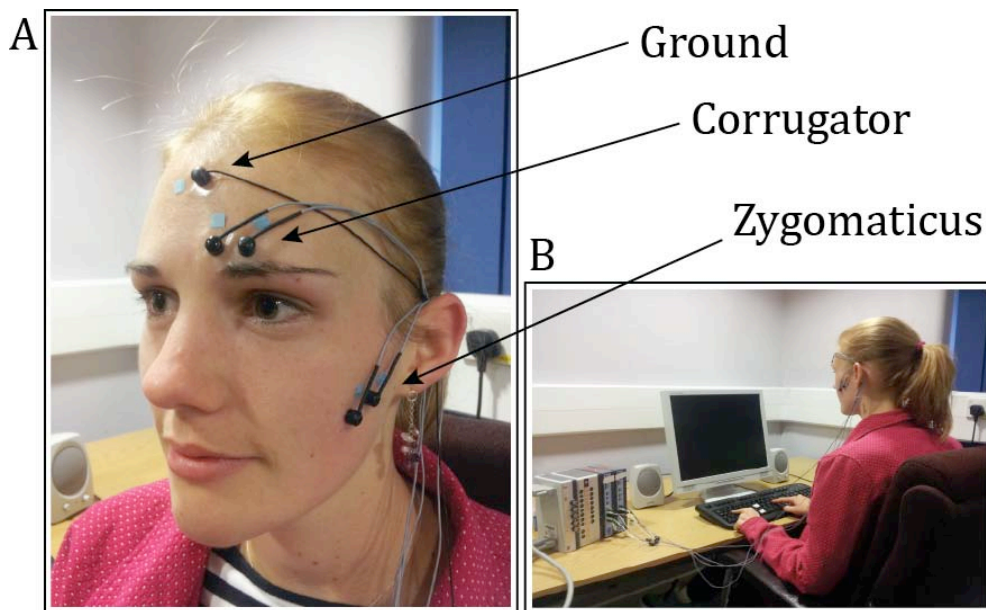


Figure 2.1. (A). Placement of the EMG electrodes over the Zygomaticus and Corrugator muscle sites. (B). Experimental setup for the EMG studies.

The attachment procedure for the EMG electrodes was conducted according to the guidance in Fridlund and Cacioppo (1986). The positioning of the electrodes, including the ground electrode can be seen in Figure 2.1 Panel A. The skin at these sites was first cleaned in order to reduce the impedance of the current between the skin and the electrodes. This was achieved by first removing any make-up, dirt or skin oils with a facial cleanser and cotton wool, then abrading the skin to remove dead cells using a

Chapter 2

kitchen scouring pad, and finally wiping the site with an alcohol swab. A small amount of conductive electrode gel was then worked into the skin using a cotton bud.

Immediately after this, the five facial EMG electrodes were adhered to the skin sites using double-sided sticky cuffs. During the experiment the experimenter insured that the participant was always comfortable and made sure they had regular breaks between tasks, but remained hidden from them during task completion.

The EMG data were recorded using a BioPac MP100 system, with two channels of EMG100C amplifiers. As recommended as best practice for facial EMG (Fridlund and Cacioppo, 1986; Van Boxtel, 2010), 4mm silver chloride electrodes were used. The BioPac system used a bi-polar electrode arrangement, with two 4mm electrodes over each muscle site, and a fifth ground electrode placed just below the hairline at the centre of the forehead. The bi-polar method collects the difference signal between the two electrodes, with a 'common-mode rejection' technique effectively removing electrical noise that is shared between each of the site electrodes, and the site electrodes and ground electrode (Fridlund & Cacioppo, 1986). The electrodes fed directly into the EMG100C amplifiers, which were set to add a gain increase of 5000x, and a sampling rate of 2000Hz. After online filtering, the signal was digitised by the MP100 unit, and sent via USB to the data collection computer. All experiments in this thesis were presented using the EPrime package (Schneider, Eschman & Zuccolotto, 2002). During the collection of EMG, the EPrime program was set to send numerical markers denoting the onset and offset of all trial events, to the MP100 unit, via a parallel output. These marker values, along with the EMG data itself were recorded on the data collection computer and displayed visually whilst the participant completed the task in hand, before being saved as a tab delimited text file by the experimenter.

Chapter 2

The EMG signal can vary in frequency from a few Hz, to 500Hz or more (Tassinary, et al., 2007), with the informative range of frequencies for the zygomaticus and corrugator muscles being in the range of 20-400 Hz (Van Boxtel, 2001). Various forms of high and low frequency noise can mask the EMG, including low frequency artefacts like eye and tongue movements, and higher frequency artefacts, most notably the 50Hz mains electrical current. Due to the constraints built into the BioPac hardware filtering system, the data were continuously online filtered with a 1Hz high pass filter, and a 5000Hz low pass filter, during data collection. A 50Hz notch filter was also applied. Once the data had been collected, they were then filtered offline with a 20-400Hz bandpass filter, and smoothed with an integration window of 20ms. The data were then rectified (to allow for meaningful summation), and log transformed to reduce the impact of extreme data points, before all data were standardized within participant and muscle site, to allow for valid comparisons to be made (Van Boxtel, 2010). Finally data from each trial phase were binned into 100ms epochs, using the arithmetic mean of the data contained within each epoch. These 100ms epochs were used for plotting time-course graphs of the data. For statistical analysis they were averaged within trial periods. For example a 2000ms presentation of a face would be the average of 20 100ms bins.

During the course of an experiment, it is possible for large changes in the baseline level of EMG activity to occur, for example because a participant becomes more fatigued, tense or concentrates less/more (Tassinary et al., 2007). For this reason, all EMG amplitudes were calculated as a change score from a baseline period, on a trial-to-trial basis. This then accounts for any increase or decrease in the 'non-experimental' levels of EMG over time. This procedure was carried out by first calculating the

arithmetic mean of the last 500ms of data from the fixation period of each trial. This baseline was then subtracted from the epochs representing the rest of the trial, when the stimulus was presented, thus creating a time-course of standard changescores for each trial. This signal then represented the dependent variable used in the EMG experiments. Trials in all EMG experiments ended with a 5000 ms relaxation screen, to allow the EMG signal to return to baseline levels.

Participant Selection

All the facial EMG experiments in this thesis used samples made up exclusively of female participants. Past research has indicated that women are more responsive in their physiological reactions to emotional and facial expression stimuli, including EMG responses (Bradley, Codispoti, Sabatinelli & Lang, 2001; Dimberg & Lundquist, 1990; Sonnby-Borgstrom, Jonsson & Svensson, 2008), than men are. Greater facial mimicry effects have also been shown in participants who have lower levels of testosterone (Hermans, Putman & van Honk, 2006), and higher levels of empathy (Sonnby-Borgstrom, 2002), a trait more associated with women (Baron-Cohen, 2002). To provide the best chance of finding facial EMG effects in our experiments, we therefore tested samples that only included female participants.

Lateralised EMG effects

The EMG equipment available allowed us to record from one side of the face only, and as past research has hinted at larger mimetic responses from the left hand side of the face (Dimberg & Petterson, 2000), this side was chosen for our EMG recording sites.

2.2.2 Methods

Participants

Twelve students from the University of Bangor, Wales (mean age = 23.7, SD = 8.3) took part in the experiment in exchange for course credit. All participants gave informed consent, and had normal or corrected to normal vision.

Apparatus

The following equipment was used in all the experiments in this thesis to present stimuli, and the facial stimuli were presented at the same sizes in all experiments. Stimuli were presented on a 19" monitor (Iiyama Vision Master) using the EPrime package. A standard QWERTY keyboard was used to collect responses. Participants sat approximately 500mm from the screen and the faces were presented at a size of 185 * 276 mm

Stimuli

Colour photographs of 7 male and 7 female actors directly gazing towards the participant displaying smiles and frowns were used as stimuli. These images were taken from the NimStim (Tottenham et al., 2009) and KDEF (Lundqvist, Flykt & Ohman, 1998) face sets. The photographs were headshots of actors who had been trained to pose particular facial expressions.

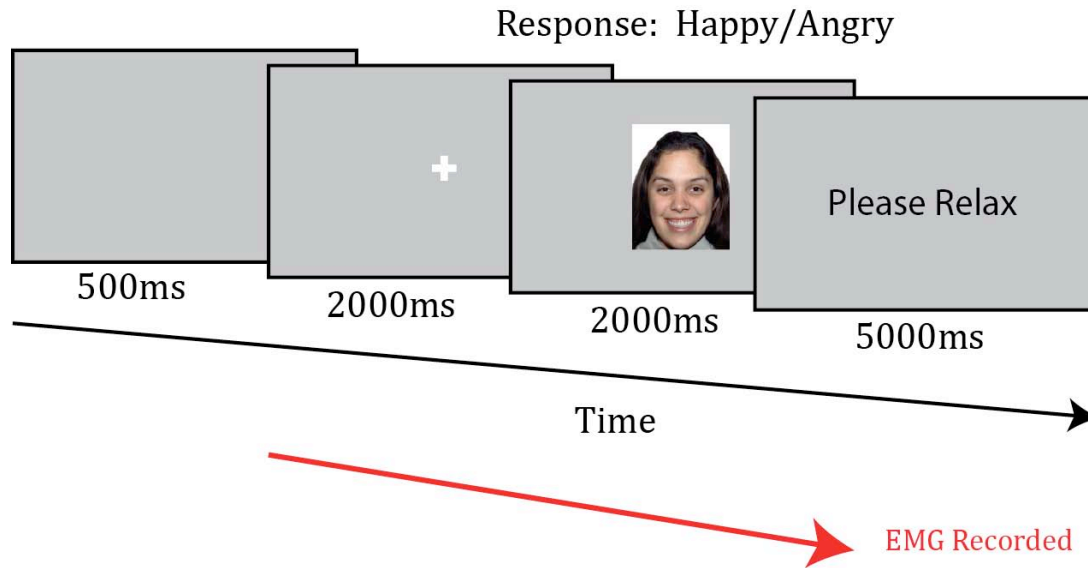


Figure 2.2. Trial diagram for Experiment 1.

Procedure

The trial procedure can be seen in Figure 2.2.

Participants initiated each trial by pressing the space bar. A blank screen lasting 500 ms was then replaced by a centrally located fixation cross that remained on screen for 2000 ms. This was then replaced by the presentation of a centrally located face, which remained on-screen for 2000 ms. Participants were instructed to categorise the emotion on the face, by pressing the 'A' key in response to happy faces and the 'L' key in response to angry faces (Response keys were counterbalanced across participants). Responding did not clear the stimuli, so the participants viewed each face for the full 2000ms. After the presentation of the face, a final screen, duration 5000ms, instructed the participants to relax.

The task was divided into two blocks, each containing 56 trials. During each block participants saw each face appear four times, displaying each emotion twice. The

faces were presented in a random order. Between the two blocks participants were given several minutes rest while the EMG data were saved.

EMG Data Acquisition

This was as described in 2.2.1 EMG Techniques.

Trial Exclusions

The first trial of each block, all error trials and trials immediately post errors were excluded. This was a decision based on previous research carried out in the lab by Cannon et al. (2009, 2010), who found that participants often showed artefacts in their muscle activity when starting trials after a break and during and after making errors. The EMG data were then plotted so that the time-course of every trial was represented by a separate line and the trials could be compared by eye against one another. On visual inspection, trials were removed if the baseline activity was unusually higher than the average across all trials, or if the EMG activity was large enough to suggest a gross movement of the face such as a yawn cough or twitch (as per Kret, Stekelenburg, Roelofs & de Gelder, 2013). The data were plotted as a function of trial number and the experimenter at this stage was blind to condition, so no biasing could occur. Various machinated means of removing these artefacts were attempted with algorithms based on the means and SDs of the baseline periods, whole trial periods, or whole task averages, but none were as effective at removing all artefacts, and were either too harsh or too conservative. This method of trial removal was implemented for all the EMG experiments in this thesis, and the result in this study was the removal of 21.5% of

trials. This may appear to be a large level of exclusion, but it probably reflects the covert nature of the EMG measurements (Cannon et al., 2009).

2.2.3 Results

The data are plotted in Figure 2.3. Zygomaticus data are plotted in Panel A, and corrugator data in Panel B.

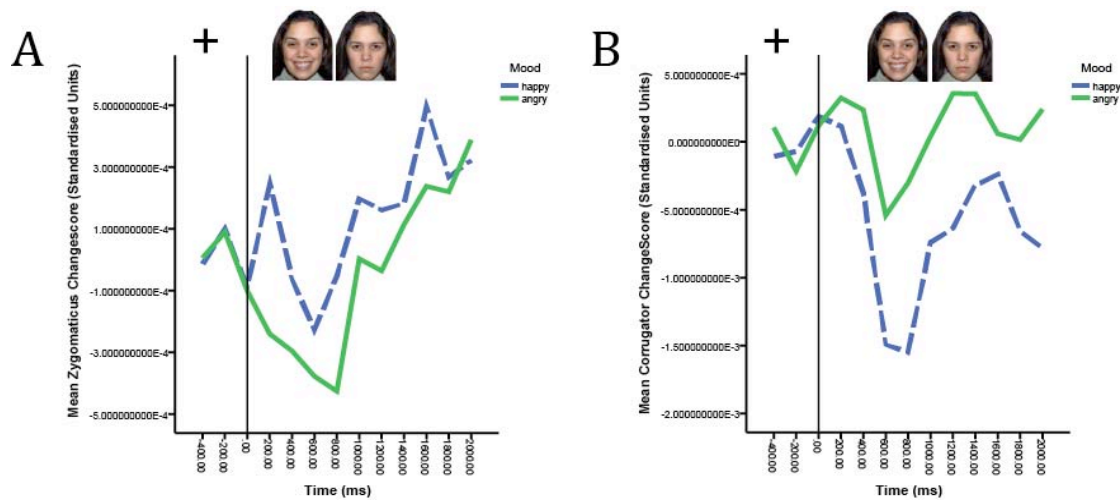


Figure 2.3. (A). Zygomaticus EMG responses in Experiment 1. (B). Corrugator EMG responses in Experiment 1.

The EMG data were entered into a within subjects ANOVA, with muscle (zygo/corr), mood (happy/angry), and block (1/2) as factors. There were no significant main effects (p values $> .25$), but the predicted facial mimicry effect was evident in the two way interaction of muscle and mood, $F(1,11) = 5.09$, $p = .045$, $\eta^2_p = .316$. Responses in the zygomaticus were greater to happy than angry faces, with the opposite response true of the corrugator. There was no three way interaction between muscle, mood and block, suggesting that mimicry did not change over the course of the experiment.

2.2.4 Conclusions

The purpose of Experiment 1 was to replicate the facial mimicry effect reported in the previous literature on facial embodiment of other people's expressions. This was largely an exercise in ensuring that the equipment we were using to record these responses operated properly, and in making sure that a task that was more active than most used in prior research, still allowed for accurate recording of facial mimicry. The two way interaction between muscle site and mood indicated that participants were indeed mimicking the emotions of the faces they were viewing on screen.

2.3 Experiments 2 and 3: Reactivation of facial mimicry and the effects of multiple exposures and task relevance

Facial mimicry and rapid facial reactions in general, have been studied under a number of conditions. Rapid facial reactions to emotional expressions and body language have been shown to occur even if stimuli are presented to the cortically blind field of neglect patients (Tamietto et al., 2009). Masked images of a negative valence will elicit rapid activations of the corrugator muscle even if they are sub-perceptual in nature (Codispoti et al., 2009). And certain stimuli that are believed to be innately threatening to humans (LoBue & DeLoache, 2008), such as snakes, cause rapid and automatic facial responses that perhaps cannot be overridden, similar to those evoked by viewing emotional faces (i.e Dimberg et al., 1998; Dimberg & Karlsson, 1997). It will be argued in this thesis that the obligatory embodiment of another person's actions, such as mimicry of their emotions, represents another person's inner state. Such

Chapter 2

embodiment has the potential to guide our behaviour towards the people we observe. One aspect of the obligatory nature facial mimicry that has not been properly researched is how it develops over time. Most studies of facial mimicry effects use relatively few exposures to a small number of faces.

For example, using simultaneous EMG and EEG recordings (Archaibou, Pourtois, Schwartz & Vuilleumier, 2008), presented participants with 250 trials, over the course of five blocks, of which half involved the presentation of smiling faces, and half the presentation of frowning faces. Participants showed facial mimicry in the corrugator and zygomaticus, and the authors claimed that this showed stability over the course of the task, but did not include block as a factor in their analysis, which raises questions about how they drew their conclusion. If facial mimicry is an automatic embodiment of another person's facial action, rather than, or as well as being an obligatory orienting response to generally arousing stimuli, it should occur even over many exposures. So facial mimicry effects would not be expected to interact with how many times participants have been exposed to the same facial identities smiling or frowning. If however facial mimicry effects are not automatic, and instead just an artefact of feelings of positive or negative affect induced by viewing pleasant or unpleasant looking people, the effect would habituate with multiple exposures. That is, the effect might decline as participants learned over multiple exposures that there were no consequences attached to the emotional expressions.

One reason that embodiment of other people's actions is thought to be an obligatory process is that it still occurs even when attention isn't being paid to the action relevant aspect of a person's appearance. Simulation of the action potentials of objects and simulation of other people's actions have been shown to differ, because

Chapter 2

attending to an action irrelevant aspect of a person does not reduce embodiment in the way it does for objects (see Tipper, 2010). If facial mimicry is an embodiment of another person's facial expression, it should be sustained even if the expression is not relevant to the task the participant is completing. This was investigated by Cannon, Hayes & Tipper (2009), who found that facial mimicry of smiles and frowns occurred even if participants attended to the colour of a translucent mask placed over the face, just as it did when they attended to the emotional expression. This indicates that as with the embodiment of other people's more gross actions, facial mimicry can survive attention being drawn to non-action related aspects of the face. However, it is not known if this would affect any later effects of encoded facial mimicry, were they to be later reinstated.

This question of reinstatement or reactivation of facial mimicry is central to experiments 2 and 3, where participants were exposed multiple times to faces that either showed smiling, frowning or neutral expressions, over the course of four blocks. Each identity either consistently smiled or frowned, as well as appearing with a neutral expression, and this consistency was important because we predicted that as hypothesised by theories of embodied memory (Barsalou, 1999; Buckner & Wheeler, 2001; Niedenthal, 2007), once participants had had sufficient exposure to the emotional versions of the faces, their embodiments should be reactivated when they saw the neutral versions.

Experiment two therefore contained two analysis of interest. The first, of the EMG responses to the emotional faces set out to investigate whether facial mimicry effects were indeed stable over multiple exposures. Also, could we replicated the findings of Cannon et al., (2009), showing that facial mimicry was not affected by the

Chapter 2

task relevance of the emotional expression. To this end, participants in experiments 2 and 3 completed identical tasks, except that participants in Experiment 2 had to identify the emotions they saw, and participants in Experiment 3 had to identify the sex of the faces they saw. The main analysis of interest though was of the EMG responses to the neutral versions of the faces, where it was predicted that facial mimicry like responses should be reactivated, with participants showing more zygomaticus activity to faces that also appeared smiling than to those who also appeared frowning, with the opposite true for the corrugator responses. This activation might be expected to develop over the course of multiple exposures, as proposed by theories of contingency learning (Rescorla & Wagner, 1972; De Houwer, 2009). Based in the work of Cannon et al., (2009), and the theoretical automaticity of embodied processes, it was predicted that this retrieval effect would occur regardless of the attention condition the participants were allocated to.

2.3.1 Methods

Participants

Participants were 36 female undergraduate students, recruited from the University of Bangor, Wales (mean age = 21.8, SD = 2.5). All participants had normal or corrected to normal vision, and gave informed consent.

Stimuli

From the photographs used in Experiment 1, six male and six female identities were chosen. These formed six pairs, matched for sex and attractiveness. The same images of each identity smiling and frowning were used, as in Experiment 1, but also images of each identity with a neutral expression, forming a stimulus set of 36 images.

Importantly, in this experiment as well as appearing with a neutral expression, each face appeared either smiling (happy), or frowning (angry). So for each participant one of the faces in each face pair appeared smiling and neutral, and the other frowning and neutral. This allocation was quasi-randomised across participant.

Procedure

Experiments 2 and 3 consisted of three tasks: (a) familiarisation task, where participants were exposed to the identities and their contingent emotions, (b) exposure task, where the participants attended to either the expressions of the sexes of the faces whilst the faces appeared with expressions and neutrally (c) recall task, where the participants were tested for their ability to remember the pairings of identity and expression. The three tasks were always run in this order. The familiarisation and recall tasks were identical across both experiments. The trial procedure of the exposure task was also identical, apart from the responses made by the participants. In Experiment 2 participants had to attend to and categorise the emotion shown by the face in each trial. In order to make the emotion task irrelevant in Experiment 3, the participants attend to and categorised the sex of the face instead, and were told they could ignore its expression.

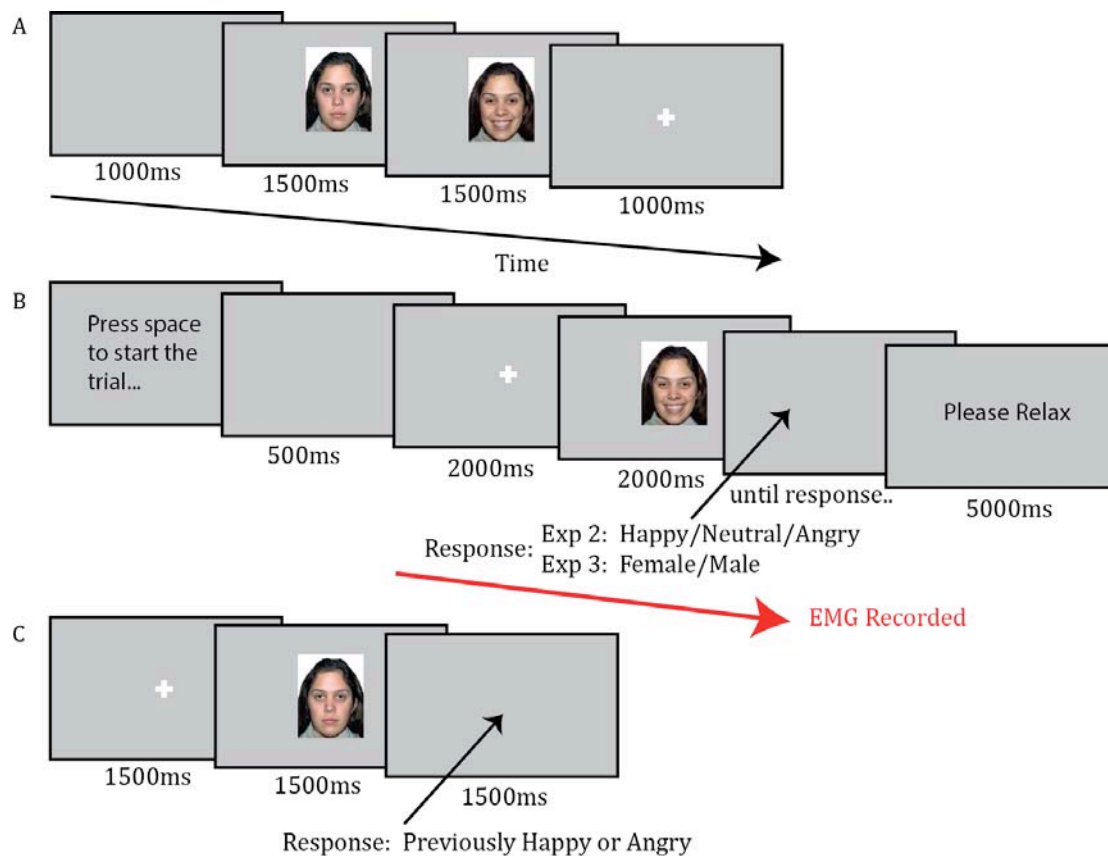


Figure 2.4. (A). Trial diagram for the familiarisation task where participants are exposed to the identities and their emotions. (B). Trial diagram for the exposure task where participant’s EMG activity is measured while they view emotional and neutral versions of the identities. (C). Trial diagram for the recall task where participants were asked to remember which emotion was shown by each identity.

Familiarisation Task. In the familiarisation task participants watched a short on-screen presentation of the faces they would see in the main tasks. The presentation showed each of the 12 identities, appearing with a neutral expression, before switching to their designated emotional expression (see Figure 2.4 Panel A). A centrally located fixation cross appeared on-screen for 1000 ms between the presentation of each identity. Each presentation consisted of the neutral version of the face appearing centrally for 1500 ms, followed immediately by the emotional version of the face, which

Chapter 2

remained on screen for 1500 ms. The order in which the identities appeared was randomised for each participant and each identity appeared only once. Participants were instructed simply to watch the faces. The intention of this phase was to boost the participant's memory for the emotions associated with each identity.

Exposure Task. The design of the exposure task can be seen in Figure 2.4 Panel B. This task exposed the participants to the emotional and neutral versions of the faces, whilst their EMG activity was measured. The procedure of the exposure task was identical across experiments 2 and 3. However, in order to manipulate the aspect of the face that the participants attended to, the response the participants had to make differed, with participants in Experiment 2 categorising the emotion each face showed on every trial, and participants in Experiment 3 categorising the sex of each face on each trial. Every trial was initiated by the participant, with a space bar press. A blank screen lasting 500 ms was replaced by a fixation cross lasting 2000 ms. This was followed by the appearance of a face, either emotional or neutral, which remained on screen for 2000 ms. The participants were instructed to wait until the face disappeared before making their response. This was to ensure that the faces remained on screen long enough for EMG responses to occur, and to ensure these responses were not masked by activity related to making a key press. The response screen, which was a blank screen, cleared after the participant made their keypress, and was replaced by the 5000 ms relax screen.

Participants in Experiment 3 used the numeric keys 1, 2 and 3 to indicate if the face that had just appeared had been happy, neutral or angry, respectively.

Participants in Experiment 4 used the numeric keys 1 and 3 to indicate if the face had

been female or male. An error sound played prior to the relax screen if participants made an incorrect response. Participants were asked to be as accurate as possible, rather than as quick as possible.

The exposure task consisted of five blocks, in which each face appeared twice, once with its allocated expression, and once with a neutral expression. This meant a total of 120 trials overall. The order of presentation was randomised within block. Between each block participants rested for approximately two minutes, whilst their EMG data were saved to disk.

Recall Task. In the final recall task the participants tried to remember whether each face had appeared in the previous exposure task with a happy or angry expression. On each trial (see Figure 2.4 Panel c), a central fixation cross lasting 1500 ms was replaced by one of the identities, with its neutral expression, which remained on screen for 1500 ms. This was followed by a blank screen also lasting 1500 ms. Participant used the 1 key to indicate a face had previously appeared with a happy expression or the 3 key if it had appeared with an angry expression. Responses could be made either when the face was on screen or during the blank screen after, or participants were asked to be as accurate as possible but to guess if necessary. Each face appeared once, making a total of 12 trials. No error sound was used. Participants did not know at the outset of the experiment that the final task would be a recall task and were instead told the task would be an attention task involving faces.

EMG Data Acquisition

This was as described in 2.2.1 EMG Techniques.

Trial Exclusions

Trial exclusions for the data from the exposure task were carried out using the same criteria as in Experiment 1. In all 18.85% of trials were removed across Experiments 2 and 3.

2.3.2 Results

Behavioural Analysis

Accuracy rates for the exposure and recall tasks were calculated for both experiments. In Experiment 2, where participants categorised the emotion displayed on each face during the exposure task, accuracy was at 98 % (SD = 1.7%). During the recall task, participants correctly remembered the emotion associated with each identity on 90% (SD = 9.2%) of trials. In Experiment 3, where the participants responded in the exposure task by categorising the sex of the faces, their responses were accurate on 99% (SD = .07%) of trials, and they successfully remembered the identity-emotion associations during the recall task for 89% (SD=15.3%) of the identities. Across both experiments the accuracy rates suggested that participants attended to the stimuli during exposure, and had a good explicit memory for the pairings of identity and emotion by the end of the task even when emotion was irrelevant to their task.

EMG Analysis

Two analyses of the EMG data from the exposure task were conducted. The first was conducted on the data from trials where participants had been viewing emotional faces. This analysis looked for facial mimicry effects, with the prediction that participants would show more zygomaticus activity in response to happy than angry faces, with the reverse true of corrugator activity. Block and experiment were included as factors in this analysis, in order to ascertain what effect multiple exposures to the faces, and the task relevance of the emotion being displayed, would have on facial mimicry.

The second analysis, which was critical to the main research question, was conducted on the EMG data from trials where the participants were viewing neutral faces. The first prediction for this analysis was that participants would show more zygomaticus activity when viewing neutral faces of identities that also appeared happy, than they would show when viewing neutral faces of identities that also appeared angry. The corrugator activity was predicted to show the opposite pattern. This would provide evidence of the facial mimicry effect being reactivated. Because learning was expected to modulate this reactivation, block was also included as a factor in the analysis. Experiment was included as a between subjects factor to probe any differences in reactivation between participants who had been attending to the emotions displayed, and those for whom the emotions were task irrelevant.

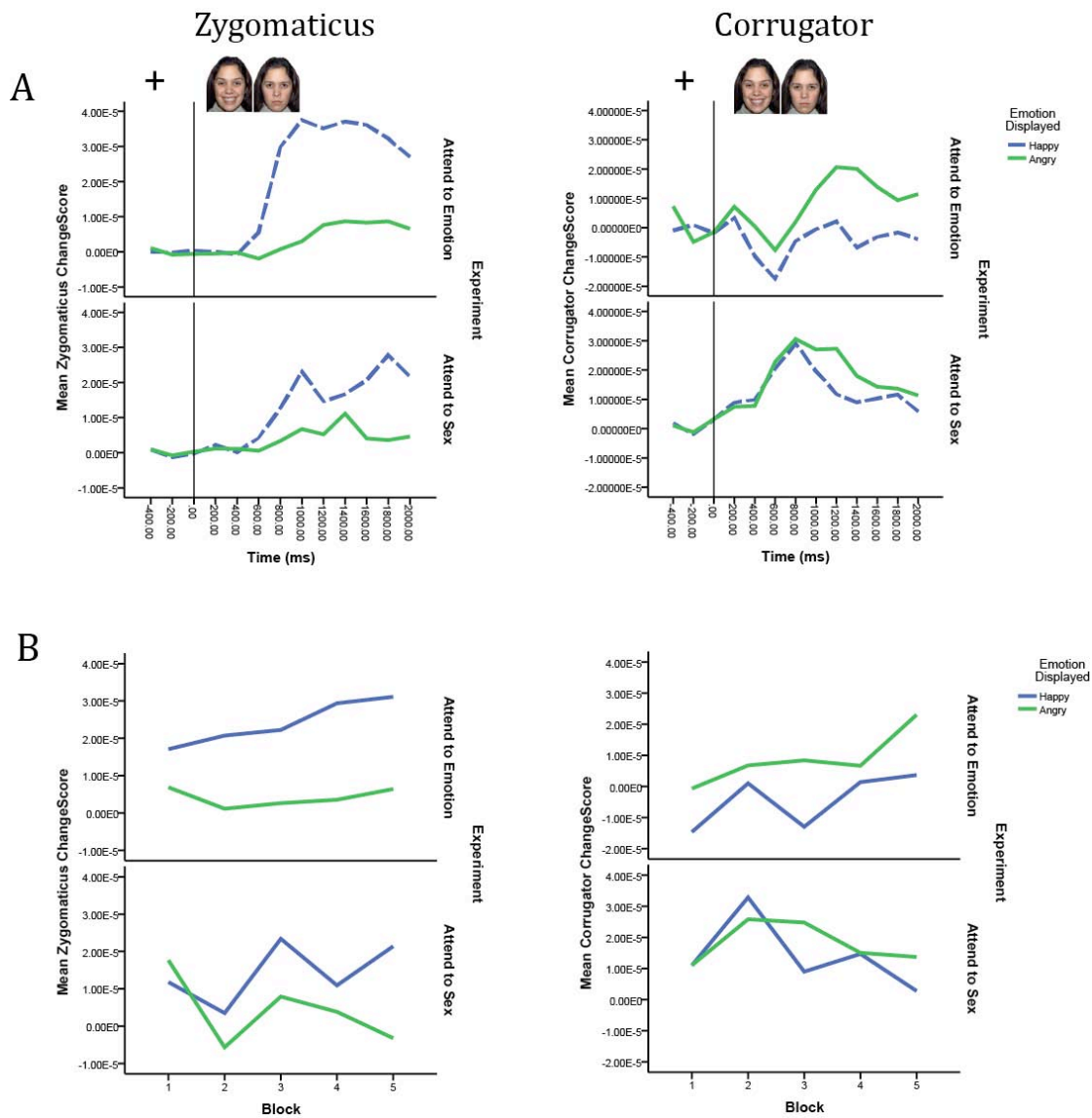


Figure 2.5. (A). Timecourse of EMG activity averaged across trials where participants viewed happy and angry faces during the exposure task. (B). EMG activity to happy and angry faces during the exposure task, across blocks.

Facial Mimicry. Data from emotional face trials were entered into a mixed model ANOVA with the within subjects factors muscle (zygo/corr), mood (happy/angry) and block (1, 2, 3, 4, 5), and the between subjects factor experiment (attend to emotion/attend to sex). The analysis revealed no main effects, but it replicated the interaction between muscle and mood that was significant at the one-

Chapter 2

tailed level, $F(1,34) = 3.85, p = .058, \eta^2_p = .102$. As predicted, the participants EMG reflected higher levels of zygomaticus activity in response to faces that appeared smiling, than to faces that appeared frowning, with the opposite true of the corrugator (see Figure 2.5 Panel A). This interaction was followed up with post-hoc t-tests, which revealed a significant difference in activation in the zygomaticus, $t(35)=2.06, p = .024$, and a difference in activation in the corrugator that was significant at the one-tailed level, $t(35)=1.68, p = .051$. These results suggested that the participants did indeed show facial mimicry.

The three way interaction between muscle, mood and experiment was non-significant, $F(1,34) = .54, p = .469, \eta^2_p = .016$, as was the four way interaction between muscle, mood, block and experiment, $F(4,136) = .350, p = .844, \eta^2_p = .010$. Therefore, regardless of whether the participants attended to the emotion displayed by the faces, or that emotion was task irrelevant and they attended to the sex of the faces, they showed facial mimicry effects, replicating the findings of Cannon et al., (2009) who showed these effects occurred without the need for the explicit allocation of attention to the emotion being displayed. Although it should be noted that there is a trend for the effects to be somewhat smaller when emotion is ignored.

The three way interaction of muscle, mood and block was significant, $F(4,136) = 3.91, p = .005, \eta^2_p = .103$, indicating that levels of facial mimicry may have varied across the multiple exposures the participants had to each face. To further investigate this interaction, the activity of each muscle was analysed in a separate mixed models ANOVA, with the within subjects factors of mood (happy/angry) and block (1, 2, 3, 4, 5), and the between subjects factor of experiment (attend to emotion/attend to sex). The means for this analysis can be seen in Figure 2.5 Panel B. The analysis of the

Chapter 2

zygomaticus activity revealed a significant main effect of mood, $F(1,34) = 4.26, p = .047, \eta^2_p = .111$, but no significant interactions with block or experiment, indicating that facial mimicry of smiles was stable across multiple exposures. The analysis of the corrugator activity revealed that whilst the main effect of mood did not reach significance, $F(1,34) = 2.67, p = .111, \eta^2_p = .073$, there was a main effect of block, $F(4,136) = 2.50, p = .046, \eta^2_p = .068$, and an interaction between mood and block, $F(4,136) = 2.50, p = .045, \eta^2_p = .069$. There was no interaction between mood, block and experiment. T-tests were calculated for the difference in corrugator activity to happy and angry faces at each level of block, and these revealed that corrugator activity was only significantly greater for angry than happy faces during blocks three, $t(35) = 2.92, p = .003$, and five, $t(35) = 2.16, p = .019$ (blocks one, two and four, $p > .15$). To compare this to the activity in the zygomaticus, similar contrasts were run which revealed significantly greater zygomaticus activity to happy faces during all blocks ($p < .035$), except for block one ($p = .33$). Therefore whilst mimicry in the zygomaticus demonstrated relative stability over multiple exposures, corrugator mimicry was less stable, not declining over time, but varying in strength. The somewhat weaker effects in corrugator are observed again in Chapter 3 during recall.

Reactivation of Facial Mimicry. The first analysis revealed that participants in both experimental groups showed facial mimicry effects, but that these were more consistent in the zygomaticus than the corrugator. To examine whether these responses were reactivated during trials where the neutral versions of the faces appeared, the EMG data from these trials were entered into a mixed models ANOVA, with the within subjects factors of muscle (zygo/corr), mood (happy/angry) and block

Chapter 2

(1, 2, 3, 4, 5), and the between subjects factor of experiment (attend to emotion/attend to sex).

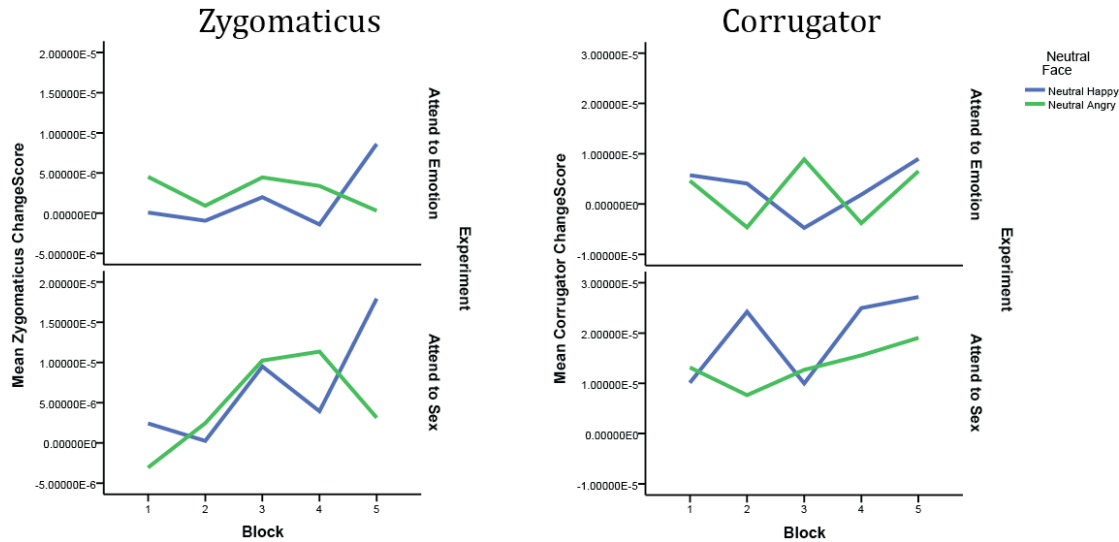


Figure 2.6. EMG activity across block during the exposure task, when participants were viewing neutral faces.

The analysis revealed a marginal main effect of muscle, with greater activity in the corrugator than the zygomaticus, in response to neutral faces, $F(1,34) = 3.77, p = .061, \eta^2_p = .100$. A three way interaction between muscle, mood and block reached significance, $F(4,136) = 3.28, p = .013, \eta^2_p = .088$, but as reflected in the means plotted in Figure 2.6, this did not reflect the expected reactivation of mimicry in either muscle. Instead the pattern of activity resembled a rebound or contrast effect. In three of the four later blocks, during which learning was expected to influence EMG responses, activity in both the zygomaticus and corrugator was in the opposite direction to the mimicry effects. This interaction did not differ between experiments ($p = .734$). The only other interaction to near significance in the main analysis was that of mood and block, $F(4,136) = 2.08, p = .086, \eta^2_p = .058$, and contrasts revealed this reflected the

Chapter 2

combined response in block five of both muscles showing greater activation in response to neutral faces that had also appeared happy, $F(1,34) = 4.36, p = .044, \eta^2_p = .114$.

To further explore the apparent rebound effect, two separate mixed model ANOVAs were run on the data from the zygomaticus and corrugator muscles. Each analysis contained the within subjects factors mood (happy/angry) and block (1, 2, 3, 4, 5), and the between subjects factor experiment (attend to emotion/attend to sex). The analysis of the zygomaticus revealed no significant main effects, but one interaction, between mood and block, which only reached significance at a one-tailed level, $F(4,136) = 2.19, p = .073, \eta^2_p = .061$. Although the interaction was non-significant, the data were explored with t-tests, which revealed that only in block five was zygomaticus activity significantly greater in response to neutral faces of one mood condition than the other, $t(35) = 2.12, p = .021$, where the zygomaticus was more active to neutral faces that had also appeared happy, than to those who had also appeared angry. In all other blocks, the zygomaticus showed no significant distinction between the faces (p 's > .12). The analysis of the corrugator revealed a significant main effect of mood at the one-tailed level, $F(1,34) = 3.32, p = .077, \eta^2_p = .089$, reflecting greater activity in response to faces that also appeared happy, than to those that also appeared angry. The only significant interaction was between mood and block, $F(4,136) = 2.70, p = .033, \eta^2_p = .074$, and again this interaction was explored with t-tests. These revealed no significant differences in activation in blocks one and four (p 's > .12), but differences that reached or trended towards significance in blocks two, $t(35) = 2.189, p = .004$, and five, $t(35) = 1.60, p = .06$, where the muscle activity reflected a rebound effect, and block three, $t(35) = 1.63, p = .056$, where the opposite was true and the corrugator was more active in response to

neutral faces that had previously appeared angry than to those that had previously appeared happy.

Analysis by Mimickers and Non-Mimickers

According to embodied theories of cognition, memory involves the reactivation of sensory and motor states experienced during earlier encounters with a stimulus. For this reason it is logical that any reactivation of muscle activity during exposure to neutral versions of the faces could only occur if the participant's muscles had been active during exposure to the emotional versions of the faces, i.e no retrieval of mimicry would occur without mimicry first occurring in response to the emotional faces. For this reason a second analysis of the neutral face data was conducted, but participants in this analysis, which was conducted separately for each muscle site, were divided into 'mimickers' and 'non-mimickers', with mimickers having shown the expected pattern of activity for that particular muscle and non-mimickers having not.

Two mixed models ANOVAs were conducted, one on the data from the zygomaticus and one on the data from the corrugator. Each analysis included Mood (also appeared happy / also appeared angry) and Block (1,2,3,4,5) as within-subjects factors, and mimicry group (mimicked with zygomaticus / did not mimic with zygomaticus) for the analysis of the zygomaticus data and (mimicked with corrugator / did not mimic with corrugator) for the analysis of the corrugator data. The analysis of the zygomaticus data revealed no significant main effects or interactions. The analysis of the corrugator data revealed only the previously reported interaction of mood and block.

2.3.3 Conclusions

Facial Mimicry

Participants in experiments 2 and 3 showed patterns of facial EMG that suggested a consistent level of facial mimicry. Although the main interaction between muscle and mood did not reach significance, the sub analyses of the separate muscles showed that the participants mimicked smiles with their zygomaticus consistently across both experimental conditions and during multiple exposures to the faces across blocks two to five. Activity in the corrugator was more influenced by block, with significant mimicry effects only occurring in blocks three and five, but again the participant's mimicry of frowning expressions was not influenced by the experimental condition.

Reactivation of Facial Mimicry

The EMG data from the trials where participants viewed neutral versions of the faces reflected a rebound effect, rather than the predicted reactivation of the facial mimicry elicited by the emotional versions of the faces. That is, when participants viewed neutral faces who also smiled, they showed greater corrugator and weaker zygomaticus activity, than when they viewed faces that also frowned, where the opposite was true.

Further analysis of this data by separating the muscle sites did not reveal any consistently significant effects.

2.4 Discussion

The experiments in Chapter 2 aimed to replicate the facial mimicry effect found in previous studies of facial embodiment of other people's emotional expressions (Cannon et al., 2009; Dimberg, 1982; Dimberg & Thunberg, 1998; Dimberg et al., 2000; Hess & Blairy, 2001; Hess et al., 1998). Experiment 1 was successful in eliciting facial mimicry, whilst using an active task where participants responded to the faces by pressing keys to categorise their expressions as happy and angry, rather than a passive viewing task as used in much of the prior literature on facial mimicry.

Experiments 2 and 3 aimed to replicate the facial mimicry shown in Experiment 1, but over a longer task where participants received multiple exposures to the emotional faces over five blocks. The two experiments differed in one key regard, whether the participants attended to the emotions displayed by the faces, or their sex, the latter task making the face emotion irrelevant. Our aim was to investigate the obligatory nature of the facial mimicry effect. If facial mimicry is a form of obligatory embodiment, it would be expected to occur every time an emotional face appeared, even if that face had appeared with the same expression on multiple occasions, with no consequences. It would also be expected, as found by Cannon et al., (2009) to occur even if participants did not pay explicit attention to the emotional action on screen, i.e the facial expression itself. Most importantly though, experiments 2 and 3 included trials where the same faces appeared with neutral expressions, and when the faces appeared with emotional expressions these were consistent across the task. On neutral trials, we predicted that the participants would reactivate their simulation of the expression each face showed when it appeared with an emotional expression. So for example, if a face appeared angry and neutrally, as the task progressed, the participant's

Chapter 2

corrugator muscle would become more active for that face when it appeared with a neutral expression, than for a face that appeared with a neutral expression and also appeared happy. This would be the reactivation of facial mimicry that would be predicted by models of embodied memory.

The patterns of EMG activity recorded in experiments 2 and 3 demonstrated that the participants showed facial mimicry. In the zygomaticus muscle, this mimicry was consistent across both multiple exposures over block, and between experiments, suggesting an automaticity in the way that viewing someone else's facial expression causes an embodiment of their emotional state with one of our own muscles associated with positive mood states. The activity of the corrugator was also suggestive of facial mimicry, although this was not as consistent over time.

Studies that have examined EMG responses to the expressions of out-group members (Bourgeois & Hess, 2007), and competitors (Weyers et al., 2006) have shown that activity in the zygomaticus in response to smiles occurs even when the face being viewed is someone who's internal state we would not expect to align with. For example, during competition seeing an opponent smile probably means something negative for us, hence we would not want to resonate with their positive mood state. Activity in the corrugator on the other hand is modulated by the social context between the observer and the person being viewed. Bourgeois and Hess (2007) suggest that as smiles are affiliative, whereas frowns are aggressive, it may be the case that muscle activations of the zygomaticus are less likely to be inhibited in case they should be noticed, because their potential social 'cost' is less.

Facial mimicry is thought to be just one possible tool used in understanding other's emotional states (Hess, Philippot & Blairy, 1998; Niedenthal et al., 2010), and it

Chapter 2

may not always be necessary to simulate another person's expression, or if that simulation does automatically occur, it may be the case that inhibition or interference from other factors reduces the extent to which it can be measured. Our data could indicate that in the zygomaticus, mimicry occurred consistently over time and regardless of what aspect of the face was being attended to, because zygomaticus activation brings the participant into a physical state that is in line with the person they are observing, whilst having low potential cost should it be detected.

However, Corrugator activity is potentially more costly, as it is a negative signal projected towards another person. It is also affected by other factors that might be expected to come into play over an extended task like ours, such as sustained effort in attending to stimuli and changes in mood (Silvestrini & Gendolla, 2009; Van Boxtel & Jessurun, 1993; Waterink & Van Boxtel, 1994), and so when participants view the same faces appearing multiple times with frowns, and no consequences of those frowns occur, it may be the case that corrugator responses are inhibited to a level that is then masked by stimulus independent causes of corrugator activity, such as tonic mood, or effort. Although there was no interaction between experiment and corrugator mimicry, the means (see Figure 2.5) suggest that corrugator mimicry may have been weakened when the participants attended to the sex of the face and not the emotion, during Experiment 3. Cannon et al., (2009) showed a pattern of inhibition of muscle activity in their data when participants had to attend to a colour mask and not the emotion of a face, with greater or lesser levels of inhibition reflecting the facial mimicry effect. They concluded this reflected possible inhibition of the emotional visual input which was in competition with the colour visual input. Association between a face and having to inhibit a physical response has also been shown to devalue the face, causing it to be

Chapter 2

perceived more negatively than a face not associated with inhibition (Doallo et al., 2012). It may therefore be the case that corrugator responses in Experiment 3 were also generally affected either by the need to inhibit the emotional input from the faces, or by an affective by-product of this inhibition. The data suggest that in future studies, we may find greater facial mimicry and more likelihood of reactivation in the zygomaticus muscle.

The data from the neutral face trials did not reveal any reactivation of mimicry effects, or any statistically significant patterns of any sort. The pattern of the data hinted at a rebound effect across both muscles in both blocks, where the muscles actually showed the opposite pattern of activity in response to neutral faces as had been shown in response to the emotions shown by each face. It may be the case that this was caused by an emotional contrast effect. That is, when a face appears smiling for example, and then soon after within the same context it appears neutrally, the neutral version of the face may appear unhappy, in contrast to the smiling face. Such contrasts have been shown to affect EMG responses. Corrugator activation in response to moderately pleasant images for example, was shown to be reduced if the target images were placed in the context of a series of less pleasant images, than if they appeared in the context of more pleasant images (Larsen & Norris, 2009). It may be the case that to our participants, the neutral versions of the faces, which are emotionally ambiguous, were interpreted in contrast to the emotional version, which send a clear emotional signal. Given that EMG responses can be elicited by positive and negative stimuli in general and not just facial expressions (Bradley et al., 2008; Dimberg & Karlsson, 1997; Dimberg et al., 1998), this contrast in the affective valence of the faces could be enough to trigger the EMG rebound effect. Studies that have looked at representational

Chapter 2

momentum in facial expressions have shown that when changes in emotional expression are perceived, their trajectory is forward modelled and continued beyond the final movement of the expression. When participants view a neutral face becoming happy over a rapid succession of frames, they will choose a slightly happier frame than the final frame actually was, when asked afterwards to identify the final expression (Yoshikawa & Sato, 2008). Conversely though, if a face appears expressive at first, and becomes neutral, even if this occurs over the course of only two frames, the final neutral face will appear as slightly emotional in the opposite valence to the original face. So if a happy face becomes neutral, the neutral face is perceived as slightly angry, and visa-versa (Mariam & Shimamura, 2013; Palumbo & Jallema, 2013). These effects have been shown to be dependent on maintenance of identity. That is, they only occur if the identity remains constant and not if one person morphs into another during a trial (Palumbo & Jallema, 2013). It could be the case that our data demonstrate a rebound effect, but as no significant pattern or activity was found, this cannot be commented on further. It was also found that examining the neutral face data in terms of which participants did and did not mimic with each muscle did not reveal any significant differences between these groups in terms of retrieval effects.

In the next set of experiments, this possible contrast or momentum effect will be addressed with a change in paradigm that exerts a contextual shift between the time when the participants encode and simulate the facial expressions, and the time when they are re-exposed to neutral versions of the same faces, which is predicted to elicit reactivation of their prior simulations. Although the experiments in Chapter 2 were not able to provide evidence for these reactivations, they have furthered what is known about facial mimicry as a form of emotional embodiment. Facial mimicry was shown to

Chapter 2

occur regardless of whether the emotions being displayed were task relevant, and facial mimicry of smiles at least, was shown to occur even when participants had been exposed on multiple occasions to the same emotional faces, providing more evidence of its automaticity.

Chapter 3

Dynamic Facial Expression Tasks: Predictive Activation and Retrieval of Facial Mimicry

3.1 Summary

The experiments in Chapter 3 investigated the predictive reactivation and retrieval of facial mimicry effects during later re-encounters with previously emotional faces.

Participants completed two-part EMG tasks, where first of all they were exposed to faces that smiled and frowned consistently. Here they showed facial mimicry effects, and also evidence of predictive mimicry in the zygomaticus. In a second task they viewed the same faces with neutral expressions, and here retrieval effects were shown, again in the zygomaticus.

Boundary effects were found for the retrieval effects. Firstly participants who did not mimic, also did not retrieve mimicry. Second, retrieval was stronger when the task requirements at encoding and retrieval stages were consistent.

3.2 Introduction

The experiments in Chapter 2 provided further insight into the nature of facial mimicry, supporting the notion that whilst facial mimicry effects may have been shown in the past to be modulated by contextual factors or current emotional state (e.g. Bourgeois & Hess, 2008; Moody et al., 2007; Sims et al., 2012), they represent a rapid, spontaneous and seemingly automatic process (e.g. Cannon et al., 2009; Dimberg, Thunberg & Grunedal, 2002; Otte et al., 2011), that could realistically support the simulation of other's emotional

Chapter 3

states. Our data in particular extended the current understanding of facial mimicry effects by demonstrating that even over a large number of exposures to faces who consistently showed the same facial expression, without the participants experiencing any consequences of those expressions, facial mimicry remained stable and was not reduced by habituation. The fact that mimicry occurred both when the expression on the face was relevant to the participant's task, and when it was not, replicates the findings of Cannon et al., (2009), and adds further strength to the first finding of the experiments because habituation might be most likely to occur when the emotion displayed by a face is not only consistent but also irrelevant.

However, the data from trials where participants viewed neutral faces did not support the hypothesis that on these trials reactivation of previous mimicry should occur. In fact the pattern of data was suggestive of a rebound effect although there were no significant interaction effects to support this. It was concluded that this might have been caused by having the neutral versions of the identities embedded amongst the emotional versions, biasing the participant's perceptions of their emotional quality through contrast or representational momentum. The experiments in this chapter were therefore designed to overcome this possible confound by utilising separate encoding and retrieval stages. First of all, participants saw identities that appeared consistently with happy or angry expressions, while they attended either to the emotion on the face, categorising it as happy or angry, or a non-emotional aspect of the face, whether the face remained as the same person, or changed identity. After this task participants took a break of several minutes before completing an entirely new task, where the majority of trials consisted of neutrally expressive versions of the identities they had seen in the first task. Again, their task was to either attend to emotion, by responding to rare appearances of emotional versions of the identities, or to attend to identity again, responding if they saw an entirely new face. We designed the experiments in

Chapter 3

this chapter as a quad, with four separate cohorts of participants completing the four combinations of these tasks, so that each pairing of attending to emotion or identity during encoding and retrieval phases was achieved. Importantly though, participants in all four experiments were exposed to the emotional versions of the faces an equal number of times, during the “exposure task”, and the neutral versions an equal number of times during the “retrieval task”, allowing a joint analysis.

In experiments 2 and 3, static faces were used as stimuli, in line with previous studies on facial mimicry (e.g. Dimberg, 1982, Dimberg, Thunberg & Grunedal, 2002). However, the dynamic aspects of facial expressions are thought to play a key role in an observer’s perception of their meaning (see Krumhuber, Kappas & Manstead, 2013), and dynamic facial expressions have been shown to elicit larger facial mimicry effects (Sato, Fujimura & Suzuki, 2008) than static presentations. Therefore, in experiments 4 to 7, we employed dynamic videos, where during the course of an exposure trial where facial mimicry was expected, a face appeared with a neutral expression, and then smiled or frowned over the course of a short series of incremental frames, before holding the final expression for a second and a half.

The changes made in these experiments allowed us to address several hypotheses. Firstly, the prediction that as in the experiments in Chapter 2, when participants viewed the emotional versions of the identities, they would show facial mimicry, and that this facial mimicry would remain constant over the course of the exposure task, and would occur even if the participants attended to the identity of the faces and not their expressions.

Secondly, the new dynamic expression stimuli allowed the examination of memory effects during the exposure task. Predictive models of action encoding (e.g.

Chapter 3

Kilner et al., 2007; Wolpert et al., 1995; Wolpert et al., 2003), suggest that our own future actions, and the future actions of others are forward modelled, and that this forward modelling involves the simulation of the future states of an action once it has begun. Interestingly, because the faces in the exposure task always begin a trial with a neutral expression, before smiling or frowning, this allows for the prediction that forward modelling might actually occur *before* this facial action begins. As the participants learn the face-emotion pairings, their simulations in the later sections of the task might actually start to become predictive, as they implicitly retrieve their prior encounters with each identity. This would be a particularly interesting finding if it occurred even when the emotion was task irrelevant, as this would suggest that predictive mimicry was a simulation of a forthcoming state in the face being observed, and not part of a participant's preparation for making a correct response.

Finally, we addressed the prediction of later retrieval of facial mimicry. During the retrieval task, it was predicted that participants would reactivate their facial mimicry responses, showing greater zygomaticus activity in response to faces that had smiled during the exposure task, than to faces that had frowned, with the opposite pattern of activation in the corrugator. However, according to an embodied account of memory, for retrieval of a prior body state associated with a stimulus to occur, that body state must be active upon encoding. Not all participants are expected to demonstrate facial mimicry, as this response has been shown to vary between individuals (e.g. McIntosh et al., 2006; Sonnby-Borgstrom, 2002). Reactivation of facial mimicry during the retrieval task was therefore only predicted for those participants who demonstrated facial mimicry during the exposure task.

Chapter 3

A further prediction concerns processing fluency/consistency between encoding and retrieval states. That is, models of memory that consider the role of processing consistency in recall suggest that recall is facilitated by similar cognitive operations being performed when a memory is encoded and retrieved (Graf & Ryan, 1990; Morris, Bransford & Franks, 1977), known as transfer appropriate processing (TAP). The quad design of the following experiments allowed us to extend the question posed in Chapter 2, regarding the effect of attention allocation on possible reactivation of facial mimicry. In experiments 5 and 7, participants attended to either emotion or identity during *both* phases of the experiment, whilst participants in experiments 4 and 6 attended to *different* aspects of the faces during the first and second phases. According to TAP, reactivation of facial mimicry, based on retrieval of this prior body state from memory, is more likely to occur in the first set of participants (experiments 5 and 7), for whom there is a greater degree of overlap between the cognitive operations required during encoding and later retrieval.

3.3 Experiments 4, 5, 6 and 7: Dynamic expressions tasks

3.3.1 Methods

Design

As discussed in the introduction to this chapter, the following experiments aimed to overcome the possible confounding effects of having mimicry and reactivation trials within the same task, by dividing the experiments into exposure and retrieval phases. The design for experiments 4 to 7 can be seen in Figure 3.1. The experiments were designed for

Chapter 3

combined analysis as four pairings, which covered each combination of attention condition for the exposure and retrieval phases. In Experiment 4 participants attended to emotion during exposure and identity during retrieval. In Experiment 5 participants attended to identity during exposure and identity again during retrieval. In Experiment 6 participants attended to identity during encoding and emotion during retrieval, and in Experiment 7 participants attended to emotion during both encoding and retrieval. This meant that experiments 5 and 7, where the participant's attention was directed toward the same aspect of the face during exposure and retrieval fulfilled the criteria for transfer appropriate processing, these tasks were considered to have "task consistency". Experiments 4 and 6, where the attention component differed between exposure and retrieval, were considered to have "task inconsistency".

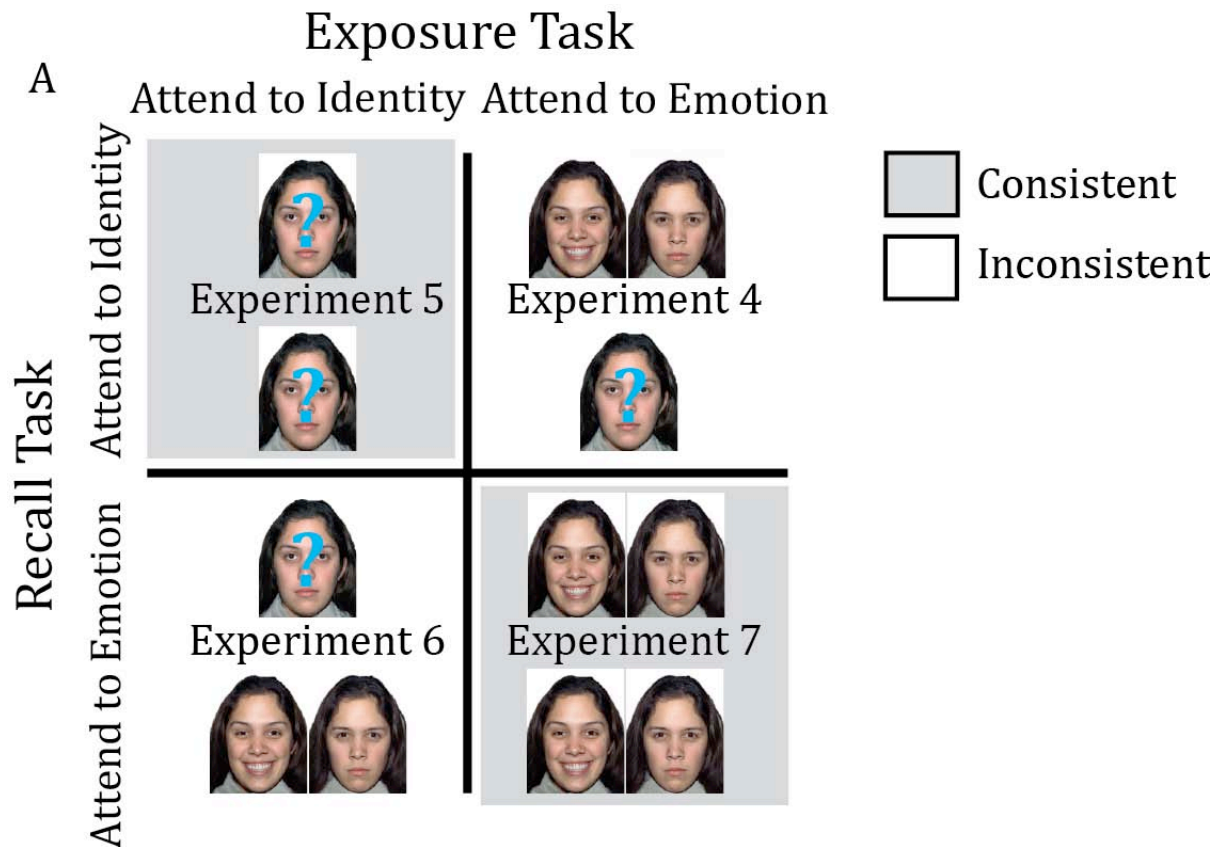


Figure 3.1. Combinations of condition in the exposure and retrieval tasks for Experiments 5 to 7.

Participants

Participants were 72 female undergraduates from Bangor University, Wales, mean age 20.7 years (SD = 2.2 years). All participants had normal or corrected to normal vision and gave informed consent.

Stimuli

Dynamic emotional morphs. As in experiments 2 and 3, the most important aspects of the experiments in this chapter were that when participants were exposed to the identities in the exposure task where facial mimicry was predicted, each identity displayed a consistent emotion, either becoming happy or angry. Half the faces of each sex became happy and half

Chapter 3

angry. During the retrieval task, where reactivation of mimicry was predicted, the identities appeared with neutral expressions during standard trials, meaning that any simulations the participants made were of the identities prior, and not current facial expression.

All four experiments used dynamic emotional morphs for the standard trials during the exposure tasks. These morphs were also used as catch trials during the retrieval tasks in experiments 6 and 7, where participants attended to emotion during retrieval. Example sections of two morphs can be seen in Figure 3.2 Panel A.



Figure 3.2. Example dynamic facial expression frames. *Panel A.* Emotional Morphs. *Panel B.* Identity change morphs.

The dynamic emotional stimuli consisted of eight of the facial identities used in experiments 2 and 3. Four identities were male and four female, consisting of four

Chapter 3

attractiveness and sex matched pairs. Morphing software was used to create short videos of each face becoming happy and angry, creating 16 video stimuli. Each video was 12 frames in length, which began with the neutral version of a face, and morphed in 11 regular steps to either the happy or angry version. Each frame in the morph was 20ms long, and presented between a 1500 ms neutral and 1500 ms expressive still of the face, creating a video of 3240 ms duration.

Oddball identity change morphs. In the exposure tasks of experiments 6 and 7, participants attended to the identity of the faces, by looking out for catch trials where faces changed mid expression from one identity to another. To create these videos the same technique was applied as above, but this time the neutral face of each identity was morphed into the happy or angry face of each other identity, creating 128 videos, which allowed for the quasi randomisation of the allocation of emotion to identity to be applied to the oddball identity change stimuli as well, thus maintaining the consistency of the face-emotion assignment for a particular participant. This meant that for every participant, if for example a particular identity appeared with a happy expression in standard trials, it would only ever morph into the happy face of another identity also assigned to the happy condition. A partial example of one of these morphs can be seen in Figure 3.2 Panel B.

Oddball new identities. In the retrieval tasks of experiments 4 and 5, participants had to look out for oddball new identities. The four new identities with neutral expressions used in this task were taken from the NimStim database (Tottenham et al., 2002) and presented in the same manner as the standard faces.

Chapter 3

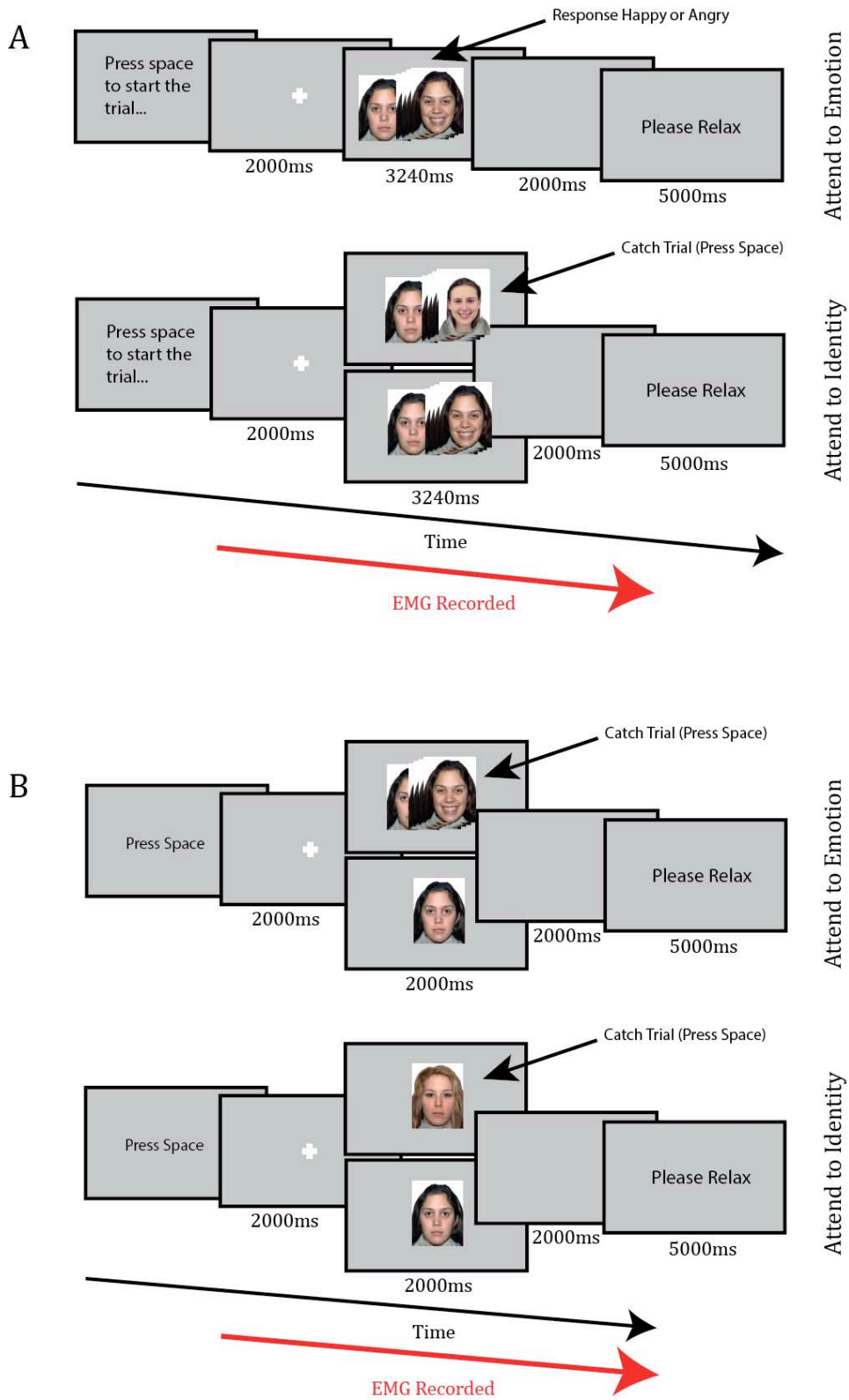


Figure 3.3. Trial diagrams for the different conditions of exposure task (Panel A) and retrieval task (Panel B).

Procedure

The trial procedures for all tasks can be seen in Figure 3.3.

Exposure tasks

Attend to emotion. In experiments 4 and 7 participants attended to emotion during the exposure tasks. In these tasks each identity appeared eight times over the course of four blocks, twice in each block, displaying its contingent emotion. This made a total of 64 trials. Each trial began with the participant pressing the space bar to start, and this was followed by a 2000 ms fixation period, then the dynamic face video which began with the 1500 ms presentation of the neutral version of an identity, morphing into a 1500 ms presentation of its emotional face, over the course of 12 20 ms frames. A 2000 ms blank screen followed this and then a rest screen of 5000 ms. The blank screen was an addition made after we noticed in the experiments in Chapter 2, that the mimicry effects appeared to begin early in the trials but continued to develop over the course of the trial. The blank screen was intended to catch this developing mimicry if it outlasted the presentation of the face. Participants were instructed to respond to each trial by pressing the 'A' key for one emotion and the 'L' key for the other, with the responses counterbalanced across participants. Incorrect responses or no response, resulted in an error tone. The order of presentation of the identities was randomised within each half of each block.

Attend to identity. In experiments 5 and 6 participants attended to identity during the exposure task, which meant they were instructed to respond to catch trials where identities changed over the course of the dynamic face video. The exposure task for these participants consisted of the same 64 standard trials used in the attend to emotion versions of the task, but for these trials participants in experiments 5 and 6 did not respond. Within each of the four blocks, two trials were catch trials, where the identity that appeared neutrally in

Chapter 3

the trial morphed into a different identity whilst becoming expressive. Participants were instructed to respond to these trials with a space bar press. This made a total of 72 trials. False alarms or misses resulted in an error tone. Each face appeared as the beginning and end of a catch trial once, and catch trials had the same time course as standard trials. Again, the order of presentation of identities, and the insertion of the catch trial, was randomised within half of block.

Retrieval tasks

Attend to emotion. In experiments 6 and 7 participants attended to emotion during the retrieval task. The retrieval task consisted of 32 standard trials, with each identity appearing four times during the task with a neutral expression. There were four catch trials, making a total of 36 trials, and in the catch trials the same dynamic face videos that appeared in the exposure task were used. On standard trials, participants began a trial by pressing the space bar, which activated a 2000 ms fixation period. This was followed by the presentation of a static neutral face for 2000 ms, and then a blank screen for 2000 ms followed by the 5000 ms relax screen. For standard trials participants were instructed not to respond. For catch trials, the trial procedure was identical, except that instead of the face remaining neutral, it became happy or angry. Participants were instructed to respond to catch trials with a space bar press, and false alarms or misses resulted in an error tone. The catch trials were randomly inserted into each quarter of the experiment, and selected quasi randomly from the original emotional stimuli used in that participant's version of the exposure task, so that two happy and two angry identities appeared as catch trials, with the emotion / identity contingency preserved. The order of standard trials was randomised within each half of the task.

Chapter 3

Attend to identity. In experiments 4 and 5, participants attended to identity during the retrieval task. The task was identical to the version used in experiments 6 and 7, except that the catch trials were four previously unseen faces that appeared with neutral expressions. Again, participants responded to these catch trials by pressing the space bar.

Memory task

At the end of all four experiments, participants completed the same memory task used in experiment 2 and 3 to see how well they remembered the pairings of identity and emotion.

EMG Data Acquisition

As described in 2.2.1 EMG Techniques

Trial Exclusion

Across all four experiments, 10.3% of trials were removed using the same exclusion criteria described in Chapter 2.

3.3.2 Results

The experiments will now be referred to by initials that represent the combination of attention conditions. The initial 'E' is used to represent 'attend to emotion' at either exposure or retrieval phase, and the initial 'I' corresponds to 'attend to identity'. Therefore experiment 4 is now E-I, Experiment 5 is I-I, Experiment 6 is I-E and Experiment 7 is E-E. E-E and I-I are task consistent experiments, and E-I and I-E task inconsistent.

Behavioural Analysis

Exposure Tasks

Accuracy rates of the exposure tasks across all experiments were high, with mean accuracies above 98% (SDs < 5%) This level of accuracy suggests that participants attended to the stimuli across all experiments.

Retrieval Tasks

Accuracy rates during the retrieval tasks were also high across all experiments, with mean accuracy over 94% (SDs < 5%), suggesting that participants were attentive to the stimuli.

Memory Tasks

Participants on average across all experiments remembered at least six of the eight identity-emotion pairings correctly, suggesting that explicit memory for identity-emotion pairings was quite high. Data from one subject were missing from this analysis. The mean accuracies for each experiment were as follows. E-I mean = 88% (SD = 27.1%); I-I mean = 78% (SD = 27.7%); I-E mean = 74% (SD = 25.5%); E-E mean = 95% (SD = 7.6%). To test for task differences and differences across condition, the accuracies were entered into a mixed models ANOVA, with the within subjects condition of emotion (appeared happy / appeared angry), and the between subjects condition of attention task (attend to emotion / attend to identity). This analysis revealed no differences in accuracy between memory for happy and angry faces, or between attention tasks, and no interaction. A similar analysis was conducted with the between subjects factor of experiment. This analysis revealed a significant main effect of experiment, $F(1,68) = 2.96, p = .038, \eta^2_p = .117$. Post hoc contrasts revealed only a difference in accuracy between Experiment 4 and

Chapter 3

Experiment 5 ($p = .064$), which only reached significance at the one-tailed level. No other experiments differed in accuracy at the one-tailed level.

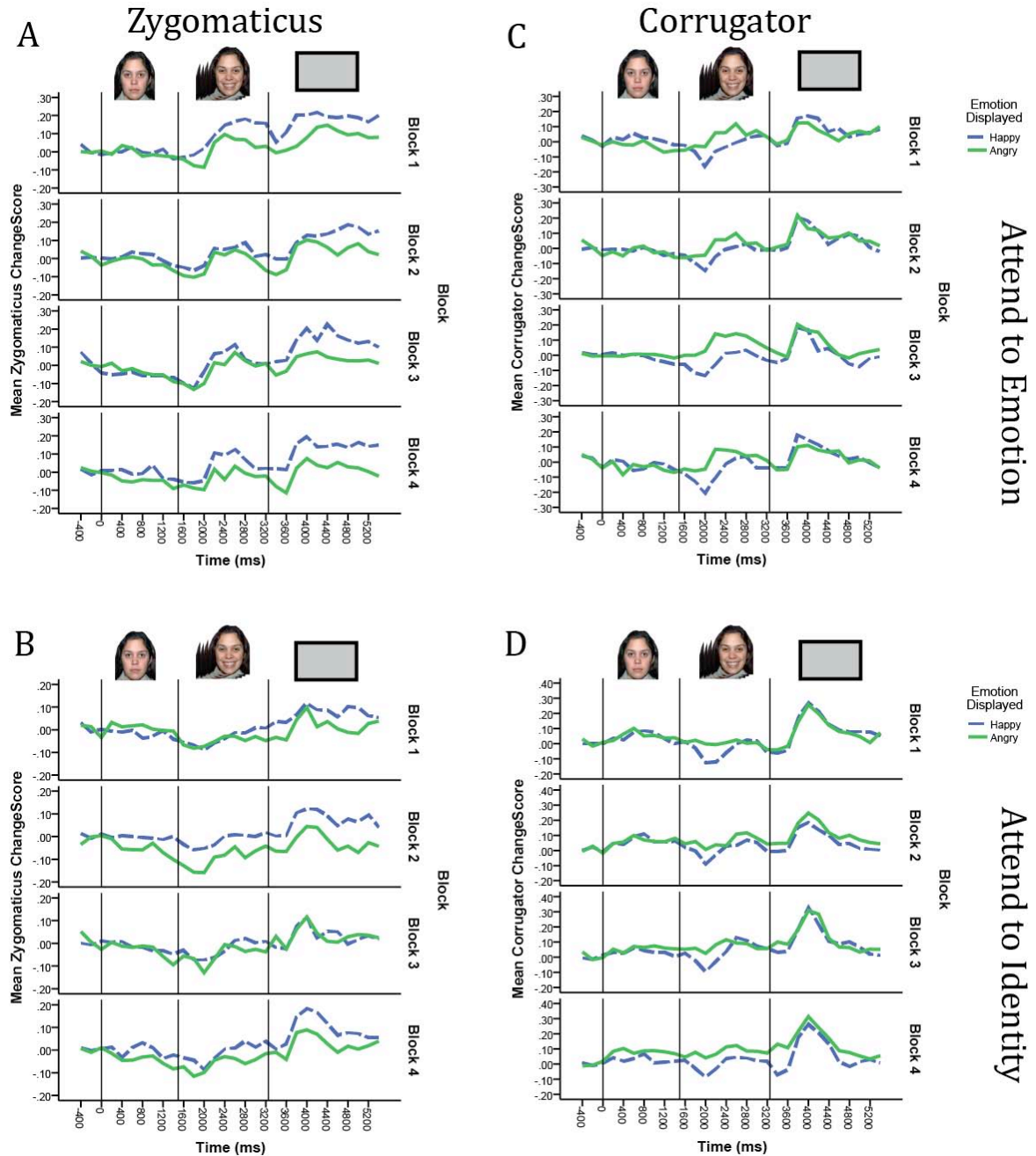


Figure 3.4. Data from trials from the exposure tasks during attend to emotion conditions (Panels A and C) and attend to identity conditions (Panels B and D).

EMG Analysis

Mimicry

Because the zygomaticus and corrugator showed different levels of facial mimicry during experiments 2 and 3, the two muscles were analysed separately.

Corrugator. The activation in the corrugator during the exposure task can be seen in Figure 3.4 Panels C and D, which represent the facial emotion, period of the trial, block and attention task (attend to emotion (Panel C); attend to identity (Panel D)). The data were entered into a mixed models ANOVA, with the within subjects factors of emotion (happy / angry), block (1 / 2 / 3 / 4) and trial period (emotional face onscreen / blank screen), and the between subjects factor of attention task (attend to emotion / attend to identity).

There was a significant main effect of trial period, with activity increasing in the corrugator in the blank screen after the emotional face, $F(1,70) = 2.01, p < .001, \eta^2_p = .231$. Importantly, there was a main effect of emotion, with the corrugator more active in response to angry faces than to happy faces, $F(1,70) = 7.9, p = .006, \eta^2_p = .102$. This confirmed the prediction that facial mimicry would occur in the corrugator.

Interestingly, an interaction was found between emotion and trial period, $F(1,70) = 18.9, p < .001, \eta^2_p = .212$. Further analysis with t-tests revealed that during the period where the emotional face was onscreen, the effect of emotion was significant, $t(71) = 4.3, p < .001$, however in the subsequent blank screen the effect was found to be non-significant, $t(71) = .93, p = .351$. This indicated that the mimicry effect in the corrugator appeared to be transient, appearing rapidly in response to the expressive face, but also disappearing rapidly as well. There was an interaction between trial period and block, $F(3,210) = 4.6, p = .004, \eta^2_p = .061$. Visual analysis of the means plot for this interaction revealed that activity during the blank screen was always greater

than during the emotional expression, but that this difference decreased slightly in the third block.

Zygomaticus. The data presented in Figure 3.4 Panels A (attend to emotion) and B (attend to identity), show the activity in the zygomaticus in response to happy and angry faces, across blocks and trial periods. The zygomaticus data were entered into an identical analysis. There was again a main effect of time, $F(1,70) = 39.5$, $p < .001$, $\eta^2_p = .361$, with the zygomaticus more active during the blank screen after the expression, than during the period where the expressive face was on screen. There was also a main effect of attention task, $F(1,70) = 4.3$, $p = .041$, $\eta^2_p = .058$, where participants attending to emotion demonstrated greater zygomaticus activity than those attending to identity. Most importantly, there was a main effect of emotion, with the expected facial mimicry being shown, $F(1,70) = 20.6$, $p < .001$, $\eta^2_p = .227$. Zygomaticus activity was greater in response to happy, than to angry faces.

Interestingly, there was an interaction between emotion and trial period, $F(1,70) = 4.6$, $p < .035$, $\eta^2_p = .062$, and in contrast to the corrugator the zygomaticus showed greater discrimination between happy and angry faces during the blank screen after the expressive face, $t(71) = 4.6$, $p < .001$, than it did during the expression itself, $t(71) = 3.2$, $p = .002$. Although mimicry was significant during both periods, its extent increased after the disappearance of the face.

The analysis of facial mimicry effects revealed significant mimicry in both muscles, although the pattern of that mimicry differed. The corrugator mimicry was transient, occurring only when the expressive face was onscreen and terminating when the face was no longer visible, and this weaker mimicry replicates our findings from experiments 2 and 3.

Chapter 3

The zygomaticus however showed significant mimicry when the expressive face appeared, which increased in the blank period after the face. Importantly no interactions were found between mimicry effects, attention task or block. Again, in replication of our previous experiments, it does not seem to matter whether the emotion is task relevant or whether the same faces appear multiple times with the same expressions, mimicry effects in both muscles display a striking automaticity.

Predictive activations during the exposure task

Corrugator. The data from the trial period where the identities appeared with neutral expressions, prior to becoming expressive, was entered into a mixed models ANOVA, with the within subjects factors of emotion (will become happy / will become angry) and block (1 / 2 / 3 / 4) and the between subjects factor of attention task (attend to emotion / attend to identity). This analysis revealed no significant main effects or interactions. Given the transient nature of the mimicry effect in the corrugator, this was not unexpected.

Zygomaticus. The same analysis of the zygomaticus data revealed a main effect of emotion, $F(1,70) = 5.5, p = .021, \eta^2_p = .073$. During the neutral face, before the expression appeared, the zygomaticus was more active to faces that would become happy, than those that would become angry. Although the interaction with block was non-significant, $F(3,210) = 2.0, p = .122, \eta^2_p = .027$, this predictive reactivation should not be expected during the first block, and might be expected to develop as the experiment went on. To test this prediction, t-tests were run on the emotion effect in each block, and these revealed that in block 1 there was no predictive mimicry, $t(71) = .192, p = .848$. This was also the case in block 3, $t(71) = .73, p = .465$, but the predictive mimicry was significant in block 2, $t(71) = 2.7, p = .008$, and block 4, $t(71) = 2.1, p = .039$.

Chapter 3

This analysis revealed that in the later stages of the experiments mimicry began to occur predictively of the oncoming emotion. This occurred only in the zygomaticus, in which mimicry effects were also stronger. Although we cannot account for the lack of predictive mimicry in block three, we did again find no interaction between this effect and attention task, suggesting that this process also represents an automatic forward modelling of an oncoming expression.

Predictive activations – mimickers and non-mimickers. The data were examined to see if those participants who mimicked the emotional expressions during the exposure phase, differed in terms of their predictive activations in response to the neutral sections of the expressive morphs. The same analyses as used in the previous section were conducted but this time mixed ANOVAs were conducted, with mimicry (mimicker with muscle site / non-mimicker with muscle site) included as a between-subjects variable (distributions of mimickers are reported in the section that follows).

Corrugator. The analysis of the corrugator data revealed no significant main effects or interactions.

Zygomaticus. The analysis of the zygomaticus data revealed a significant interaction between mood and mimicry, $F(1,70) = 14.07, p < .001, \eta^2_p = .167$. To further investigate this, separate analyses were conducted on the mimickers and non-mimickers with the zygomaticus. In mimickers significant predictive activation occurred, $F(1,49) = 14.6, p < .001, \eta^2_p = .229$, and in non-mimickers there was significant predictive activation in the opposite direction, $F(1,21) = 6.01, p = .023, \eta^2_p = .225$.

Implicit reactivation during re-exposure

During the retrieval task participants were exposed to neutral versions of the identities they had seen becoming expressive several minutes earlier in the exposure task. We predicted that reactivation of facial mimicry effects would occur, but that this would be modulated by whether or not individual participants mimicked the expressions during the exposure task. If an individual did not embody the state of a face when it smiled or frowned, it was predicted that they would have nothing to reinstate when retrieving that face from memory. For this reason the analysis of the data from the retrieval task was conducted separately for those participants who showed facial mimicry effects and those who did not. This was achieved using a straight split in each muscle between those participants who showed a pattern of activity in the expected direction during the expressive face and blank screen in the exposure task (e.g. for zygomaticus, greater activity to happy than angry faces), and those who did not. Fifty participants mimicked with their zygomaticus, and 22 did not. The consistent (E-E and I-I), and inconsistent (E-I and I-E) experiments contained 25 zygomatic mimickers, and 11 non-mimickers each. Forty-nine participants mimicked with their corrugator, and 23 did not. In the consistent tasks the division was 22 mimickers to 14 non-mimickers, and in the inconsistent tasks it was 27 to nine.

We also predicted that as purported by the transfer appropriate processing account, reactivation of mimicry should be likely if the task the participants were completing was consistent between encoding and retrieval. As no differences in mimicry, or predictive mimicry were found between attending to emotion and identity conditions, this factor was replaced in the following analyses by task consistency during encoding and retrieval. Therefore the data from mimickers and non-mimickers within each muscle were entered into mixed models ANOVAs with the within subjects factors of emotion (previously happy /

Chapter 3

previously angry), block (first half / second half) and trial period (neutral face / blank screen), and the between subjects factor of task consistency (consistent / inconsistent).

Corrugator. The data from the corrugator during the retrieval task can be seen in Figure 3.5 Panels C and D, which depict the data during consistent and non-consistent experiments from mimickers (Panel C) and non-mimickers (Panel D).

Non-mimickers. The analysis of the non-mimickers revealed only a significant effect of trial period, with the corrugator of non-mimickers more active as the trial progressed, $F(1,21) = 8.4, p = .009, \eta^2_p = .285$.

Mimickers. Again a main effect of trial period was found, with activity increasing as the trial progressed, $F(1,47) = 18.1, p < .001, \eta^2_p = .278$. Trial period and block interacted, $F(1,47) = 6.6, p = .013, \eta^2_p = .123$. This interaction, on examination of the means, appeared to be caused by a decrease in degree to which corrugator activity in mimickers was greater during the blank screen, in the second half of the task. There were no other main effects or interactions, suggesting that the corrugator mimicry seen during the earlier exposure task was not being reactivated.

Zygomaticus. The data from the zygomaticus during the retrieval task can be seen in Figure 3.5 Panels A and B, which depict the data during consistent and non-consistent experiments from mimickers (Panel A) and non-mimickers (Panel B).

Non-mimickers. Analysis of participants who did not mimic during encoding revealed only a main effect of trial period, $F(1,20) = 8.4, p = .009, \eta^2_p = .295$, with zygomaticus activity increasing over the duration of the trial.

Chapter 3

Mimickers. A main effect of time was found, $F(1,48) = 56.3, p < .001, \eta^2_p = .540$, with activity increasing over the course of the trial. The key main effect was that of emotion. In those participants who had previously mimicked with their zygomaticus while viewing faces expressing emotion, activity in this muscle was greater in response to those identities who had previously appeared happy, than to those who had previously appeared angry, $F(1,48) = 4.9, p = .031, \eta^2_p = .093$. There was also an interaction between emotion and trial period, $F(1,48) = 5.9, p = .02, \eta^2_p = .108$. This was investigated with t-tests, and these revealed that whilst the difference in zygomaticus activity in response to previously happy and angry faces was non-significant in the face period of the trial alone, $t(49) = 1.1, p = .14$, it reached significance when the blank screen was analysed alone, $t(49) = 2.6, p = .013$. This result mirrored that found in the facial mimicry during the exposure task, where mimicry effects in the zygomaticus increased as the trial progressed. As predicted by the transfer appropriate encoding account, there was an interaction between emotion and task consistency, $F(1,48) = 4.2, p = .047, \eta^2_p = .080$. When participants completed a consistent tasks (E-E or I-I) at encoding and retrieval (emotion – emotion or identity – identity), retrieval of prior mimicry occurred, $t(49) = 3.1, p = .005$. However, when participant's tasks at encoding and retrieval were inconsistent (E-I or I-E), retrieval of prior mimicry did not occur, $t(49) = .108, p = .915$.

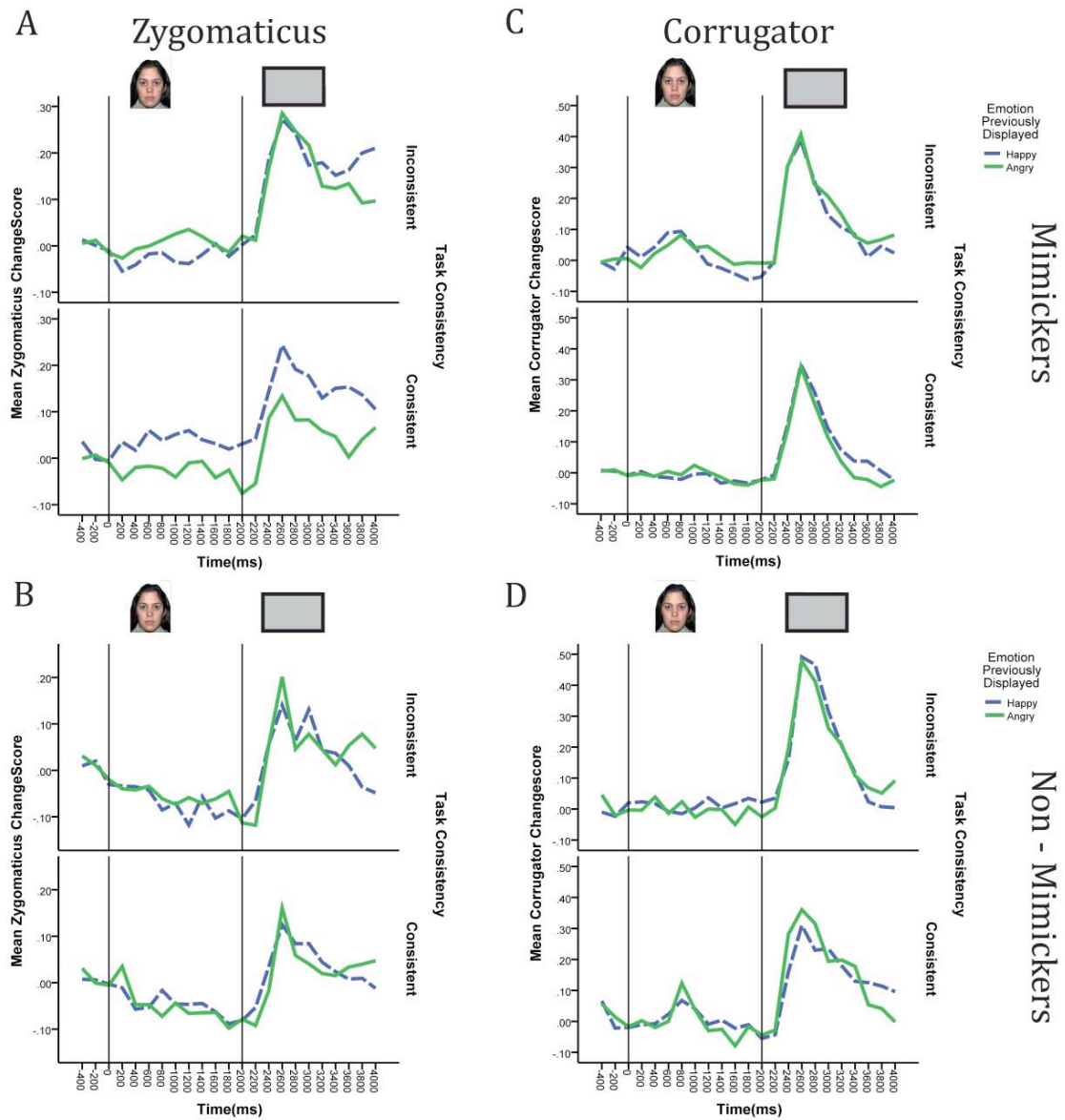


Figure 3.5. Data from trials in the retrieval task. *Zygomaticus* mimickers (Panel A) and non-mimickers (Panel B). Corrugator mimickers (Panel C) and non-mimickers (Panel D).

Chapter 3

Analysis of memory by mimicry group. A final analysis was conducted to see whether participants who mimicked, had better explicit memory for the identity – emotion pairings than those who did not mimic. Participants who mimicked with their corrugator showed better memory than those who did not, $t(69) = 2.3, p = .013$, whilst there were no differences between zygomaticus mimickers and non-mimickers, $t(69) = .45, p = .65$. No difference in accuracy was found between those participants in the consistent and inconsistent conditions, $t(69) = .879, p = .382$.

3.3.3 Conclusions

The experiments in this chapter provide the first evidence that facial mimicry is reactivated during later re-exposure to a previously expressive individual. Facial mimicry effects were found in response to the smiles and frowns in the encoding task, regardless of how many times they had seen the identities or whether or not the emotions being displayed were task relevant. The data from the exposure task provide evidence that this facial mimicry began to occur predictively. The participant's zygomaticus responses to the identities began to occur before the identities became expressive, suggesting their simulation of the emotion was occurring in a manner that forward modelled the actual action of the face. Interestingly further analysis revealed that both simulation and a counter simulation like effect appeared to occur predictively depending on whether participants demonstrated mimicry or not respectively. Furthermore, those participants who demonstrated facial mimicry, when re-exposed to the identities with neutral expressions some minutes later, reinstated the muscle activity that they showed in their zygomaticus during the earlier exposure task; their

zygomaticus muscles were more active to faces that had previously appeared happy, and less active to those that had previously appeared angry. As the faces at this stage were appearing with neutral expressions, this can only have occurred through a retrieval of their prior embodiments of the identity's expressions. In accordance with an embodied account of memory, this retrieval only occurred in those participants who showed facial mimicry whilst encoding during the exposure task. In accordance with the theory of transfer appropriate processing, the reactivation of facial mimicry was increased when the cognitive requirements of the exposure and retrieval tasks were matched, that is, the participants were attending to the same aspect of the face during both initial encoding and later retrieval.

3.4 Discussion

The experiments in Chapter 3 provided further evidence for the automaticity of facial mimicry, replicating the results of Chapter 2 in showing that simulation of other's emotional expressions through activation of the observer's own facial muscles occurs even when the expression is not relevant to the current task, and without habituation over multiple exposures. However, the novel findings of this series of experiments regarded the reactivation of these simulations, both in prediction of the onset of an expression that was yet to occur, and during a later task where participants saw only neutral or almost exclusively neutral versions of the previously expressive identities.

Embodied theories of memory (Barsalou, 1999; Buckner & Wheeler, 2001; Damasio, 1989; Danker & Anderson, 2010) suggest that simulations of, or sensory-motor states caused by a stimulus during encoding are reinstated as part of retrieval of that stimulus. This theory

Chapter 3

has been applied to memory for emotions and emotional experiences (e.g. Niedenthal, 2007). Memory facilitates the prediction of future events, and in terms of our understanding of others, this is vital for cooperative behaviour as well as our own survival (Frith & Frith, 2006). Models of perception and action suggest that future actions are predicted in the brain by the running of simulations, or forward models, created through learning during prior experiences (e.g. Kilner et al., 2007; Wolpert et al., 1995; Wolpert et al., 2003). So when we perceive an action that we recognise, a simulation of that action's future helps us to understand the goals and intentions of the actor. Based on these ideas we predicted that once associations had been implicitly learnt between identities and expressions, embodiments of those expressions in our participants might begin to occur in a manner suggestive of forward modelling. Furthermore, facial mimicry effects might occur during the later retrieval task when participants viewed neutral versions of the faces.

Activity of the participant's zygomaticus muscle provided evidence to support both predictions. Zygomaticus and corrugator mimicry were both consistent during the exposure task, although the mimicry effects in the zygomaticus were more pronounced, which replicated the effects we found in Chapter 2. The zygomaticus responses lasted beyond the exposure to the emotional face and into the blank screen that followed it, whereas the corrugator response was transient and did not last beyond the expressive face. As discussed in Chapter 2, the weaker mimicry in the corrugator may come down to effects of mood, or social acceptability. As we hypothesised that any retrieval effects would only occur after embodiment, the weaker embodiment in the corrugator set a precedent for later reactivation of this muscle in any later memory driven simulation.

Importantly, it was in the zygomaticus that evidence for predictive simulation was found, with participants activating their zygomaticus muscle in later blocks of the

Chapter 3

exposure task in a manner that pre-empted the oncoming emotion, with greater activity to identities who would smile, than to those who would frown. This is novel, in that previous studies looking at similar effects with oncoming actions have shown forward modelling occurring after the onset of an action (e.g. Kilner et al., 2007) and not before it. Our results also extend those of Heerey and Crossley (2012), who showed similar effects when smiles appeared during feedback screens of an associative learning task, in that our results occurred both when the oncoming emotion was relevant to the current task, in the attend to emotion condition, and when it was not, in the attend to identity condition. Therefore it can be concluded that the simulations of the oncoming emotion occurred in a manner that was independent of any task related predictions the participants were making, i.e the prediction that they would see an expression associated with a correct answer, or predictions of whether they should press the key assigned to happy or angry. Our data support the notion of automatic and non-conscious simulations forward modelling of other's actions and intentions (e.g. Behrens, Hunt & Rushworth, 2009). Of further interest was the fact that upon sub analysis of the mimicker and non-mimickers with the zygomaticus, it was found the whilst mimickers activated mimicry like muscle responses predictively, non-mimickers actually activated the opposite pattern of activity predictively of the faces smiling or frowning. It could be the case that for some individuals viewing another person's smile actually causes a suppression of zygomaticus activity or indeed an activation of a muscle state associated with a negative emotional state and that this muscle state is then retrieved. It would be of interest to follow this finding up with a more detailed study of the individual differences between this group and facial mimickers.

Chapter 3

Two important boundary conditions were revealed by the reactivation of the participant's zygomaticus muscles to neutral versions of the faces during the later retrieval task. Firstly, this reactivation only occurred in participants who showed mimicry during the exposure task. These participants simulated the expressions they saw in this task, and were the participants who reactivated this simulation in the later retrieval task, which corresponds with the predictions of embodied accounts of memory. Secondly, the consistency of the task demands influenced the degree of retrieval of zygomaticus mimicry, with, as predicted, greater retrieval effects in participants whose tasks had been consistent (experiments 5 and 7), in accordance with theories of transfer appropriate encoding. Explicit recall of the face-emotion pairings was not affected by task consistency, and although in corrugator mimickers it was better than non-mimickers, the same was not true in the zygomaticus where mimickers and non-mimickers were differentiated by reinstatement of mimicry, but not by explicit memory. Past research has shown that implicit memory and familiarity are influenced by embodied processes, whilst explicit memories are not (Topolinski, 2011). Interfering with embodied processes during encoding and recall does not affect the ability to explicitly recollect information, but does affect implicit forms of memory such as familiarity, or effects like mere exposure. Our data appear to show that even when participants were equally able to explicitly remember if someone had been happy or angry in the past, their unconscious retrieval of prior emotional motor states associated with that person was more sensitive to their own prior embodiment and the matching of their cognitive state during this encoding to their current cognitive state (consistent v inconsistent encoding and retrieval).

Chapter 3

Our data are not the first to provide evidence that during passive viewing of neutral faces, previous emotion related embodiments might be reactivated. Halberstadt et al., (2009), showed a similar effect when participants viewed neutral faces paired with written emotional concepts, like happy or angry. On later re-exposure to the faces, in the absence of the concepts, the same pattern of facial muscle activity elicited on original viewing was reinstated. However, their task lacked the ecological validity of the current experiments, where our participants were not asked to explicitly think about the emotions being displayed or why the identities might express them and were not asked until after the end of facial EMG collection, to carry out any kind of memory task, beyond looking out for previously unseen faces. The current experiments provide the first evidence that facial embodiments of another person's expression are automatically reactivated upon re-exposure to that individual, and that this process can occur both in a predictive manner, when encountering an individual in a situation where an upcoming emotion is likely, and in a situation where emotion is not necessarily expected. Together this supports the central hypothesis of this thesis; that simulations of other people's emotional expressions may play a role that goes beyond the current interaction and supports prediction during future interactions.

Chapter 4

Retrieval of Rapid Facial Responses to Valenced Non-Facial Stimuli

4.1 Summary

The mimicry and retrieval effects reported in Chapter 3 could be explained in terms of associative learning rather than simulation. If participants learn to associate a particular identity with a positive or negative emotional response, elicited by viewing the identity's facial expression, a reinstatement of this response, and not a simulation of the previously embodied expression, might cause the reactivation of their own facial expression seen upon later exposure. In Chapter 4 we investigated this possibility by pairing faces with positively and negatively valenced animals, rather than expressions, that would not be simulated. The results of these experiments indicated that the effects in Chapter 3 appear to be facial expression specific. Valenced animals cause similar but less powerful mimicry-like effects, but participants do not reinstate these responses upon later re-exposure in the same way as for facial expressions. We suggest that facial expressions as powerful social stimuli therefore afford greater simulation and activate reinstatements of simulation that non-social stimuli do not.

4.2 Introduction

Many experiments have shown facial mimicry effects in the past (e.g. Cannon et al., 2009; Dimberg, 1982; Dimberg & Thunberg, 1998; Hess & Blairy, 2001), but the experiments in Chapter 3 provided the first evidence that facial mimicry is implicitly

Chapter 4

retrieved from memory and reactivated upon later exposure to previously mimicked individuals. The experiments also provided two possible boundary conditions for this reactivation. Firstly, that as predicted by embodied accounts of memory, people who do not show facial mimicry also do not reactivate it. Secondly, it appeared that the reactivation was more powerful in a situation where the focus of attention in the tasks matched between encoding and retrieval. The data from the period of the experiments where participants were exposed to the emotional versions of the identities also revealed an apparent forward modelling of the oncoming emotion. In the later blocks of this task, when participants viewed a neutral face that would become happy, they showed more zygomaticus activity than they did when viewing a neutral face that would become angry. This supports the notion that simulations of other's actions involve projection of the future course of the action, but novel in that the predictive simulations in this case appeared to begin before the action being observed was even initiated.

We have interpreted our data as reflecting embodied processes, in line with theories of simulation in emotion comprehension (e.g. Niedenthal et al., 2010). That is, facial mimicry effects are caused by simulations of the expression on the face being observed, which are then retrieved and reactivated as part of retrieving the identity of an individual from memory. In this way our data would support embodied accounts of social cognition that suggest simulations underpin reactive and also predictive responses to other people's emotional states.

However, another interpretation would be that the facial responses we measured were simply caused by an emotional reaction in the participants to the positive and negative facial expressions, and not by embodiment of their motor states.

And that the retrieval effects were due to associative learning, rather like the electrodermal (EDA) responses shown in Bechara et al., (1997). Here participants showed larger EDA responses whilst pondering playing risky decks in a gambling task, than when pondering playing safe decks. These physiological markers of the arousal state associated with the losses on those decks appeared to occur quite early in the task, during trials where the participants chose advantageously without knowing they were doing so. If the effects we demonstrated in Chapter 3 are caused by associating emotional value with the identities and not by reactivation of simulations, this does not mean they are not embodiments. Emotions are themselves embodied states (Damasio, 1989), which shape our behaviours. These physiological states are partially and unconsciously reactivated during implicit memory retrieval, guiding judgements. It might be the case that the participants are reactivating their own emotional body states rather than simulations of other people's, and this is in itself a form of embodied cognition, but not the form we proposed at the outset of this thesis.

Facial mimicry effects have also been referred to as rapid facial reactions, because they also occur in response to valenced but non-facial stimuli. Images of snakes (Dimberg, Hansson & Thunberg, 1998; Dimberg & Karlsson, 1997), body postures (Tamietto & DeGelder, 2009; Tamietto et al., 2009) and affective pictures (Codispoti et al., 2009) have been shown to elicit rapid and apparently automatic (Eisenbarth, Gerdes & Alpers, 2011; Tamietto et al., 2009) activations of the zygomaticus and corrugator muscles. All of these stimuli carry some kind of positive or negative emotional value. Halberstadt et al., (2009) provided the only other evidence of the reactivation of facial-mimicry like responses during later passive viewing. In their study participants reactivated their facial reactions made originally in response to neutral faces paired

with written emotion concepts, during later viewing of faces alone. They did not find similar results with pairings of emotion concepts and symbols, or pairings of faces and positive or negative concepts that were not directly related to emotional expressions, e.g. tidy, or lazy. Their results would suggest that retrieval of prior mimicry might not occur if the mimicry was not caused by facial expression, but by a positive or negatively valenced stimulus. We propose that although the mimicry effects in Chapter 3 could be explained by emotional reactions to the facial expressions and not simulation (or likely both, see Tamietto et al., 2009), the retrieval and predictive reactivation of facial mimicry represent does represent simulation, and should not occur if the stimuli being 'mimicked' are non-facial.

Another possibility is that the emotional value of the expression contributed to the mimicry and retrieval effects we measured. Emotional expressions have been shown to have value, just as card decks do in gambling tasks (Shore & Heerey, 2011), and other studies showing facial mimicry like responses to emotional bodies as well as facial expressions (Tamietto et al., 2009) have hinted that this emotional value might drive initial muscle activations but that these reactions then are bolstered by simulation in the case of emotional expressions (see also Niedenthal et al., 2010, pp. 40). However, we predict that even if facial mimicry effects are partly underpinned by initial emotional reactions to the value of the facial expression, the forward modelling and retrieval effects are not. For example, the retrieval effects occurred whilst participants were passively viewing neutral faces, in situations where occasional emotional expressions were expected (attend to emotion), and where no emotional expressions were expected (attend to identity). We would predict that the neutral faces would lose emotional value, just as a card deck might do if it stopped rewarding, but the reactivation of the

Chapter 4

zygomaticus continued in these later tasks unaffected by block and without differentiation between conditions where expressions were or were not expected. We therefore propose that the retrieval effects must represent retrieval of motor simulations, not emotional body states designed to guide behaviours.

In order to investigate whether we are correct in this assertion, the two experiments in this chapter replicate the experiments in Chapter 3 in which the strongest retrieval effects were shown; the two task consistent experiments (I-I and E-E) where participants attended to emotion or identity during both encoding and retrieval. However, instead of emotional expressions, we paired the faces with positive or negatively valenced animals, leaving the neutral faces during both exposure and retrieval tasks identical. These stimuli should elicit facial responses during the exposure task but not responses that can be considered simulations of action. If these responses are forward modelled during the later periods of the exposure task, or reactivated during the retrieval task, this would suggest that the participants are reactivating their own emotional state and not a simulation. However, if the stimuli elicit facial reactions during the exposure task but these reactions are not retrieved at any stage, this would support the notion that the retrieval effects are specific to simulations of facial expression.

4.3 Experiments 8 and 9: Non-facial expression stimuli

4.3.1 Methods

Participants

Participants were 36 female undergraduates from Bangor University, Wales, mean age 19.8 years (SD = 2.0 years), who all gave informed consent and had normal or corrected to normal vision.

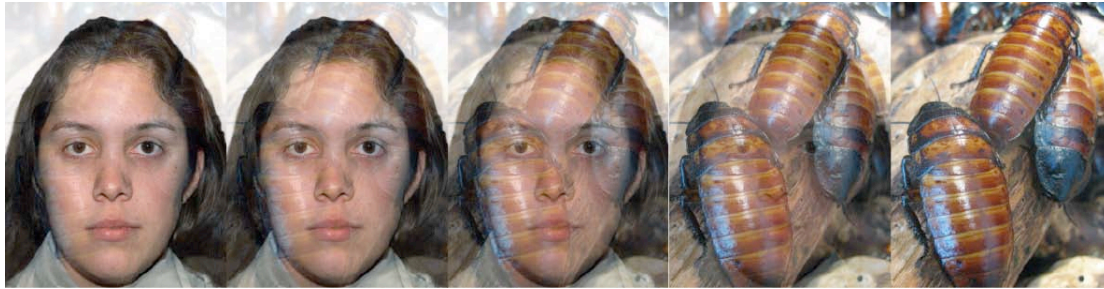


Figure 4.1. Example frames from a neutral face to animal morph.

Stimuli

Dynamic valenced morphs. The stimuli were identical to those used in Chapter 3, except that instead of emotional faces, the neutral faces were now morphed into valenced animals (see Figure 4.1). Pictures of a puppy, kitten, seal pup and rabbit were used instead of happy versions of the faces. Pictures of a snarling dog, spider, cockroach, and shark were used instead of angry faces. During the attend to identity version (now attend to category) of the exposure task, instead of the faces changing identity, morphs were created of each face changing into each of four images of cars, pictured front on. During the retrieval task, the same valenced morphs were used in the

Chapter 4

attend to emotion condition (now attend to valence) and the same new neutral identities used in Chapter 3 were used in the attend to category task

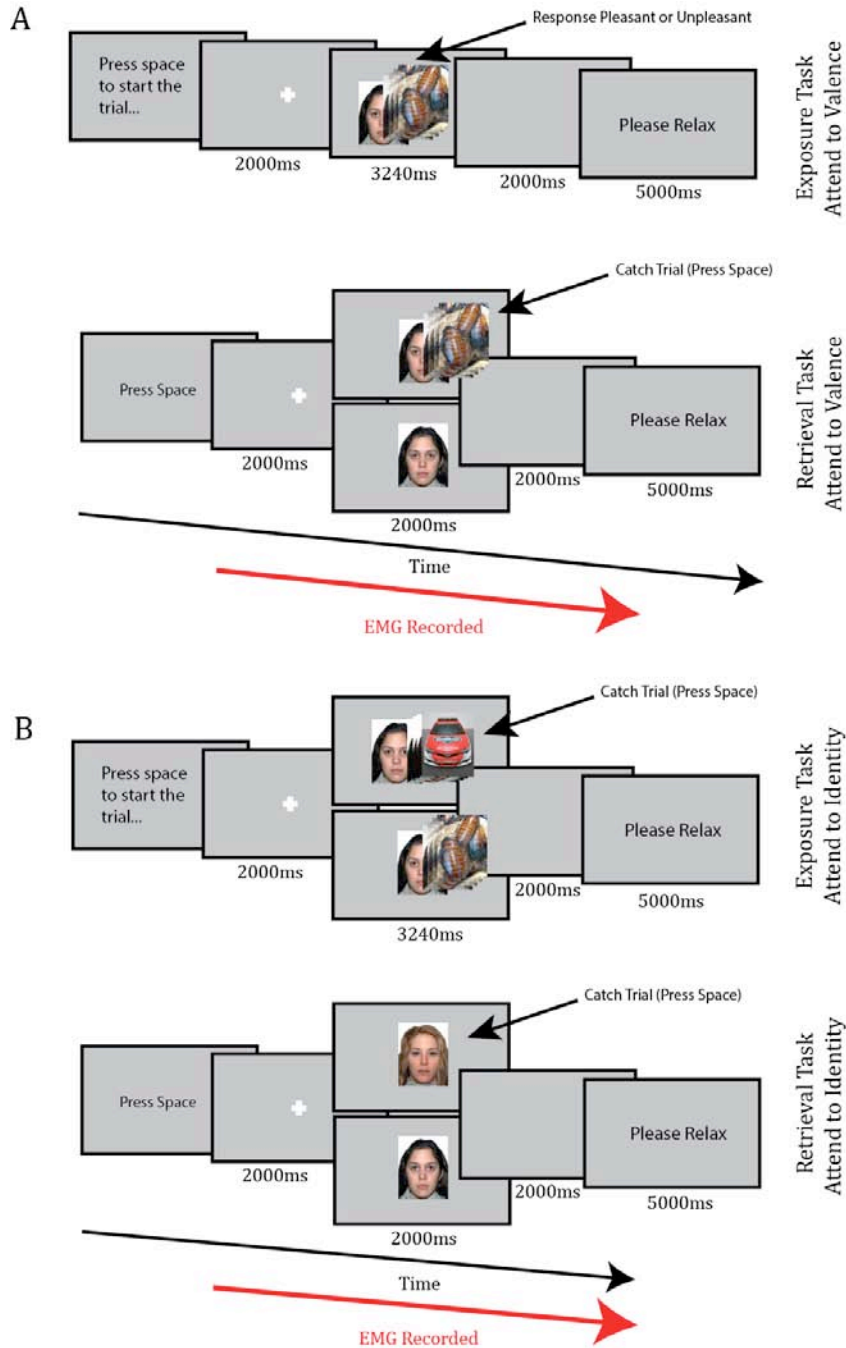


Figure 4.2. A) Trial procedures for Experiment 8 (V-V), exposure task top of panel and retrieval task bottom, and B) trial procedures for the same tasks in Experiment 9 (C-C).

Procedure

Rating Task

In order to ascertain whether the images chosen were indeed different in terms of their valence, participants performed a rating task at the start of each experiment. Each image appeared once during the task, for 750ms preceded by a fixation cross. After the image had cleared participants made a rating of how pleasant they found the image, on a scale of 1-7. The order of presentation of the stimuli was randomised.

The trial procedures for the exposure and retrieval tasks can be seen in Figure 4.2, where the procedure for the two tasks in Experiment 8 (attend to valence / attend to valence (V-V)) appears in Panel A, and for Experiment 9 (attend to category / attend to category (C-C)) in Panel B.

Exposure tasks

Attend to valence. In Experiment 8, participants attended to the valence of the stimuli. The procedure was identical to that used in experiments 4 and 7 for attend to emotion, except that instead of responding to the stimuli in terms of whether the expression shown was happy or angry, they now responded in terms of whether the face became a pleasant or unpleasant animal.

Attend to category. In experiment 9 the exposure task was identical to that of experiments 5 and 6 for attend to identity, except that instead of oddball identity changes, participants responded to oddball trials where identities changed into cars instead of animals. This design was used to equate the attention condition to that of the earlier experiments, so that the valence became task irrelevant and the identity of the face had to be tracked during each trial.

Retrieval tasks

Attend to valence. The retrieval task in Experiment 8 was identical to that used in experiments 6 and 7 for attend to emotion, except that instead of catch trials being emotional faces, catch trials were valenced morphs, to which the participants responded with space bar presses. Standard trials remained as neutral faces.

Attend to category. The retrieval task in Experiment 9 was identical to that used in experiments 4 and 5 for attend to identity, with new faces appearing as catch trials, and old neutral faces appearing as standard trials.

The combination of attend to valence tasks used in Experiment 8 for exposure and retrieval phases will now be referred to as V-V, with the combinations of attend to category tasks in Experiments 9, referred to as C-C.

Memory task

At the end of both experiments the participants completed the same recall task used in Experiments 4 -7, except that in the new experiments they were asked to try and remember if the faces had changed into pleasant or unpleasant animals.

EMG Data Acquisition

As described in 2.2.1 EMG Techniques

Trial Exclusion

Across both experiments, 4.84% of trials were removed.

4.3.2 Results

Behavioural Analysis

Ratings. The participant's ratings of the pleasantness of the stimuli were analysed to ensure that the animals were perceived to match the emotion they were chosen to elicit. Mean ratings across both V-V and C-C conditions for pleasant animals were higher than those for unpleasant animals, 6.6 (SD = .44) versus 2.3 (SD = .7), and a mixed models ANOVA with the within subjects factor of valence (pleasant / unpleasant) and the between subjects factor of experiment (V-V / C-C) revealed a main effect of valence, $F(1,34) = 841.5, p < .001, \eta^2_p = .962$, but no interaction between valence and experiment ($p > .5$). It can therefore be concluded that the animals elicited the correct perceptions of pleasant and unpleasant valence in the participants.

Exposure Tasks. Participants were highly accurate in both experiments during the exposure task, making correct responses in E-E on 98% (SD = 3.8%) of trials, and in I-I on 98% (SD = 1.0%) of trials.

Retrieval Tasks. Again participants were highly accurate on the retrieval tasks, making correct responses in the V-V condition on 99% (SD = 1.4%) of trials, and in the C-C condition on 98% (SD = 3.4%) of trials.

Recall Tasks. Participants were accurate at remembering the pairings of identity and valence, remembering on average at least five out of eight pairings. Accuracy in the V-V condition was 71% (SD = 19.6%) and in the C-C condition it was 70% (SD = 18.1%). Comparison of the two experiments revealed no difference in accuracy, $t(34) = .077, p = .939$. Participants in the two experiments therefore appeared to explicitly remember the valence to identity pairings equally well.

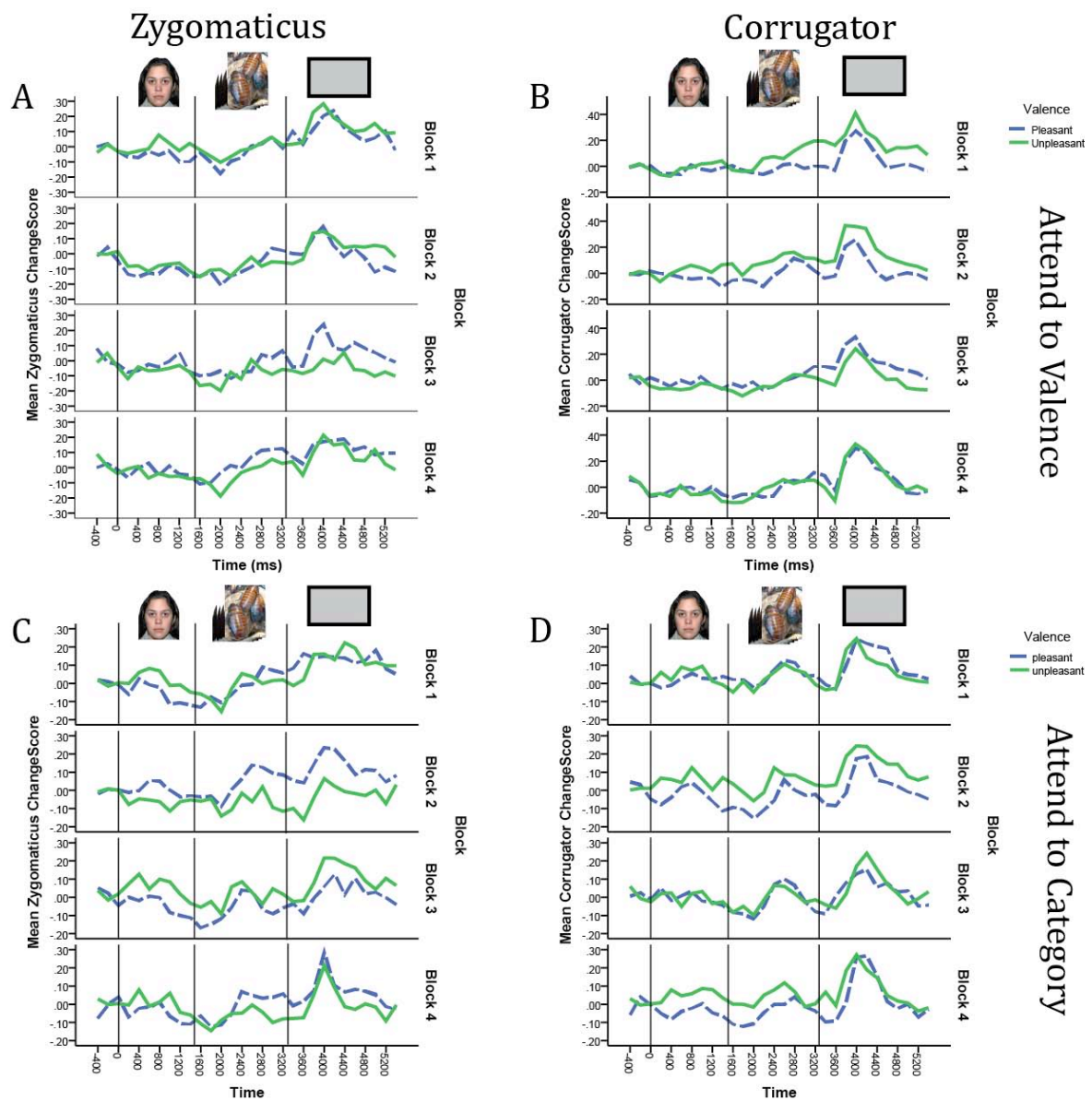


Figure 4.3. Data from trials where participants viewed faces becoming positively or negatively valenced animals, during the exposure tasks. Data from Experiment 8, attend to valence, are plotted in Panels A) zygomaticus, and B) corrugator, with data from Experiment 9, attend to category, plotted in panels C) zygomaticus, and D) corrugator.

EMG Analysis

Mimicry. The data from the exposure task can be seen in Figure 4.3, with zygomaticus responses from experiments 8 (V-V) and 9 (C-C) in Panels A and C, and corrugator responses in Panels B and D. Data were analysed for mimicry like responses.

Rapid facial reactions

Corrugator. To test for mimicry like effects, the corrugator data from the trial periods during the exposure tasks where participants viewed the valenced animals were entered into a mixed models ANOVA, with the within-subjects factors of valence (pleasant / unpleasant), block (1, 2, 3, 4) and trial period (animal / blank screen), and the between subjects factor of attention condition (attend to valence / attend to category). The analysis revealed a main effect of trial period, $F(1,34) = 12.12, p = .001, \eta^2_p = .263$, with activity in the corrugator increasing as the trial progressed. There was also a main effect of valence that was just significant, although only at the one-tailed level $F(1,34) = 4.12, p = .050, \eta^2_p = .108$, with corrugator responses greater to unpleasant than pleasant animals, a pattern that mirrored that found in the corrugator responses to angry and happy faces in the experiments in Chapter 3. There were no other significant main effects or interactions.

Zygomaticus. The same analysis of the zygomaticus revealed only a main effect of trial period, with activity increasing as the trial progressed, $F(1,34) = 30.61, p < .001, \eta^2_p = .472$.

Whilst the activity of the corrugator was similar to that found when participants were exposed to happy and angry faces during the experiments in Chapter 3, the zygomaticus, which showed consistent mimicry effects to happy and angry faces, showed no significant pattern of activity in response to the valenced animals.

Combined analysis: Comparison with facial expression data. In order to compare the reactions to the valenced stimuli with the reactions to facial expressions in Chapter 3, the data from the exposure task was compared in a combined analysis with the equivalent data from experiments 5 (I-I) and 7 (E-E). A mixed-models ANOVA was conducted on each muscle with the within-subjects factors of valence/expression (pleasant/happy / unpleasant/angry), block (1, 2, 3, 4), and trial period (face/animal / blank screen), and the between subjects factor of stimulus type (valenced animal/ expression).

Corrugator. The combined analysis of corrugator activity revealed main effects of valence/expression, $F(1,70) = 10.56, p = .002, \eta^2_p = .131$, and of trial period, $F(1,70) = 30.19, p < .001, \eta^2_p = .301$, with activity greater to the negative conditions overall, and in the latter half of the trial. There were three significant interactions, between valence/expression and trial period, $F(1,70) = 7.59, p = .007, \eta^2_p = .098$, valence/expression, trial period and stimulus type, $F(1,70) = 6.17, p = .015, \eta^2_p = .081$, and valence/expression, block and stimulus type, $F(3,68) = 3.59, p = .014, \eta^2_p = .049$. Whilst the corrugator activity in response to valenced animals was comparable to that in response to facial expressions in overall pattern, it differed over long and short term time periods.

Zygomaticus. The analysis of the zygomaticus revealed significant main effects of valence/expression, $F(1,70) = 5.78, p = .019, \eta^2_p = .078$, block, $F(3,210) = 3.11, p = .027, \eta^2_p = .043$, and trial period, $F(1,70) = 33.78, p < .001, \eta^2_p = .326$. Zygomaticus activity was collectively greater to the positive conditions overall, and during the latter half of the trial. Activity in block two significantly differed from block one ($p = .035$). The zygomaticus activity during exposure to valenced animals differed

from that elicited by facial expressions, in that significant mimicry like effects were not found. However, the overall pattern of activity in the zygomaticus did not statistically differ between the two categories of stimulus.

Predictive activations during the exposure task. Although the zygomaticus activity did not show significant mimicry activity, analysis was still run on both muscles to look for predictive activations in order to be compare back to the results in Chapter 3.

Corrugator. To test for predictive muscle activations, the corrugator data from the neutral face periods of the exposure task were entered into a mixed models analysis of variance, with the within subjects factors of valence (pleasant / unpleasant) and block (1, 2, 3, 4) and the between subjects factor of attention condition (attend to valence / attend to category). The analysis revealed no significant main effects or interactions.

Zygomaticus. The same analysis of the zygomaticus also revealed no significant main effects or interactions.

Predictive activations by mimicry group. In a replication of the analysis conducted on the predictive activations data in Chapter 3, an analysis of the data from the neutral face period was conducted which split the participants in those who showed mimicry, or in this case mimicry like effects and those who did not. Once again these were conducted separately for each muscle with mixed models ANOVAs, with the within-subjects factors of Mood (pleasant/unpleasant), Block (1,2,3,4) and the between-subjects factor of mimicry (mimicked / did not mimic).

Chapter 4

Zygomaticus. There was a significant interaction effect in the zygomaticus between mood and mimicry, $F(1,34) = 10.64, p = .003, \eta^2_p = .235$, which was followed up with separate analyses of the mimickers and non-mimickers. Whilst mimickers showed no significant predictive activations, non-mimickers showed predictive activations in the opposite direction to mimicry-like activation; main effect of mood $F(1,14) = 10.0, p = .007, \eta^2_p = .416$ and no interaction between mood and block.

Corrugator. Analysis of the corrugator data revealed a significant interaction between mood and mimicry, $F(1,34) = 7.1, p = .011, \eta^2_p = .174$. This was followed up with separate analyses for the mimickers and non-mimickers, which revealed that whilst those participants who mimicked with their corrugator showed predictive activation of that muscle in a mimicry like manner. $F(1,22) = 8.6, p = .008, \eta^2_p = .282$, an effect which did not interact with block, non-mimickers showed no predictive activations.

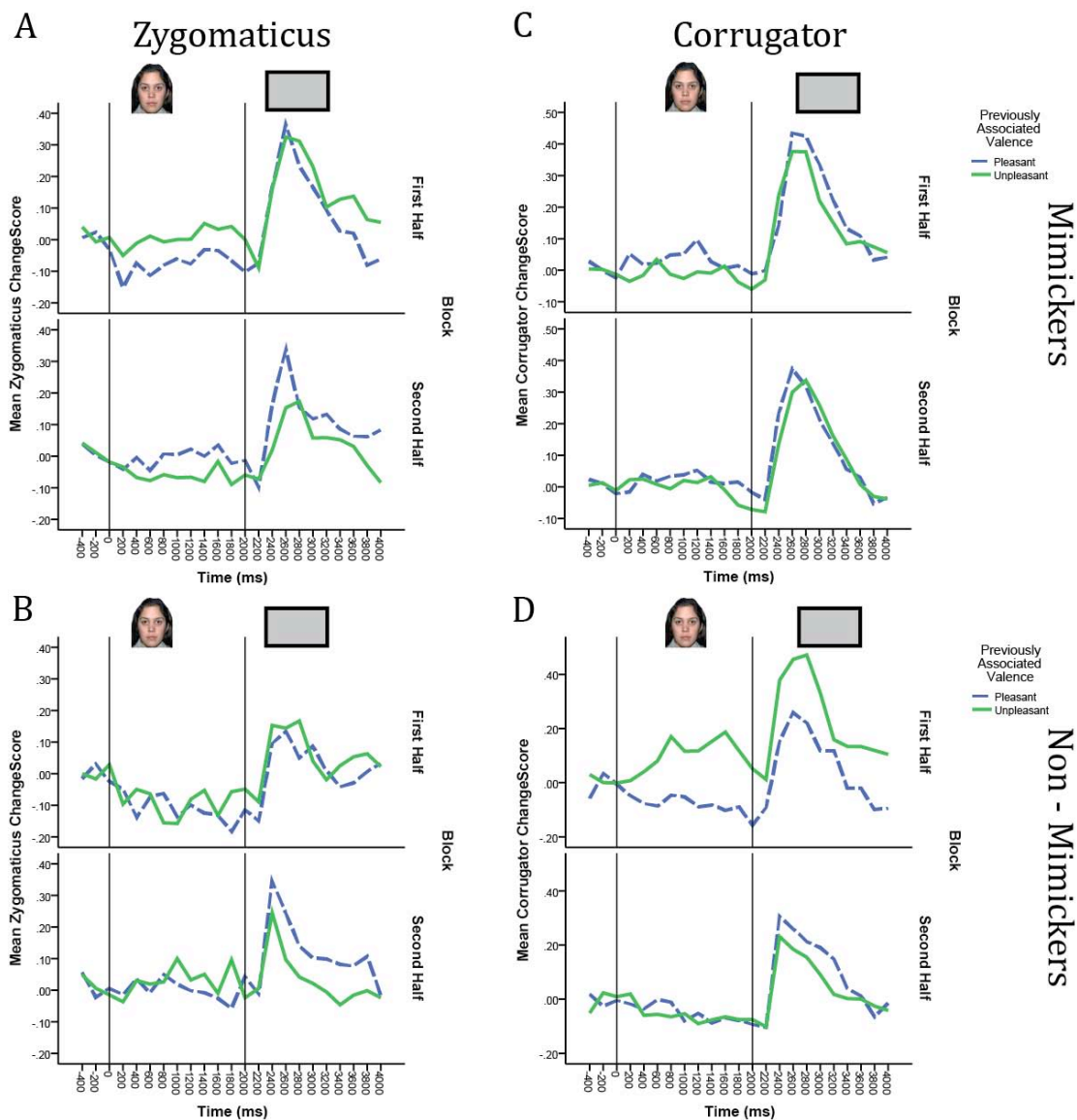


Figure 4.4. Data from trials where participants viewed neutral faces during the retrieval tasks, collapsed across V-V and C-C conditions and showing zygomaticus activity for mimicker and non-mimickers in panels A and B, and corrugator activity for mimickers and non-mimickers in panels C and D.

Implicit reactivation during re-exposure. The data from the retrieval task can be seen in Figure 4.4. Panels A and C contain the data from zygomaticus, from mimickers and non-mimickers respectively, collapsed across V-V and C-C conditions.

Chapter 4

Panels B and D contain the data from corrugator mimickers and non-mimickers respectively.

As in Chapter 3, participants who demonstrated the predicted pattern of activity in a muscle site were considered mimickers in that muscle. Twenty-three participants mimicked with their corrugator, 12 in the V-V condition and 11 in the C-C condition. Twenty-one participants mimicked with their zygomaticus, 11 in V-V condition, and 10 in C-C condition.

Although the zygomaticus, where reactivation was found in Chapter 3 did not show mimicry-like effects in the current experiments, and the mimicry-like responses in the corrugator only trended toward significance, the data from the retrieval task were analysed for reactivation effects by running mixed models ANOVAs on each muscle, and within muscle each mimicry group. Valence (pleasant / unpleasant), block (first half / second half) and trial period (neutral face / blank screen), were entered as within-subjects factors, and attention task (attend to valence / attend to category) as a between-subjects category.

Corrugator.

Non -mimickers. Analysis revealed a main effect of trial period, $F(1,11) = 10.32, p = .008, \eta^2_p = .484$, with corrugator activity greater in the later period of the trial. No other main effects were significant. There was a significant interaction between valence and block, $F(1,11) = 5.47, p = .039, \eta^2_p = .332$, which when explored with paired t-tests revealed that in the first half of the experiment, corrugator activity in non-mimickers was greater in response to faces previously paired with negative animals, $t(12) = 4.2, p = .001$, and in the latter half the effect in the corrugator reversed, and non-significant, $t(12) = .463, p = .652$

Chapter 4

Mimickers. Analysis of those participants who mimicked with their corrugator revealed only a main effect of trial period, $F(1,21) = 15.18, p = .001, \eta^2_p = .420$, with activity increasing over the course of the trial.

Zygomaticus.

Non-mimickers. The only significant effects in the analysis of zygomaticus non-mimickers were a main effect of trial period, $F(1,13) = 8.51, p = .012, \eta^2_p = .396$, with activity increasing over the course of the trial, and an interaction between block and trial period, $F(1,13) = 7.37, p = .018, \eta^2_p = .362$, where the means indicated that the effect of trial period reduced in the second half of the task..

Mimickers. Only a main effect of trial period was found in the analysis of participants who mimicked with their zygomaticus, $F(1,19) = 18.44, p < .001, \eta^2_p = .493$, with activity increasing in the zygomaticus in the latter part of the trial.

The analysis of the data from the retrieval task indicated that the muscle activity was not reflective of that found when participants viewed faces who had previously shown facial expressions of emotion. The zygomaticus showed no retrieval effects in response to faces who had previously been paired with positive or negative animals. The only effect in the corrugator was a transient difference during one trial period in non-mimickers, where activity was greater in response to faces previously paired with negative animals.

4.3.3 Conclusions

The analysis of the data from the exposure tasks, where participants attended to either the valence of the animals that the identities morphed into, or changes to

Chapter 4

category when identities became cars, hinted that in the corrugator, mimicry like effects occurred. In the zygomaticus no mimicry like effects were found. A comparison with the data from the attention consistent tasks in Chapter 3 demonstrated that the zygomaticus activity elicited from exposure to the valenced animals was not statistically different in pattern to that elicited by emotional faces, and that the corrugator activity that appeared mimicry like in response to valenced animals, differed in terms of its long and short term temporal qualities, over block and trial period. There was no evidence of predictive activation in either muscle in either the valence of category attention conditions during the exposure task. Analysis of the retrieval task confirmed our hypothesis that facial mimicry like effects made in response to valenced animals would not be reactivated during later viewing of the neutral faces associated with those animals in the same way it did for faces whose expressions had previously been mimicked. The only hint of any retrieval occurred in the corrugator non-mimickers, who showed a very transient response during the first half of the retrieval task. Importantly, neither mimicry like effects or any hint of retrieval effects were found in the activity of the zygomaticus, unlike the responses seen in the experiments in Chapter 3.

4.4 Discussion

The experiments in this chapter explored the possibility that the effects shown in Chapter 3, where participants retrieved their zygomaticus mimicry when later exposed to neutral faces that had previously appeared happy or angry, might not have been caused by the retrieval of simulation, but by emotional value associated with the stimuli. Past research has shown that emotional expression carry social-emotional value (Shore &

Chapter 4

Heerey, 2011) and that viewing another's expression causes rapid emotional responses in the viewer (Geday, Gjedde, Boldsen & Kupers, 2003). As emotional but non-facial stimuli can cause facial reactions that are similar to facial mimicry (e.g. Codispoti et al., 2009; Dimberg, Hansson & Thunberg, 1998; Dimberg & Karlsson, 1997), and this has been suggested to be underpinned by rapid emotional reactions (Tamietto et al., 2009), our facial mimicry effects might be explained by emotional valence and not simulation. Also, in accordance with ideas of somatic markers, our retrieval effects might represent implicit reinstatement of emotional responses and not simulations (e.g. Bechara et al., 1997).

However, we posited at the start of this chapter that as suggested by the findings of Halberstadt et al., (2009) our data represent a process of simulation that is facial emotion specific. Whilst emotional but non facial-expression stimuli might cause rapid facial responses, that as suggested by Tamietto et al., (2009) and Niedenthal et al., (2010), facial expressions cause both emotional and simulation responses because of their motor component. We hypothesised that in the experiments in this chapter, valenced animals might cause emotion-based mimicry like responses during exposure, but that as in accordance with the findings of Halberstadt et al., (2009), no retrieval effects would occur, as these would should only occur with facial expressions.

In the two experiments in this chapter, participants carried out identical tasks to the ones where retrieval effects were strongest in Chapter 3, except that this time instead of faces morphing into expressions, they morphed into valenced pleasant or unpleasant animals, with the same consistency of facial identity to positive or negative valence, as there had been to happy or angry expression. The data muscle activity elicited during the exposure tasks where participants viewed the faces become animals,

Chapter 4

indicated that in the corrugator there was a weak mimicry like reaction to the stimuli. The zygomaticus did not show this reaction but did not differ in overall activity pattern to the activity elicited in experiments 5 and 7, where participants attended to emotion or identity. However, there was no sign of any predictive mimicry like activation in either muscle, in line with our hypothesis that this should not occur when stimuli are not facial expressions.

The conditions of the retrieval tasks in experiments 8 and 9 matched the consistency of experiments 5 and 7 in that those experiments had the participants either attend to emotion upon encoding and emotion upon retrieval, or identity and identity, while the new experiments had participants attend to valence and valence or category and category. The data from the retrieval task confirmed our hypothesis that retrieval effects should not occur for valence stimuli as they do for facial expression stimuli, even in participants who showed mimicry like responses, during consistent task conditions. In the zygomaticus, the key comparison, as this was where retrieval effects for faces were found, there was no sign of any retrieval. In the corrugator only those participants who had not mimicked showed any hint of retrieval. This was very transient in nature, occurring only in the first half of the retrieval task. Further research could investigate whether those individuals whose facial muscle activity does not show the expected activations for emotive stimuli consistently behave differently in tasks like ours. However, it is important to our current research question that these participants were not reinstating a prior body state. No evidence of reactivation was found amongst the participants who contributed to the trending mimicry like effect in the corrugator during exposure, and so we conclude that unlike the facial expressions in Chapter 3, the

Chapter 4

valenced stimuli did not cause retrieval of the body states they elicited in the participants.

The experiments in this chapter suggest another boundary condition for the reinstatement of prior body states; that this implicit retrieval only occurs when facial reactions are elicited by other people's expressions and not by other kinds of positive and negative emotional stimuli. In sum the experiments in this half of the thesis present the first evidence that as well as facial expressions causing automatic simulation in a viewer, these simulations are also automatically reactivated upon later re-exposure when no cue to a person's emotion is available. This appears to occur, as facial mimicry does, even when emotion is not relevant, and our data therefore support the idea that simulations of other's body states may play a role in understanding their internal states, but also beyond that, in predicting their future states.

Chapter 5

Incidental Encoding of Other's Pupil Size

5.1 Summary

Pupil size offers a very subtle cue as to the internal arousal state of another individual, just as facial expression does. Whereas facial expressions are very much overt indicators of emotion, pupil size appears to often be perceived without conscious awareness, but still exerts mimicry like influences on the perceiver. The effects of pupil size on person perception have been demonstrated in past research where pupil size caused changes in participant's feelings about faces at the time of unconscious detection of the cue. However, no past research has ever shown that pupil size is encoded and can cause lasting changes in person perception. Using a similar paradigm to that used in the previous experiments on facial expression simulation, we show for the first time that pupil size is indeed encoded into long term memory to cause changes in the way individuals are perceived that go beyond the time of an initial interaction. These effects are shown to occur without the participant's awareness and to be stronger in female participants than male participants. They also appear to be influenced by the static traits a face possesses, such as sex and trustworthiness.

5.2 Introduction

The experiments in Chapters 2 to 4 demonstrated that when we see another person's emotional expression, we embody, or simulate that state with our own facial

muscles. When we experience that person again, we reactivate that simulation in a manner that is predictive of the emotional state we now expect from that individual. This embodiment occurs even when we are not actively attending to the person's expression. These results were discussed in relation to the idea that these rapid facial responses (and their reinstatement) represent the activation of a system that automatically aligns our basic emotional state with that of another person, through physical embodiment of their outward emotional body language. This system is suggested to work alongside the action observation system in decoding social cues, facilitating joint action, but also allowing us to rapidly pick the best course of action for our individual benefit (Avenanti, Candidi & Urgesi 2013; de Gelder, 2006).

As discussed in Chapter 1, the human visual system appears to be particularly sensitive to certain very salient social cues from the human face. Humans are very social creatures, and our brains may have evolved in the way that they have done, partly due to the need for the cooperation of large social groups (Silk, 2007). It is perhaps not surprising therefore that, for example, when we detect the direction of another person's gaze, our own gaze is automatically drawn in the same direction (Driver, et al., 1999). Our brains respond to the appearance of large fearful eyes, even if we do not consciously perceive them (Whalen, 2004). And when we perceive facial expressions, these exert automatic effects of both our own facial muscles, and our autonomic systems, that we are unable to override (Dimberg, Thunberg & Grunedal, 2002; Tamietto et al., 2009).

As shown in Chapter 3, these embodied responses, where our own physical state is aligned with another person's, do not simply exist at the moment of interaction, but appear to be encoded alongside the identity of the individual, to be retrieved when we

meet them again. These effects are in line with the idea that the human brain is not only responsive to other's social actions, but also predictive, preparing us to respond appropriately before another person has acted (Frith & Frith, 2006; Kilner, Vargas, Duval, Blakemore & Sirigu, 2004). This process may occur through the forward modelling of other's actions (i.e Kilner et al., 2004; Pelphrey, Singerman, Allison & McCarthy, 2003; Saxe, Xiao, Kovacs, Perrett & Kanwisher, 2004), but it may also be the case that we attach to other people affective or semantic labels which change our representations of them in a manner that prepares us for later encounters with them.

Gaze cueing studies have provided evidence of this. In these studies participants respond to laterally presented targets, either simply detecting (Friesen & Kingstone, 1998), or categorising (Bayliss & Tipper, 2006; Bayliss, Griffiths & Tipper, 2009; Driver, 1999) the targets. Faces are presented centrally at the start of each trial, and these gaze left or right just before the presentation of the target, either looking towards where a target is about to appear (congruent) or in the opposite direction (incongruent). Despite being told that the faces are not task relevant, the participants attention is drawn by the eye gaze, causing a cueing effect with faster reaction times to congruent than incongruent face trials. In studies that have controlled for the behaviour of the faces, making some look consistently in the direction of forthcoming targets, and other consistently away, evidence of changes in person perception were shown when the participants were later probed about the faces (Bayliss & Tipper, 2006; Bayliss, Griffiths & Tipper, 2009). Predictive-invalid faces, those who looked consistently away from where the target would appear, were judged as less trustworthy than their companion predictive-valid faces. Importantly this effect occurred despite the participants reporting later that they were not aware that the faces had contingencies. These

experiments represent a situation where a body state was shared between two actors (participant and stimulus) and the results of this shared state (slowed/sped reactions to a target) caused a change in the lasting representation of one actor in the eyes of the other. This of course was not driven by a reinstatement of the shared state, as in the earlier experiments in this thesis, but most likely by the addition of an emotional marker (Damasio, 1989) to the stimulus face, which of course may be underpinned by physical reactions to that emotion (an on-going topic of investigation).

Embodied responses that affect our representations of others may be caused by a reactivation of a previously embodied action state associated with an individual. For example, seeing the face of a famous footballer or tennis player speeds reactions with feet and hands respectively (Bach and Tipper, 2006). The face alone is of course inactive, but the association is enough to cause a simulation in the viewer, preparing the relevant body part for action. Importantly though, this effect also works in reverse. The association of a fluent hand or foot response with a previously unknown person, can cause a change in the percept for that individual (Bach & Tipper, 2007; Tipper and Bach, 2008). In a series of experiments, participants identified two actors by means of a finger or foot button response. The actors appeared an equal number of times in videos where they were conducting a foot related (football kicking) or hand related (typing) action. For every participant one of these actions was of course fluent with the response they made themselves in order to identify the actor, and it was shown that it was this motor fluency, the shared body state between participant and actor, that later caused person percept changes, with actors who had been fluent with hand actions being seen as more academic, and those who had been fluent with foot actions more sporty.

These lasting effects of embodying another's body state on our long-term representations occur in response to very overt cues, such as gazing, smiling, frowning or kicking. However, some cues are far subtler but are equally a marker of a state in another person that should be attended to and remembered. Pupil dilation is one such cue, and this chapter considers the question of whether pupil dilation is not only a cue that might elicit changes in how we consider a person during an interaction, but also change our long term representation of them.

The Pupillary Response. The pupil, the small hole at the centre of the iris, allows light to pass into the eye. The amount of light that can pass through the pupil is controlled by its constriction and dilation; operations enacted by the sphincter pupillae, and dilator pupillae muscles of the iris respectively. The most common causes of pupil size change are physical processes (Andreassi, 2007). The pupil is involved in the accommodation reflex that the eye performs when focussing. Its role in this response is to reduce the scattering of light from the edges of the cornea by dilating when objects are far away, and constricting when they are close. Changes in pupil size also prevent too much light entering the eye and damaging the cornea, and allow greater amounts of light into the eye when light levels are low.

Pupil constriction is controlled by activity of the parasympathetic nervous system, with signals to the sphincter pupillae originating in a mid-brain region called the Edinger-Westphal nucleus (EWN). Pupil dilation is controlled by the sympathetic nervous system, with signals to the dilator pupillae originating in the hypothalamus. These control systems allow for changes in pupil diameter ranging between approximately 1.5mm and 9mm (Guyton, 1977, cited in Andreassi, 2007).

Psychological Influences on Pupil Size. Although the majority of pupil size changes occur due to physical processes, psychological processes appear to exert an influence on pupil size that can override these more commonly occurring mechanisms. Such processes include states of arousal, and increasing cognitive load. These processes induce changes in the activity of the sympathetic and parasympathetic systems, and in turn on pupil diameter. Because we don't feel our pupils change size, and we can't consciously control them, these effects are very interesting to cognitive and social psychologists. If carefully measured, they offer an insight into the internal state of an individual that is more objective than other means, in much the same way as the facial EMG captured in the earlier chapters of this thesis. Pupil size has in the past been measured with ordinary video cameras, or special infrared cameras. More recent research most commonly uses eye-tracking equipment, which uses very high frequency infrared video capture to track the position, but also the size of the pupils.

A painful stimulus such as an electric shock, which causes negatively valenced arousal in a recipient, also causes pupil dilation, which correlates in size with perceived pain (Ellermeier & Westphal, 1995), and is resistant to the pupil's light reflex (Hofle, Kenntner-Mabiala, Pauli & Alpers, 2008). Positive, arousing stimuli also cause pupil dilation, including images of babies, and nudes (Hess & Polt, 1960). One study that used positive, negative and neutrally valenced images, with arousal balanced across the positive and negative stimuli, demonstrated that pupil dilation is arousal and not valence sensitive. The participant's pupils grew equally large in response to positive and negative images, as long as they were arousing in nature. Interestingly, correlations of this response with electrodermal activity but not with heart rate deceleration,

indicated that this pupillary response was controlled by sympathetic and not parasympathetic activity (Bradley, Miccoli, Escrig & Lang, 2008).

Pupil size changes have also been observed during problem solving, with pupil dilation increasing with the difficulty of mathematical challenges (Hess & Polt, 1964). The size of a digit string to be held in short-term memory also correlates positively with the amount of pupil dilation during this task (Kahneman & Beatty, 1966). One study asked participants to observe the Necker Cube visual illusion while their pupil size was measured. A pupil dilation response occurred at the time the participants reported seeing the illusion visually shift, which is thought to represent a shift in visual attention. Interestingly the pupil dilation preceded the participant's conscious awareness of this shift by 200ms (Einhauser, Stout, Koch & Carter, 2008). Pupil size changes therefore appear to not only represent internal states of arousal, concentration or shifts in attention, but also may provide an external cue to states that a person is not yet consciously aware of themselves (for a review see Laeng, Sirois & Gredeback, 2012).

The engagement and disengagement of attention are thought to influence pupil size, through the action of the norepinephrinergic (NE) system which is thought to control whether attention is focused upon a salient stimulus, or left to wander so to speak, in order to better detect novel stimuli in the environment (see Aston-Jones & Cohen, 2005). The NE system exerts influence on pupil dilation and constriction responses by action upon the Edinger-Westphal nucleus and hypothalamus. Pupil dilation may reflect phasic activation of the NE system, as a stimulus of interest is sighted, and further pupil dilation may occur if that stimulus then proves to be arousing. For example, Laeng & Falkenberg (2007), showed female participants images of their boyfriends, favourite actors, actresses and other women's boyfriends. Pupil size

measurement showed that when the participants were in the most fertile period of their ovulatory cycle, their pupils dilated more to their boyfriends and favourite actors than to the other categories. The participants were unaware of any extra motivation towards these sexually relevant stimuli at the time, but their pupils indicated an unconscious additional engagement of attention, and potentially state of arousal.

The Effects of Other's Pupil Size on Person Perceptions. Pupil size changes appear to offer a signal of another person's internal state in a similar but far more subtle way than facial expression, and in one way more interesting as it cannot be consciously controlled. However, it is an extremely subtle cue, compared with gross movements of the facial muscles. Given that the brain appears to have specially developed systems for dealing with information from the eye regions of another's face though, it is perhaps not surprising that research evidence suggests that other people's pupil size is indeed detected, and without the conscious awareness of the observer.

For example, Hess (1965) showed male participants images of female faces that were identical, except that one face had had its pupils manipulated to make them look larger. The participants perceived the faces with 'dilated' pupils as being 'soft', 'more feminine' and 'pretty', while the face with the smaller pupils was seen as 'hard' and 'cold'. Male participants have been shown to find female faces with dilated pupils more attractive than those with average sized or constricted pupils (Bull & Shead, 1979; Tombs & Silverman, 2004), and male participants are more likely to choose a female partner to carry out a task with if her pupils have been artificially caused to dilate (Strass & Willis, 1967). When men have viewed male faces with different sized pupils, the results are not as clear however. Bull and Shead (1979) reported no effect in their

participants, whilst Tombs and Silverman (2004) reported a 'linear relationship' but not its direction.

Female participants have been shown to prefer other women's faces with dilated pupils, to those with constricted or average sized pupils (Tombs & Silverman, 2004). Although the reverse has also been reported (Hicks, Reaney & Hill, 1967). When viewing male faces, Bull and Shead (1979) reported no effects of pupil dilation on women's perceptions of attractiveness, but effects related to individual differences in the faces and the observers have been reported. For example, attractive male faces appeared more attractive to female observers when the faces had dilated pupils (Hicks, Pellegrini & Tomlinson, 1978), while pupil size did not influence ratings of less attractive faces. Tombs's and Silverman's (2004) study interestingly reported a correlation between preferences for male faces with dilated pupils, and preferences for 'bad boy' type personality characteristics. It is important to point out that in all of these studies, the participants did not report any awareness of the pupil size manipulations.

So pupil size changes do seem to influence immediate decisions about how we feel about another individual. The evidence suggests these are not purely aesthetic influences, but are more likely driven by an unconscious understanding of what pupil dilation or constriction means in another person. And the effect that this has on our perceptions may be influenced by who the other person is, at least when women look at men's faces. If pupil size is unconsciously being read as a sign of arousal or engaged attention, it is perhaps not surprising that this may be interpreted in the context of who the owner of the pupils is. Women's preferences for masculine faces have been shown to vary across individuals, as well as stages of the hormonal cycle (Jones et al., 2008; Little & Jones, 2012; Penton-Voak et al., 2012; Scarborough & Johnston, 2005), with

masculine features suggested as representative of healthy genes, but lower levels of trustworthiness and higher potential for aggression. It may be the case therefore that when women view male faces alongside female faces the contrast between the two genders drives differential responses to pupil size in most participants.

Cortical Activity and Pupillary Contagion in Response to Other's Pupil Size.

Emotional faces are known to cause cortical responses even when not consciously perceived (Tamietto & de Gelder, 2010, for review; Whalen et al., 1998; Williams, Morris, McGlone, Abbot & Mattingley, 2004), as well as contagious physical effects such as the alignment of one's facial muscles with the current emotional state of a visually masked body (Tamietto et al., 2009). In a similar manner, pupil size differences have been shown to evoke cortical responses in regions of the brain associated with emotion and face processing, without conscious awareness, and to evoke contagion responses in observer's own pupils. Demos, Kelley, Ryan, Davis & Whalen (2008) reported bilateral activation of the amygdala in male participants when they saw female faces with dilated, as opposed to constricted pupils. The activations were not related to later reported attractiveness ratings, so appeared to be specifically driven by detection of the pupil dilation and not by overall impressions of the face. A second study replicated these findings (Amemiya & Ohtomo, 2011), and also found similar activations in the insular cortex, which has been implicated in representations of self and other's internal states (see Walter, 2012). Interestingly this study found these activations only in response to human and not cat faces, and in Japanese participants (who will have been used to dark eyes which hide pupil signals) looking at western faces. Again, suggestive of a hard wired process for reading pupillary signals in conspecifics.

Chapter 5

Just as facial expressions were shown in the earlier chapters of this thesis to cause automatic matching responses in observer's own facial muscles, pupil size changes have been shown to cause automatic matching responses in observer's pupils. This was first shown by Hess (1965), using very basic schematic representations of big, medium and small pupils, which elicited matching changes in the size of participant's pupils. The effect appeared to be driven not by luminance differences, but by the specific pupil-like properties of the drawings, because it only occurred when these rough representations of eyes were presented in twos, and not in ones or threes. This pupillary contagion effect has been linked to empathy-like responses. Sad faces with constricted pupils appeared significantly sadder than the same faces with average or dilated pupils (Harrison, Wilson & Critchley, 2007), and this effect on emotion judgements, also found when participants were fMRI scanned whilst viewing the faces, was modulated by the degree to which the participant's own pupils constricted in response to the face's (Harrison, Singer, Rotshtein, Dolan & Critchley, 2006). Activity of the left amygdala, and superior temporal sulcus correlated with this contagion response, and these brain regions which have been implemented in tracking facial expressions and gaze direction, were also shown to activate preferentially when a participant's pupils were, unknown to them, mimicked in size by the pupils of a facial stimulus they were viewing. If the face's pupils acted incongruently to the participant's, i.e getting bigger when the participants' became smaller or visa-versa, this appeared to be tracked by activity of the anterior cingulate cortex, amygdala and left insular cortex. (Harrison, Gray & Critchley, 2009). The parallels with the neuroimaging data discussed in Chapter 1, suggest that similarly to when we embody someone else's emotional expression with a rapid facial response, viewing another person's pupil's change size

may trigger an automatic embodiment, whereby our own autonomic responses are activated by aligning this one physical state with the person we are viewing.

The Current Experiment. Pupil size changes appear to represent internal states that are very salient during a social exchange but not usually consciously perceived by interaction partners. This very subtle social cue appears to be unknowingly detected in one person, by another, and can change the way that a person is perceived. This process appears to be modulated by who the owner of the pupils and the observer are, and may be caused by an embodiment of one person's pupil size by the other person. One question that has never been addressed however is whether similarly to more gross, physical actions, such as gaze, or emotional expression, pupillary cues might be encoded into long term memory. It seems a sensible hypothesis that if we meet someone multiple times, and we unconsciously detect a change in their pupil size on each occasion, this information should change our long term perceptions of that person. When we meet them again, our feelings about them should be affected by their prior pupil size, even if at this current time their pupils are not providing a cue to their current internal state. Theories of embodied emotion (Damasio, 2006; Danker & Anderson, 2010 for review), suggest that when we re-experience a stimulus which was encoded in the past in association with a sensory-motor state, such as a state of autonomic arousal, this state should be reactivated automatically upon re-exposure to that stimulus. It may be the case that in a similar manner to the retrieval of facial mimicry activations, any effects of encoded pupil size change are driven by a reactivation of pupillary contagion. This in turn might cause a reactivation of the same arousal state experienced on initial exposure to an individual (see Niedenthal, 2005), a

Chapter 5

state which would then be interpreted by the observer in whom it has been reactivated, in terms of the contextual factors, such as whether the face they are looking at belongs to a man or a woman, or a trustworthy or dangerous looking character.

Experiment 10 uses a novel paradigm to address the first key hypothesis. When participants are exposed on multiple occasions to faces whose pupils consistently dilate or constrict, it is predicted that despite their being unaware of these changes, their later perceptions of the faces will have been affected by them, so that faces whose pupils dilated will be perceived differently to those whose pupils constricted. Importantly, this will occur when the faces are being rated whilst appearing with average sized pupils, so any effects of earlier pupil size changes must be exerted through encoding into long-term memory.

5.3 Experiment 10: The effects of pupil size changes on long-term person perceptions

5.3.1 Method

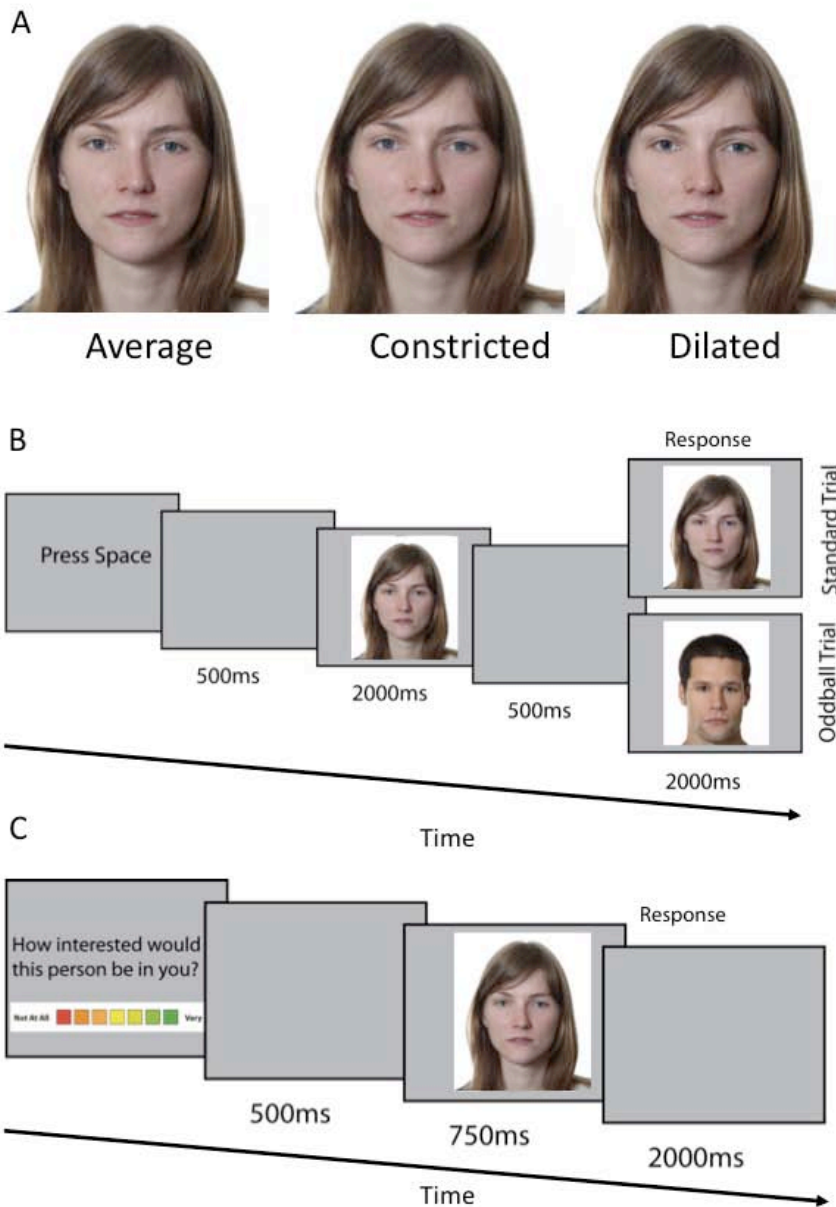


Figure 5.1. Panel A) Example stimuli. Panel B) Trial procedure from the vigilance task. Panel C) Trial procedure from the ratings task.

Participants

Participants were 27 female undergraduate students from Bangor University, Wales, recruited via the School of Psychology participation panel (mean age 19.9 years, SD = 3.0 years). All participants gave informed consent and had normal or corrected to normal vision. The participants were given course credits as compensation for their time. Female participants were initially tested, in order to retain consistency with the facial EMG studies in previous chapters.

Stimuli

The stimuli consisted of 20 colour photographs of adult faces, selected from a larger database of headshots of past university students, pre-rated for attractiveness. From this set, 10 female and 10 male faces, consisting of 10 pairs of sex and attractiveness matched faces were chosen. The photographs had all been taken under the same lighting conditions against a white background, cropped at the neck, and sized to the same dimensions.

Photo editing software was then used to manipulate the pupil size of each face (see Figure 5.1 Panel A). Version of each face were created with average (as shot), large (33% larger) and small (33% smaller) pupils. The final stimulus set therefore consisted of 60 images.

During the experiment the participants were exposed to 10 faces whose pupils would become dilated, and 10 whose pupils would become constricted. Within each condition five faces were female and five were male. To control for attractiveness, one

member of each attractiveness and sex-matched pair was always in the dilated condition and the other member in the constricted condition. Assignment to condition was quasi randomised for each participant, considering these restrictions.

Procedure

The experiment consisted of two tasks. The first vigilance task was designed to expose the participants to the faces, and unknowingly to the changes in pupil size. In this task each face identity possessed a consistent pupil change, always dilating or always constricting, over 10 exposures. The second ratings task was designed to measure the participant's assessments of the faces, when the faces were presented once again, with average pupils.

Vigilance Task. Participants initiated each trial with a space bar press. A blank screen with duration 500ms was followed by the presentation of a face, which remained on screen for 2000ms. This initial face always appeared with average sized pupils, and was always followed by the presentation of a second face, duration 2000ms, whose pupils were either dilated or constricted. A blank interval of 500ms was placed between the two faces. Previous studies of change blindness have confirmed that a 500ms interval is sufficient to block awareness of substantial changes to scenes, and of particular relevance here, changes to person identity (e.g., Simon & Levin, 1998). This procedure was therefore employed to prevent the majority of participants from gaining awareness of the very subtle changes in pupil size (see Figure 5.1, Panel B). Participants completed 240 trials over five blocks. In 40 trials per block the second face to appear was identical to the initial face, except for the change in pupil size. In these trials participants passively observed the faces, making no response. In eight

catch trials per block, the second face to appear differed in identity from the first. Participants were told to respond to these catch trials with a space bar press. Every face appeared twice in each block in standard trials, and twice over the entire course of the task in oddball trials; once as the first half of an oddball and once as the second half. Importantly, when the face appeared as the second presentation in a trial, it always displayed the pupil size condition assigned to it, regardless of standard or oddball trial-type. Prior to starting the task participants undertook a short practice, with non-experimental faces as stimuli. Errors during the task resulted in a siren tone.

Ratings Task. During the ratings task participants were re-exposed to the faces from the vigilance task, but importantly the faces now appeared exclusively with average sized pupils. Two questions were used to gauge the participant's assessments of the faces: 'How friendly is this person?' And 'How interested would this person be in you?' Responding required participants to use a set of seven colour coded keys which ranged from red, which corresponded to a 'not at all' response, through orange and yellow, to green, which corresponded to a 'very' response. The task consisted of two blocks of 40 trials, with each face appearing once in relation to each question in each block. The order of faces and questions was randomised within block. At the start of each trial the question to be answered was presented, along with a graphic of the response keys. After a space bar press to initiate the trial followed by a 500ms blank, a face was presented for 750ms and then the screen went blank until the participant made their rating, and for 2000ms afterwards (see Figure 5.1, Panel C). Participants undertook a short practice before starting the task, during which non-experimental stimuli were presented.

Debriefing. After completing both tasks participants were given the

Chapter 5

opportunity to report their thoughts about the experiment on paper. The experimenter also asked them whether they had spotted any changes or variations in the stimuli in the exposure task, which had been described in briefing as a sustained vigilance task. Of the 27 participants tested, 25 were naïve to the pupil manipulation. Only the data from these 25 participants were analysed.

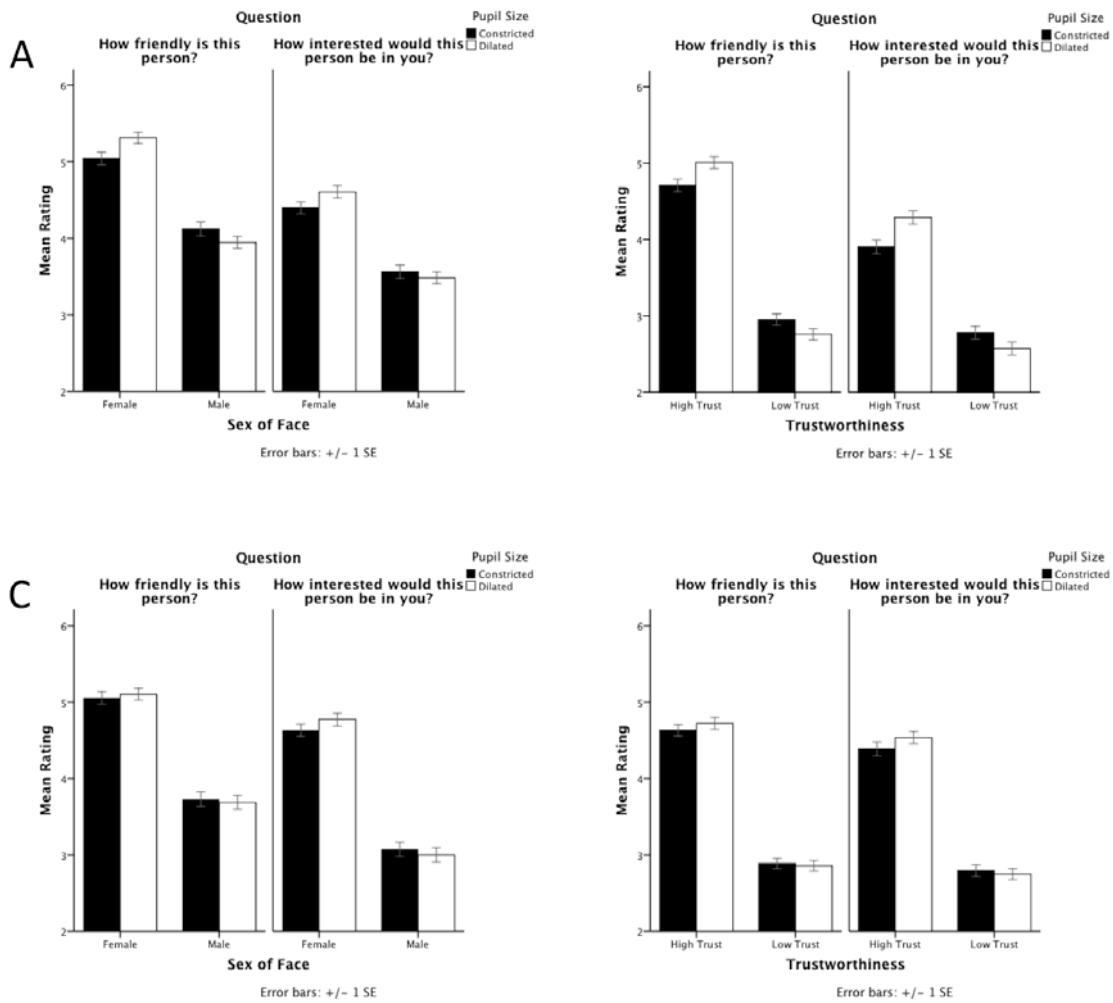


Figure 5.2. Data from the ratings tasks for Experiment 10 (Panel A), Experiment 11 (Panel B), Experiment 12 (Panel C) and Experiment 13 (Panel D).

5.3.2 Results

Vigilance Task

Participants demonstrated a high level of accuracy when responding to both standard and oddball trials during the vigilance task. Participant's responses to standard trials were accurate 99% of the time (SD = 0.09%), with accuracy to oddball

trials also at 99% (SD = 0.11%). From this it can be concluded that participants were attentive to the stimuli.

Ratings Task

The participant's ratings data can be seen in Figure 5.2 panel A.

The ratings participants gave the faces during the ratings task were entered into a within subjects ANOVA. Pupil size (dilated/constricted), sex of face (female/male) and question (how friendly is this person?/how interested would this person be in you?), were included as within subject factors. There were significant main effects of both sex of face, $F(1,24) = 59.13, p < .001, \eta^2_p = .71$, and question, $F(1,24) = 34.60, p < .001, \eta^2_p = .59$. Participants gave higher ratings to female faces than to male faces and gave higher ratings when asked how friendly they found a face than when asked how interested they thought a face would be in them.

There was no main effect of pupil size, $F(1,24) = 0.43, p = .520, \eta^2_p = .02$ but a significant interaction was found between pupil size and sex of face, $F(1,24) = 7.40, p = .012, \eta^2_p = .24$. Post-hoc t-tests revealed that whilst participants rated women whose pupils had enlarged more highly than those whose pupils had become smaller ($t(24) = 2.26, p = .033$) there was a trend for the opposite pattern in male faces where enlarged pupils were rated less highly than those whose pupil had become smaller ($t(24) = 1.16, p = .257$).

5.3.3 Discussion

The results of Experiment 10 demonstrate that when female participants are exposed to subtle changes in pupil size during an incidental-viewing task, these changes are encoded into long-term memory. Despite the participants being unaware of the pupil size changes, their perceptions of the faces they saw during the vigilance task were affected in the later ratings task by whether a face's pupils had previously dilated or constricted. Most importantly this occurred despite the faces appearing in the ratings task with average sized pupils. This is the first demonstration of such an effect

The findings of Experiment 10 are in line with the general hypothesis that pupil size is automatically perceived, without the need for conscious monitoring, and causes changes in the bodily state of the perceiver, bringing them into a similar state to the person whose pupil size change they have detected. It may be effects of the retrieval of this shared state on later perceptions that we are measuring. However, this first study only provides behavioural evidence that pupil size changes causes lasting changes to person representations.

Interestingly the sex of a face modulated the way in which its pupil size affected the female participant's judgements. Female faces whose pupils had previously dilated, were judged more positively than those whose pupils had previously constricted. The opposite effect was true for male faces. This finding is in line with that of Tombs and Silverman (2004) who found the majority of their female participants did not prefer a male face with dilated pupils. It may be the case, as suggested in the introduction to this chapter, that this effect is driven by the characteristics of a male face that make them appear less trustworthy and potentially more aggressive than their female

counterparts. Pupil dilation in male faces may be judged as an indicator of an unwanted and potentially threatening state of arousal.

Therefore in Experiment 11, only male faces were used as stimuli. This time the face set consisted of men rated as having highly trustworthy, or untrustworthy faces. There are two hypotheses to be tested in this experiment. Firstly, it may be the case that for female participants, all male faces with dilated pupils are represented negatively in long-term memory. In this case there should only be a main effect of pupil size on ratings, and perhaps a main effect of trustworthiness, but no interaction between pupil size and trustworthiness. On the other hand, it may be the case that when paired with untrustworthy looking men, trustworthy looking men are perceived in a similar way to women, in which case an interaction between trustworthiness and pupil size would be expected.

5.4 Experiment 11: The effects of high and low trustworthiness on pupil size induced changes in long-term person perceptions.

5.4.1 Method

Participants

Thirty-one female undergraduate students (mean age 24.1 years, SD = 6.2 years) were recruited from the participation panel at the School of Psychology, Bangor University, Wales. All participants gave informed consent and were tested to ensure they have normal or corrected to normal colour vision. The participants were compensated for their time with course credits.

Stimuli

The stimuli consisted of 20 male faces, selected from a larger database of male faces, including faces from the Kramer and Ward (2010) face set, and faces sourced online. The faces in this database had been rated for attractiveness and trustworthiness. The final stimuli consisted of 10 faces rated as high in trustworthiness and 10 faces rated low in trustworthiness, with each group made up of 5 pairs, matched as closely as possible for attractiveness. The same background and cropping applied, as in the previous experiment. The same photo editing was applied to manipulate the pupil sizes of the faces, creating the final 60 stimuli.

Procedure

The procedure was identical to that of the previous experiment, including the debriefing procedure. At debriefing, six participants were found to have spotted the pupil manipulation, and their data were removed from the analysis.

5.4.2 Results

Vigilance Task

Accuracy in the vigilance task was at 99% (SD = .09%), with accuracy on oddball trials at 98% (SD = .13%).

Ratings Task

The participant's ratings data can be seen in Figure 5.2 panel B.

The participants' rating of the trustworthy and untrustworthy faces were entered into a within subjects ANOVA, with pupil size (dilated/constricted), trustworthiness (high/low), and question (how friendly?/how interested?) as three, two level factors. Main effects were found for trustworthiness, $F(1,24) = 122.99, p < .001, \eta^2_p = .86$, and for question, $F(1,24) = 12.55, p = .002, \eta^2_p = .34$. Participants gave trustworthy faces significantly higher ratings than untrustworthy faces. And, as in Experiment 1, participants gave higher ratings in response to the question 'how friendly is this person?' than in response to the question 'how interested would this person be in you?'

No significant effect of pupil size was found, $F(1,24) = 1.58, p = .221, \eta^2_p = .06$, but the interaction effect between pupil size and trustworthiness reached significance at $F(1,24) = 11.83, p = .002, \eta^2_p = .03$. Post hoc t-tests revealed that high-trust faces whose pupils enlarged, were given higher ratings than those whose pupils became smaller ($t(24) = 4.71, p < .001$). In contrast, low-trust faces whose pupils became larger, were given lower ratings than those whose pupils became smaller ($t(24) = 2.56, p = .014$).

5.4.3 Discussion

The results of Experiment 11 replicated the effects of encoded pupil size first demonstrated in Experiment 10, in that the participant's perceptions of the faces they were exposed to in the vigilance task were differentially affected in the later viewing task by whether a face had previously appeared with dilated or constricted pupils. Interestingly, low trustworthiness faces were rated in the same way as male faces in Experiment 10, in that they were given lower ratings of friendliness and interest if they

had previously appeared with dilated as opposed to constricted pupils. However, high trust male faces were rated in the same way as female faces had been. They were viewed more positively if they had previously shown dilation responses rather than constriction.

These results suggest that static features of the face do indeed affect the way in which pupil size changes are interpreted, not just at the time of perception, but also in terms of changing long term representations. This is the first time that the effects of pupil size on person perception has been investigated in relation to levels of trust read from the face, and certainly the first time that this factor has been shown to modulate long term person perceptions alongside the effects of pupil size.

Pupil size is a very subtle cue and it is sensible to suggest that not everybody will be equally susceptible to detecting and interpreting it in others. Men have been shown to be less perceptive or responsive to social cues than women. For example, men show weaker gaze cueing effects than women (Bayliss, di Pellegrino & Tipper, 2005), which correlate with their levels of sub-clinical autistic traits. Men have also been shown to present weaker electro-cortical evidence of representing other's actions (Cheng, Tzeng, Decety, Imada & Hsieh, 2006), poorer performance in motion prediction tasks (McGivern, Adams, Handa & Pineda, 2012), and a reduced ability in comparison to women in recognising biological motion (Alaerts, Mackaerts, Meyns, Swinnen & Wenderoth, 2011) and emotional expressions (Baron-Cohen, Wheelright, Hill, Raste & Plum, 2001). It has been suggested that the female brain has developed a greater capacity for decoding the internal states of others (Baron-Cohen, 2002), and poorer male performance on socially relevant cognitive tasks may be caused by relative weaknesses in attentional systems that monitor social cues.

Chapter 5

To investigate such possible sex differences Experiments 12 and 13 replicated experiments 10 and 11, but this time a male sample was used. Male participants have been shown in past research to be affected by pupil size changes, when looking at female faces, and male participants have been used in studies showing non-conscious detections of emotion (e.g. Williams et al., 2004). It may be the case therefore, that men also show pupil encoding effects. However, it may be the case that these effects are attenuated, or may not occur at all, if male participants are less sensitive to the pupillary cues than female participants. Also, given that past research (e.g. Bull and Shead, 1979) suggests men may not be sensitive to pupil dilation in other men, their patterns of person perception responses may differ from women's if they do indeed encode pupil size.

5.5 Experiments 12 and 13: Effects of encoded pupil size in male participants

5.5.1 Methods

Participants

Participants were 64 male undergraduate students, recruited from the participant panel of the School of Psychology, Bangor University, Wales. Thirty three participants took part in the male and female face experiment (mean age 19.9, SD= 2.1). Thirty one participants took part in the high and low trust face experiment (mean age 19.9 years, SD = 1.8 years). All participants gave written informed consent, and had normal or corrected to normal colour vision. Course credits were given in compensation for their time.

Stimuli

The same stimuli generated for the original versions of each experiment were used.

Procedure

The procedures were identical to those used in Experiment 10 (Sex condition) and Experiment 11 (Trust condition).

Debriefing

At debriefing eight participants in the Sex experiment, and six participants in the Trust experiment had spotted the pupil manipulation and were removed from the analyses.

5.5.2 Results

Vigilance Task

Male participants were also highly accurate when completing the vigilance task, with accuracy to standard trials in the Sex condition at 99% (SD = .10%), and 98% (SD = .12%) in the Trust condition (data from one participant in the sex condition was lost due to computer failure). Accuracy in response to oddball trials was at 98% (SD = .13%) in the Sex condition, and 98% (SD = .13%) in the Trust condition. Male

participants were therefore not less attentive to the stimuli than female participants, at least to the extent reflected in their responses.

Ratings Task

Sex (Experiment 12). The ratings participants gave the faces in the Sex condition were entered into a three factor, within subjects ANOVA, with sex of face (Male/Female), pupil size (dilated/constricted) and question (how friendly?/how interested?) entered as factors. As in the data from female participants, there were main effects of sex ($F(1,24) = 61.27, p < .001, \eta^2_p = .72$), with rating of female faces higher than those of male faces, and of question ($F(1,24) = 25.54, p < .001, \eta^2_p = .52$), with ratings in response to the how friendly question, higher than in response to the how interested question.

Just as in the data from female participants there was no main effect of pupil size on ratings ($F(1,24) = .045, p = .834, \eta^2_p = .002$), and this time the interaction between pupil size and sex was also non-significant ($F(1,24) = 1.32, p = .261, \eta^2_p = .052$). To make a comparison to the data from female participants, planned t-tests to compare the effect of pupil in each condition of sex revealed that in neither condition did pupil size cause a significant difference in ratings ($p > .4$ in both male and female face ratings).

There was a significant interaction between sex and question ($F(1,24) = 4.66, p = .041, \eta^2_p = .163$). When male participants were rating male faces, the degree to which the ratings in response to the friendly question were higher than those in response to the interested question, was larger than when they were rating female faces.

These results can be seen in Figure 5.2 panel C.

Trust (Experiment 13). The ratings from the trust condition were entered into an identical analysis, only with the factor of sex replaced by trustworthiness (high/low). Again, there was a main effect of trustworthiness ($F(1,24) = 154.14, p < .001, \eta^2_p = .87$), with responses higher to high trust than low trust faces. However, this time there was no main effect of question ($F(1,24) = 2.17, p = .15, \eta^2_p = .083$), as well as no main effect of pupil ($F(1,24) = .24, p = .70, \eta^2_p = .010$) on ratings.

Again, the interaction between pupil size and trustworthiness was non-significant ($F(1,24) = 1.48, p = .24, \eta^2_p = .058$), and planned t-test comparisons revealed that the difference in rating between faces dilated and constricted pupils did not differ in either high or low trust faces ($p > .17$ in both cases).

These results can be seen in Figure 5.2 panel D.

Analysis across both sexes of participant. The data from male participants showed the same overall pattern as that from female participants. Although the interactions between pupil size and sex/trustworthiness did not reach significance, the results suggest that men might show a similar pupil size encoding effect to women, but the effect is less salient. To test whether men and women differed significantly in their response to encoded pupil size, the data from female and male participants was combined for the Sex and Trustworthiness conditions, and a mixed models ANOVA was run on this mixed sex dataset.

Pupil size (dilated / constricted), sex / trustworthiness (female or high trust / male or low trust), and question (how friendly / how interested) were entered as within subjects factors, with sex of participant as a between subjects factor. The analysis revealed the expected main effects of sex/trust, ($F(1,98) = 338.60, p < .001, \eta^2_p$

= .776), and question, ($F(1,98) = 38.40, p < .001, \eta^2_p = .373$), as well as the pupil size by sex/trust interaction, ($F(1,98) = 19.61, p < .001, \eta^2_p = .167$). The three way interaction between pupil size, sex / trust and sex of participant, ($F(1,98) = 4.90, p = .029, \eta^2_p = .048$), revealed that male participants did indeed show a less salient effect of pupil encoding.

5.5.3 Discussion

The results of experiments 12 and 13 showed the same pattern of data with male participants as the pattern of data found in experiments 10 and 11, where female participants were tested. However, although male participants showed evidence of encoding the pupil size of the stimuli they viewed during the vigilance task, the effect of this encoding on their later ratings did not reach significance. Combined analysis of male and female participant's data indicated that participants did indeed show less salient effects of the encoding of pupil size changes, even though their pattern of data was identical.

The experiments in Chapter 5 have shown for the first time that pupil size changes are indeed encoded into long-term memory, and affect later person judgements without explicit awareness of either encoding or retrieval. However, that this effect is only seen in female participants. This retrieval of a very subtle social cue appears to affect person perception in a manner which is modulated by the integration of featural information, such as whether the face is male or female, trustworthy or not. These data reflect previous studies that have shown that pupil dilation and constriction in a face exerts an effect on immediate person perceptions (e.g. Bull and Shead, 1979; Harrison

Chapter 5

et al., 2006; Tombs and Silverman, 2004). It is worth commenting on the fact that the similar (although significantly different) patterns of responses in male and female participants, is not in line with previous research that has suggested effects of pupil size on person judgements may be psycho-sexual in nature (Bull & Shead, 1979; Hess & Polt, 1960; Tombs & Silverman, 2004). Assuming the samples used in Chapter 5 were largely heterosexual, the data suggest that the pupil size changes were perceived in terms of general arousal of engagement and not in terms of something sexual in nature, in which case it might be expected that the male participants would respond differently to the male stimuli than the female participants and visa-versa. The current experiments, unlike prior research, did not use any overtly sexual stimuli such as nudes, nor any sex related questions, such as ratings of attractiveness. These factors might bias the judgements of the participants. Also, our results replicate those of Tombs and Silverman (2004) and (Hicks, Reaney & Hill, 1967) who showed that women respond positively to other women's pupil dilation. It could be suggested that when pupil dilation is encoded and later retrieved, the retrieval of this autonomic response is interpreted in light of who we are perceiving and the context in which we are perceiving them. If the context is not sexual in nature, then the arousal state we now associate with that individual will be interpreted as representing general interest or cognitive engagement with ourselves, on their part.

In summary, the experiments of Chapter 5 present the first evidence that pupil size changes are encoded into long-term memory and affect lasting person perceptions. This effect appears only significant in women, and is affected by the static facial traits of the person whose pupils have been observed changing size.

Chapter 6

Activation of the sympathetic nervous system during pupil size encoding and retrieval, and the direction of the pupil size effect.

6.1 Summary

Perceiving changes in pupil size appears to influence the physical state of the perceiver. This embodiment may underlie the influence that pupil size exerts on person perception. In the first experiment in this chapter we look for evidence of embodiment of the arousal state indicated by another person's pupil size change, but critically embodiment occurring both when seeing a person's pupils change size and also when experiencing the same person again at a later time, with normally sized pupils . Evidence is presented to show that when pupil size changes are perceived in certain negative salient faces, these cause sympathetic arousal in the observer, which is reinstated when the same faces are encountered again. Also, the second experiment in this chapter examines the direction of change that encoded pupil size causes in person perceptions, showing that less preferred faces with dilated pupils are actually liked less upon re-encountering, whereas other faces are generally preferred, regardless of their previous pupil size.

6.2 Introduction

The experiments in Chapter 5 demonstrated for the first time that changes in pupil size, despite their subtlety, are encoded into long-term memory, to change lasting person perceptions. However, this effect was only found in female participants. Although past research has demonstrated that changes in pupil size can alter 'online' perceptions of another person's attractiveness (Bull & Shead, 1979; Hess, 1960; Hicks, Pelligrini & Tomlinson, 1978; Tombs & Silverman, 2004), as well as affecting the way we perceive their emotional expressions (Harrison et al., 2006, 2007), no study has shown that these changes last beyond the moment of the initial interaction. Nor has any prior work looked beyond sex and attractiveness to investigate how other static features of the face might work alongside pupil size in causing changes in person perception. By following up on our original finding that male faces are perceived differently to female faces in relation to their encoded pupil size, we were able to show that the relative trustworthiness of a male face appears to modulate the way pupil dilation and constriction alter long-term representations of a person.

Neuroimaging and behavioural research indicates that when we view another person's pupils change size, our own pupils automatically change size in a mimetic manner (Harrison et al., 2006; Hess, 1965). Neural activations in response to viewing other people's pupils dilate and constrict appear to be similar to those seen in studies of brain activity in response to viewing emotional expressions (Amemiya & Ohtomo, 2011, Demos et al., 2008; Harrison et al., 2006), in that they encompass regions such as the amygdala, implicated in responses to generally arousing stimuli, as well as regions that are thought to monitor salient movements of the face, such as the superior temporal sulcus. Interestingly, Harrison et al., (2006) reported activation in a brain stem region

that appeared likely given its anatomical location, to be the Edinger-Westphal nucleus (EDN). Activity in this region, and other regions sensitive to the pupil size of facial stimuli, correlated with the level of pupillary contagion participants showed. This only became significant when participants viewed sad faces, their perception of which was modulated by observed pupil size in a way that didn't occur for neutral, happy or angry faces.

The findings of Harrison et al., (2006) are strikingly similar to those of studies that have looked at the relationship between facial mimicry and neural activation (Likowski et al., 2012; Schilbach et al., 2008). Viewing both pupil size changes and facial expressions causes cortical activations in brain regions that control these physical processes, along with actual physical mimicry responses in the viewer. These are associated with activation of emotion processing regions, most notably the amygdala. Although the study of Harrison et al., (2006) can still claim to be the only evidence that simulation theories of social cognition extend to pupil size changes, it does appear to support the idea that the effects of pupil size on person perception may be underpinned by similar processes to those that support emotion recognition. In this case we would predict that if perception of pupil size changes causes simulation of another person's physical and neural state, this simulation should be retrieved when we meet that person again, in a similar manner to the facial mimicry effects studied in Chapters 2 – 4. This retrieval might drive the effects that were evidenced in the previous chapter.

In Experiment 14 we monitored the levels of sympathetic nervous system (SNS) activity in our participants, while they completed the high and low trustworthiness version of the pupil size experiment. Pupil size changes have been shown to occur due to activation of the SNS (Bradley et al., 2008) during arousal, which also causes other

Chapter 6

associated physical responses, including electrodermal activity (EDA) (Bradley & Lang, 2008; Bradley et al., 2008; Lang, Greenwald, Bradley & Hamm, 1993). We measured EDA responses rather than pupillary contagion, as a measure of the extent to which our participants embodied the faces that they viewed in the vigilance task, because the equipment we had available for measuring pupil size involved a cumbersome headset. As a first pass at measuring a shared physical state between stimulus and participant, we felt it was better to use a measure that was a covariant of pupil size that can be recorded without much obtrusion or any discomfort for the participant.

In relation to this experiment, there are three hypotheses. Firstly we should replicate the behavioural results of the experiments in Chapter 5. Secondly, we should see changes in EDA when participants view faces whose pupils dilate, if indeed their autonomic state is matched to that of the stimulus. However, given that initial simulation effects are thought to occur automatically, but then be modulated by who is being simulated (Niedenthal et al., 2010) and SNS activity is also likely to be greater in response to more immediately arousing stimuli (as low trust faces might be supposed to be), the effects of pupil size on EDA response may differ between the high and low trust faces. The greatest activation would most likely occur as a sum of a low trust face, and dilated pupils. Lastly, the key prediction relates to the EDA responses in the ratings task. Here we predict that the same pattern of EDA responses seen in the vigilance task will be reactivated when the participants view the faces again with average sized pupils.

6.3 Experiment 14: Activation of the sympathetic nervous system during the encoding and retrieval of pupil size changes.

6.3.1 Methods

Participants

Participants were 34 female undergraduate students (mean age 19.3 years, SD = 2.4 years), recruited from the participation panel of Bangor University, Wales', School of Psychology. All participants gave informed consent and had normal to corrected to normal colour vision. The participants were compensated for their time with course credits. Female participants were chosen because in the previous experiments they demonstrated effects of encoded pupil size where male participants did not.

Stimuli

The stimuli were 16 faces, selected from the high and low trust faces used in experiments 11 and 13. The set consisted of eight high trust and eight low trust faces (attractiveness matched as pairs, within trust group). The reduction in the number of stimuli was introduced to allow more time for the addition of the EDA measurement, and for the counterbalancing required to optimise the EDA signal collection.

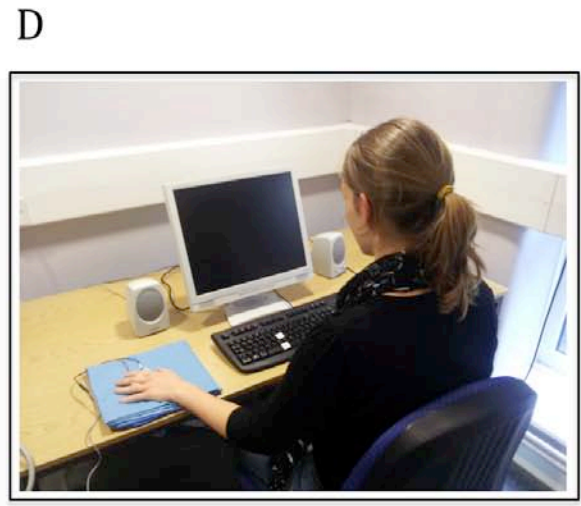
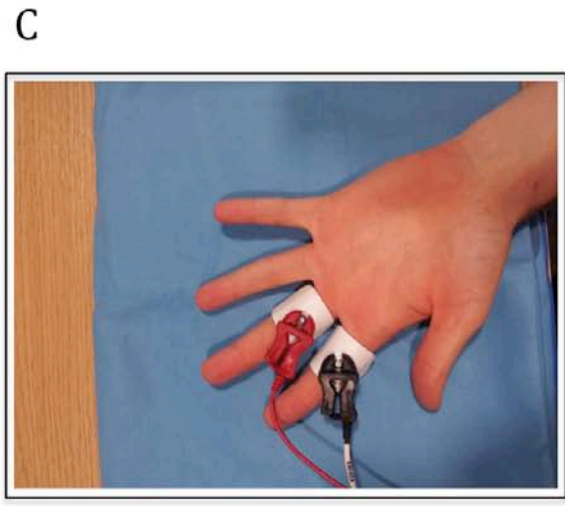
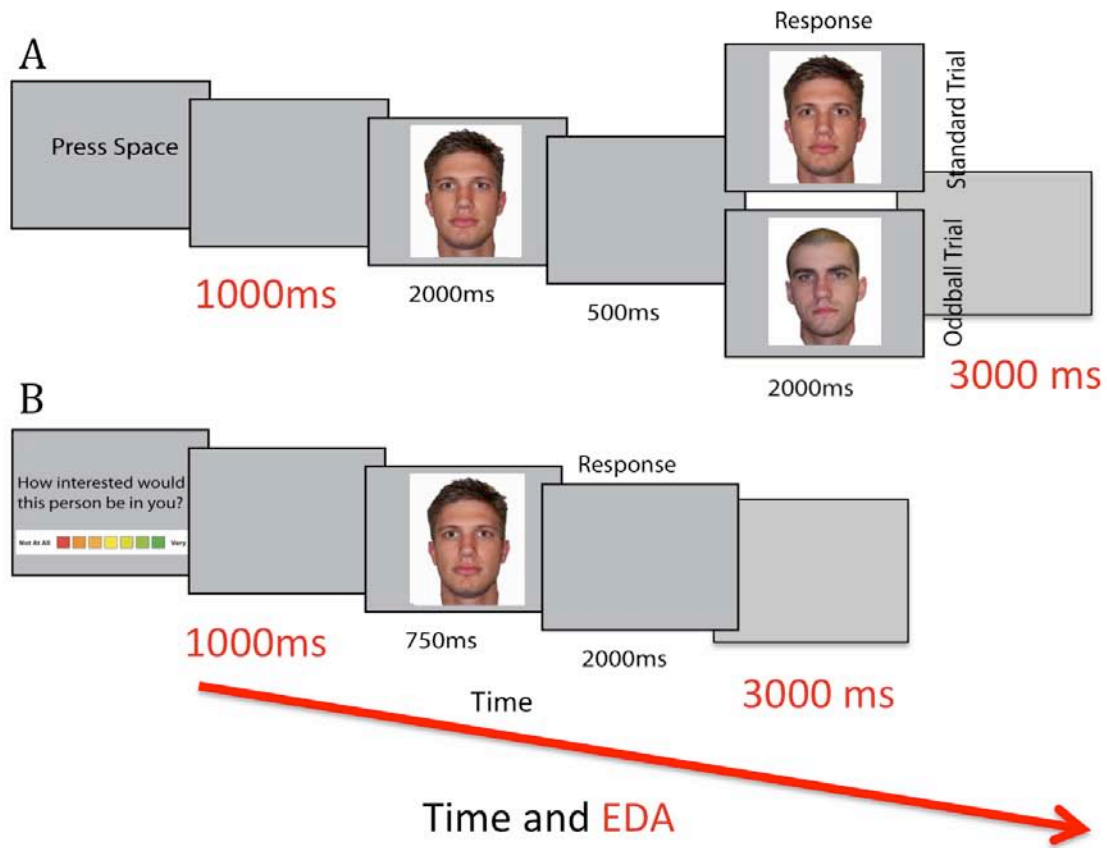


Figure 6.1. Trial procedures for the vigilance (Panel A) and ratings (Panel B) tasks during Experiment 14. Panel C. Placement of EDA electrodes. Panel D. Testing setup for EDA measurements.

Procedure.

Behavioural. The experimental procedure was for the most part identical to that used in experiments 11 – 13, however, with the addition of the EDA measurements, some adjustments were made to the behavioural tasks. The same cover story of a facial vigilance task was used, and the EDA measurement was explained as a measure of the effects of concentration on the body.

After briefing and the collection of informed consent, the EDA electrodes were attached as described below. From this point onwards the course of the experiment was the same as Experiments 10-13, but slight adjustments were made to the slide timings in both tasks. The fixation period before the onset of the average pupil face, in both the Vigilance and Ratings tasks was increased to 1000ms. A 3000ms rest screen was added to the end of each trial of the Vigilance task, to allow longer for the EDA response to subside between trials (see Figure 6.1 Panels A and B). The order of stimulus presentation in each task was counterbalanced using purpose built computer code, as stringently as possible, so that every combination of Trust and Pupil condition followed one another an equal number of times. In the Vigilance task, each face now appeared 12 times to allow for correct counterbalancing, with 32 oddball trials interspersed quasi-randomly, making 224 trials in total. The trials were divided into four blocks of 56 trials, with eight oddballs and 48 standard trials per block. The Ratings task now consisted of two blocks of 32 trials, with each face appearing twice in relation to each question, as in the previous versions of the experiment.

Electrodermal Activity Measurement. Electrodermal activity (EDA) reflects the ability of the skin to conduct an electrical current. This ability fluctuates as the skin becomes damper or dryer, and assuming that the atmospheric conditions are stable, this fluctuation is caused by the amount of sweat being released through the skin's eccrine sweat glands. The release of sweat from these glands serves the primary function of regulating body temperature through evaporative cooling. However, the sweat glands on some areas of the body, such as the palm of the hands and pads of the fingers, are thought to have a more psychological than physiological role (Edelberg, 1972, cited in Dawson, Schell & Filion, 2007).

A suggested reason for the link between the sympathetic nervous system and EDA, is that sweating at times of arousal has potentially advantageous effects during interactions with novel stimuli, or during fight or flight responses. For example, wet skin is less prone to being cut or bruised, and is harder to grab hold of. Wet palms and finger tips are superior to dry ones for gripping objects, which could help when learning to grasp a novel object, or grasping a weapon (Edelberg 1973, in Andreassi, 2007).

As sweat is released into the eccrine sweat ducts, the result is a decrease in the level of resistance at the skin's surface level, the stratum corneum, as the increase in salty moisture takes effect. Greater sympathetic nervous system activity results in a greater number of sweat glands becoming active, and so a greater drop in surface level electrical resistance (Figner, & Murphy, 2010).

Measuring EDA involves running a small current between two electrodes on the surface of the skin, and applying Ohm's Law: Resistance = voltage/current. If the voltage is left constant, then any fluctuations in current must reflect fluctuations in the skin's level of resistance. This technique is used to measure conductance, the reciprocal

of resistance, and so EDA is expressed in terms of units of conductance, microSiemens (μS).

In the current experiment, EDA was measured using a BioPac MP36 system, which is a general-purpose amplification system for measuring physical and psychophysical responses. The BioPac system uses a constant application of .5V across the two electrodes attached to the participant's fingers. As recommended in Dawson et al., (2007) and Figner and Murphy (2010), the electrode pair was attached to the medial phalanges of the index and middle fingers of the left hand (see Figure 6.1 Panel C) after the attachment sites were cleansed with alcohol and dried. SSL57A EDA leads, paired with disposable silver chloride, isotonic gel EL507 electrodes were used, which conform to the electrical requirements for reliable EDA measurement (Fowles et al., 1981). The participants rested their hand on a soft cloth (see Figure 6.1, panel D) and were asked to keep their hand stationary and palm down. Between blocks they were given the opportunity to move the hand around if it was uncomfortable. Surgical tape was gently wrapped around the electrodes and fingers to reduce the likelihood of the electrodes shifting if the participant needed to move.

The signal was sampled at 200Hz and amplified with a gain of 2000x (as per recommendations of Braithwaite, Watson, Jones and Rowe, 2013), and markers were outputted from EPrime via a parallel port, denoting the onset and offset of all trial events. The signal data and markers were sent via USB to the data collection computer, where they were displayed during the tasks, and saved afterwards by the experimenter as tab delimited text files.

During recording, the signal was filtered using a 50Hz notch filter, built into the BioPac amplifier, in order to attenuate the effects of mains electrical noise, and a 35Hz

low pass filter, so reduce high frequency artefacts (Braithwaite et al., 2013). After data collection, the signal was filtered with a 0.5Hz high-pass filter to remove tonic changes in signal and slow drifts due to effects like equipment temperature change, and a 2Hz low pass filter to remove high frequency electrical or EMG noise (Figner and Murphy, 2010). A square root transform was applied to correct for skew, and data were then standardised within participants to control for individual differences (e.g thickness of stratum corneum) and allow for meaningful comparisons (Ben-Shakhar, 1985).

The EDA response is relatively slow, with phasic (rapid) changes to stimuli occurring in roughly 1-4 seconds, but acting like small waves riding on the back of tonic (slower) changes (Dawson et al., 2007). Traditionally EDA research has used long trial periods and inter-stimulus intervals, ranging up to 60 seconds, but shorter intervals have been shown to be as effective in capturing reliable data (Breska, Maoz & Ben-Shakhar, 2011; Moaz, Breska & Ben-Shakhar, 2012). In our study, partly due to the already lengthy nature of the task, and the requirement to try and replicate the previous versions of the task, we used shorter than normal inter-stimulus intervals of only about 4 seconds, but counterbalanced the order of trial conditions to attempt to best reduce the chances of losing any experimental effects because of carry over of the EDA from one trial to the next. To account for the phasic nature of the EDA being affected by tonic changes during the tasks, we calculated mean responses to our stimuli as changescores from the average of each trial's fixation period, and then used these changescores as the dependent variable in our EDA analysis. In this way we hope that we accounted for any large changes in the baseline level of EDA over time ~35 minute period that the longer of the two experimental tasks took to complete, whilst giving ourselves the best chance of avoiding type one and two errors in our analysis of the data.

Debriefing. Debriefing was completed in the same manner as in previous experiments, and nine participants were found to have spotted the pupil manipulation. Their data were removed from the analysis. It was discovered after recording that EDA data from four of the participants were cut short by an experimenter error. One participant reported that they had detached the electrodes part way through the session, but they had not told the experimenter. Twenty participants data were therefore entered into the final analysis.

6.3.2 Results

Behavioural data

Vigilance. As in previous experiments, accuracy was very high at 99% (SD = .10) for all trials, and 97% for oddball trials (SD = .18%), reflecting the fact that the participants attended to the stimuli.

Ratings. The participant's ratings can be seen in Figure 6.2 panel A.

The ratings data were entered into a within subjects ANOVA. Pupil size (dilated/constricted), trustworthiness (high trust/low trust) and question (how interested/how friendly), were entered as within subjects factors. As in the previous experiments where high and low trust faces were used, there was a main effect of trustworthiness, $F(1,19) = 297.11, p < .001, \eta^2_p = .94$, with participants giving significantly higher ratings to the high trust faces. There was also a main effect of

Chapter 6

question $F(1,24) = 42.47, p < .001, \eta^2_p = .69$, with ratings in response to the how friendly question, higher than those in response to how interested?

There were no significant interactions, including the interaction between pupil size and trustworthiness, which reached $F(1,24) = .302, p = .587, \eta^2_p = .012$. The pattern of data for the how friendly? question demonstrated the same direction as seen in the experiments in Chapter 5, but was non-significant. However, the how interested? question trended in the reverse direction to that predicted when participants viewed high-trust faces, with participants rating high trust faces whose pupils had previously constricted, more positively than those whose pupils had previously dilated.

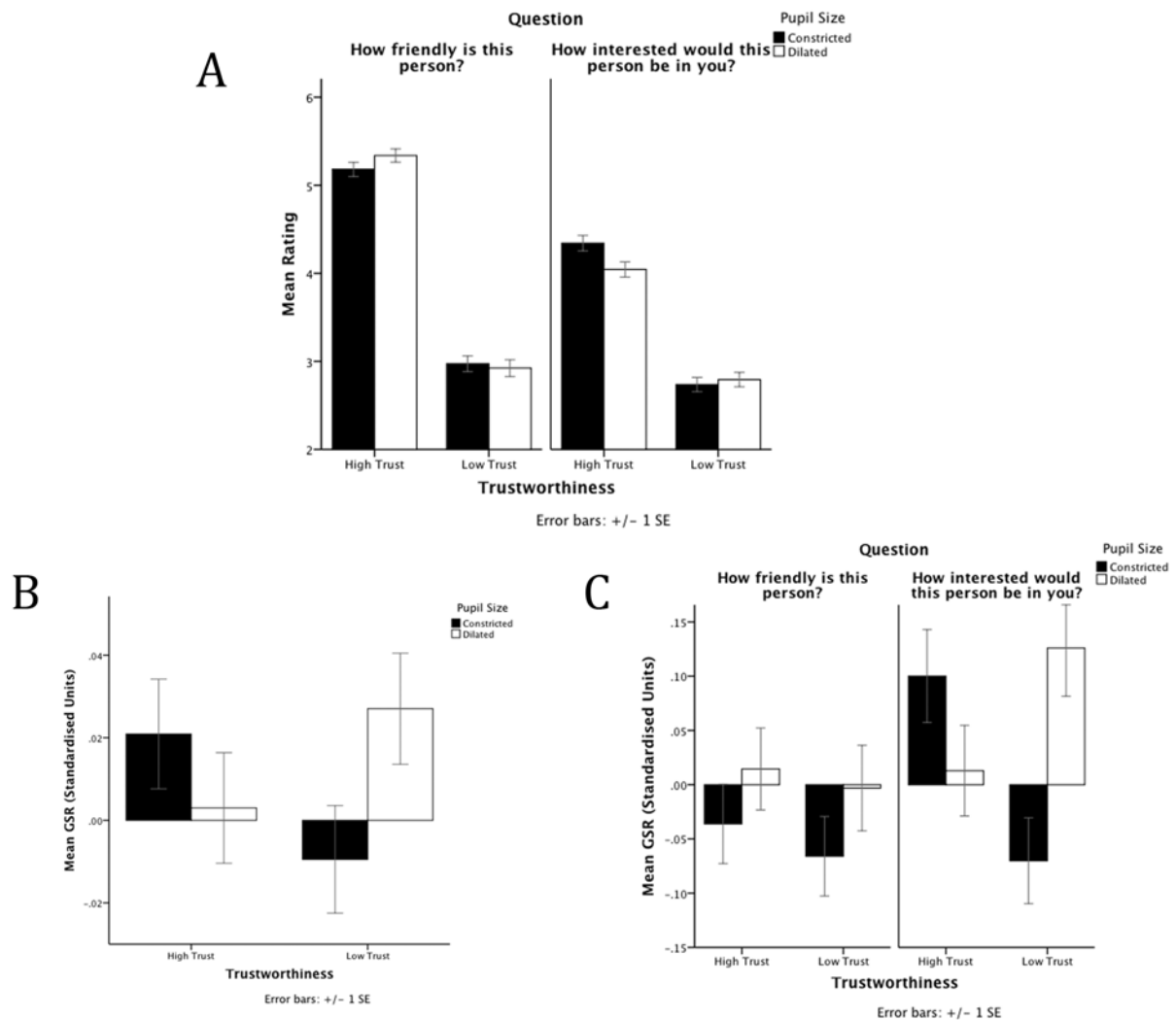


Figure 6.2. Panel A) Ratings data. Panel B) EDA data from the vigilance task. Panel C) EDA data from the ratings task.

EDA data

Vigilance task. In order to assess whether the EDA response to faces viewed during the vigilance task changed over multiple exposures, as might be predicted in a task where participants were implicitly learning associations between faces and pupil responses, task half was considered in the EDA analysis. The period of the trial in which the EDA data was collected was also considered, as this might be expected to interact with any effect of learning. For example, in the first half of the experiment, EDA

Chapter 6

responses might be larger to faces with dilated pupils, and in the second half when the association between these identities and this arousal cue has been encoded, this response might start during the first presentation of the face, when the pupils were of an average size. This would be a learning process that is similar to the EMG response to neutral faces that have a predictable emotion change shortly afterwards (see Chapter 3).

The EDA data from the vigilance task were entered into a within subjects ANOVA, with the factors trustworthiness (high trust/low trust), pupil size (dilated, constricted), experiment half (first half/second half) and trial period (average pupil face/changed pupil face and rest period). There were no main effects, and no significant interaction effects. However, at a one-tailed level there was a trend towards an interaction between pupil size and trustworthiness (see Figure 6.2 panel B), $F(1,19) = 3.41, p = .080, \eta^2_p = .15$, with, as predicted, greater EDA responses evident to low trust faces whose pupils dilated, as opposed to those whose pupils constricted, and the opposite pattern in the high trust faces. Further analysis of this effect revealed that the low trust faces with dilated pupils elicited a larger EDA response in participants than those faces whose pupils had constricted, $t(79) = -1.85, p = .067$, whilst this difference was not found in high trust faces, $t(79) = -.91, p = .37$. Although this effect in low trust faces only trends toward significance, the interaction between trust and pupil was predicted, and it sets up an interesting possibility that these low trust individuals might be the most likely to induce a pupil size related EDA response in the later ratings task, despite the pupils at this stage being average sized across all faces.

Ratings Task. The EDA data from the ratings task can be seen in Figure 6.2 panel C.

Chapter 6

Because the ratings task contained fewer trials, and a shorter exposure to the face on each trial, the EDA data were analysed in the same way as the behavioural data, without the addition of block and trial period as factors. Therefore a within-subjects ANOVA, with trustworthiness (high trust/low trust), pupil size (dilated/constricted) and question (how friendly?/how interested?) was conducted.

Participants EDA responses to faces whose pupils had previously dilated, were larger than those whose pupils previously constricted $F(1,19) = 4.39, p = .050, \eta^2_p = .19$. Their responses whilst answering the how interested? question were greater than whilst answering the how friendly? question $F(1,19) = 5.54, p = .030, \eta^2_p = .23$, and the pattern of data suggested that during the how friendly? question, the EDA response decreased from baseline levels, whereas in the how interested question the activity on average increased.

There was a significant three way interaction, between trustworthiness, pupil size and question, $F(1,19) = 7.19, p = .015, \eta^2_p = .28$. The pattern of data suggested that during exposure to low trust faces participants EDA responses were greater to faces whose pupils had previously dilated, than to those whose pupils had previously constricted, but that for low trust faces, the pattern was reversed between the two questions. This interaction was further investigated by running within-subjects ANOVAs on the two trustworthiness levels separately, with the factors pupil size (dilated/constricted) and question (how friendly?/how interested?) included in each analysis. In the high trust faces, no main effects or interactions were significant. However, in the low trust faces, whilst there was no significant main effect of question, or interaction between question and pupil at either one or two-tailed levels of significance (p 's $> .12$), there was a significant main effect of pupil size, $F(1,19) = 29.69$,

$p < .001$, $\eta^2_p = .61$. Participant's EDA responses were significantly larger to low trust faces whose pupils had previously dilated than to those whose pupils had previously constricted. This pattern mirrors that found in the vigilance task, but importantly occurring now when no pupillary differences existed between these faces, hence reflecting retrieval of prior processes.

Because this experiment is exploratory, an analysis of the same three-way interaction was also conducted by analysing each question separately, as the patterns of activity differed between the two questions. When participants responded to the how friendly? question, there was no effect of trustworthiness, but a main effect of pupil size, $F(1,19) = 3.14$, $p = .092$, $\eta^2_p = .142$, which just reached significance at the one-tailed level and reflected larger EDA responses to dilated pupils. In contrast, during responses to the how interested? question, there were no significant main effects, but a significant interaction effect between pupil size and trustworthiness, $F(1,19) = 18.82$, $p < .001$, $\eta^2_p = .498$. Post hoc t-tests revealed that whilst in high trustworthiness faces there was no significant difference in EDA activity between the two conditions of pupil size ($p = .26$), there was however in the low trustworthiness faces, where responses to those faces whose pupils had previously dilated were significantly larger than to those whose pupils had constricted $t(19) = 3.45$, $p = .003$.

6.3.3 Discussion

The results of Experiment 14 hinted that people's pupillary signs of arousal are reinstated upon re-exposure to the same individuals at a later time. As predicted, modulation of these simulations occurred as a reflection of how trustworthy the other

person appeared. However, against our predictions, we did not replicate the same pattern of behavioural results found in the previous chapter.

The participants responded as predicted when asked how friendly they thought the faces were, although the patterns of data for both responses to this question and to the How Interested? question did not demonstrate significant differences. Participants gave higher ratings of friendliness to high trustworthiness faces that had previously appeared with dilated pupils, than to high trust faces that had previously appeared with constricted pupils. The opposite pattern was shown in response to low trust faces. However, the pattern of ratings for the how interested? question was the reverse of that predicted. There were still main effects of trustworthiness and question however. After careful examination of the data to ensure there were no coding errors, the only conclusion we can draw for this unexpected result is that somehow the participants were influenced by the addition of the EDA measurement. When the briefing was given, the EDA recording was explained as being a measure of arousal state, used to gauge how sustained vigilance to facial identity affected the participant's SNS activity. It may be possible that once the participant's were asked to make personal judgments about the faces, the fact they knew that a measure of arousal was being taken caused them to respond differentially to previous experiments. Responses to the how interested? question have consistently been lower than to the how friendly? question, which may reflect the more personal and introspective nature of the question. Deciding if a person would be interested in you requires measuring your self concept against the person you are viewing, and responses to this question may be more sensitive to interference from contextual influences than a question that asks you simply to judge how friendly someone looks. This may also be reflected in the fact that the how interested? question

drove the EDA responses to low trust faces seen during the ratings task. It may be that answering this question engages the participants more in evaluating their feelings towards the faces. It is however, a puzzling result none the less.

The EDA data suggested that during the vigilance task, the pupil size of the stimuli affected the SNS activity of the participants, despite the fact they were not aware that the face's pupils were changing size. This is in line with the findings of Harrison et al., (2006) and the proposition that as with facial expressions, viewing pupil size changes may cause embodied responses in the viewer. Although this effect did not reach two-tailed significance, the pattern of EDA responses suggested that the trustworthiness of a face modulated the way its pupil size influenced the participant's own arousal state. As predicted the largest increase from baseline activity was in response to low trust faces whose pupils dilated, and the difference between this response and the response to low trustworthiness faces whose pupils constricted, neared statistical significance. Interestingly the opposite pattern of EDA activity occurred when participant's viewed high trustworthiness faces. We predicted that viewing pupil dilation should trigger a SNS response, which might be increased in response to low trustworthiness faces, but this response is in contrast to that prediction because in high trustworthiness faces, pupil constriction elicited larger EDA responses.

One possibility is that the EDA responses in fact represent a reaction to a violation of expectation, or some degree of uncertainty in the participant. We have strong predisposed ideas about how we expect other people to act in terms of their emotions and states of arousal (see Hess, Adams and Kleck, 2005). Violations of our social expectations of others have been shown to cause changes in neural activity that may reflect greater attention, perhaps as a result of a need to update our prior beliefs

(e.g Bayliss, Naughtin, Lipp, Kritikos & Dux, 2012; Pelphrey, Singerman, Allison & McCarthy, 2003; Tipples, Johnston & Mayes, 2013). It may be the case that when our participants viewed the high trustworthiness faces they unconsciously expected pupil dilation, because an approachable looking person might be expected to want to engage with us. Detection of the opposite signal, the pupils actually getting smaller, may have resulted in heightened attention on the participant's part, reflected in a heightened SNS response. It is not inconceivable that the difference in the EDA responses to the low trustworthiness faces may also reflect a similar reaction.

Importantly though, the pattern of activity seen in the ratings task in response to low trustworthiness faces matched that seen in the vigilance task for low trust faces. When participants viewed low trustworthiness faces, their EDA responses were significantly greater in response if the face's pupils had previously dilated, than if the face's pupils had previously constricted. Given that at this stage the faces all had average sized pupils, it can be assumed that this activation reflects a reinstatement of the arousal elicited during the vigilance task. Although the EDA responses to the high trustworthiness faces did not significantly differ between pupil conditions, the effects in the low trustworthiness faces reflect our prediction that the combination of low trustworthiness and pupillary signs of arousal would be most likely to cause an embodied response in a participant's own autonomic state. It is worth noting that the second follow up analysis of the three-way interaction effect during the ratings task, indicated that the EDA effects during this task differed between trials where the participants were responding to the two different questions. Interestingly, during the how interested? question trials, where the behavioural effects were not as expected, the EDA effects were strongest, which might reflect the extra engagement with the stimuli

suggested earlier. Here, the pattern of activity seen in response to high trustworthiness, as well as low trustworthiness faces, matched the activity elicited in the vigilance task. Tentatively, it might suggest a deeper evaluation of the faces was required in order for reinstatement of the prior simulation to occur.

6.4 Experiment 15: The direction of the pupil size effect

When we simulate another person's body state, it can change our later perceptions of that person. For example, in gaze cueing studies where faces either helped participants achieve faster reaction times by gazing in the direction of forthcoming targets, or slowed their reaction times by gazing away from forthcoming targets, later ratings of the same faces reflected this help and hindrance. Although participants were unaware that the faces had contingencies in this manner, faces that previously gazed away from forthcoming targets were perceived as being less trustworthy than their helpful counterparts (Bayliss & Tipper, 2006; Bayliss et al., 2009). A later study demonstrated similar results whereby participants would make larger financial offers in later investment games to previously helpful, as opposed to unhelpful faces (Rogers et al., 2013). At the moment, the exact mechanism driving these perception changes is not known. However, it seems sensible to suggest that when we simulate the gaze of another person, and that gaze either helps us to achieve a goal, or particularly if it hinders us, this causes an arousal, or affective response. When we experience that person again, it is that response that is reinstated and without our awareness drives our perceptions of the individual. This matches a somatic marker (Damasio, 1989) account of learning about stimuli in the world, and is supported by the

Chapter 6

greater changes in person perception that occur after unhelpful gaze is paired with a happy expression (Bayliss et al., 2009). Here a violation of social expectation might occur because we predict that a happy person should act in a way that helps us. Such violations have been shown to elicit neural responses in regions associated with encoding negatively valenced stimuli (Bayliss et al., 2012).

The effects of encoded pupil size demonstrated in the previous experiments in this and the last chapter appear to indicate that in a similar way to gaze cueing, another person's pupil size can affect our long lasting perceptions of them. This occurs despite our being unaware that we have encoded any association between this physical state and their identity. Based on the evidence of neuroimaging studies, and our previous EDA based investigation, this can tentatively be suggested to be driven by a simulation of their arousal state in our own autonomic system, that is then unconsciously retrieved when we come to make a later judgement about them, in much the same way as arousal caused during gaze cueing may be retrieved during later person perception. However, a key question that is unanswered in both gaze cueing experiments and our pupil size investigations is what direction this effect takes. That is, does somebody's unhelpful gaze cause us to like them less in the future, or their helpful gaze more? Or does one condition not affect our later perceptions? Similarly, does pupil dilation in a face that we have a positive expectation of, for example a female face, cause us to perceive that face as friendlier in the future? Or does it not affect our later perception because we already predict females will be positive and friendly (see Brody & Hall, 1993)?

In Experiment 15, we addressed this question by having participants provide ratings of the faces, with average sized pupils, at both the start and end of the experiment, rather than just at the end. This allowed us to measure the direction of the

change in their person perceptions elicited by the face's pupil size during the vigilance task, by subtracting the earlier ratings from the later ones to create change scores.

Negative change would indicate that the participants liked a certain category of face less after exposure to its pupil size, and positive change would indicate that faces were liked more. We predicted that the same pattern of results as occurred in Experiments 1 – 4 would be found in this experiment, but that from the direction of this pattern we would then be able to discern exactly how the pairings of pupil size and face characteristics affected a change in person perception.

We used the same set of male and female faces that was used in Experiments 10 and 12. As the unusual results in the how interested question in Experiment 14 may have been caused by the context created by the EDA measure, we were concerned that a similar result might occur if participants were asked to make social judgements about the faces before the pupil manipulation. We therefore decided to use the question 'how attractive is this person?' instead of the how interested? question, as the question of attractiveness is less introspective and similar to the how friendly? question. It would also provide an interesting replication of prior research if we could show that the attractiveness of a face can be altered in a lasting way, not just an immediate way, by changes in pupil size.

6.4.1 Methods

Participants

Participants were 30 female undergraduates (mean age 21.3 years, SD = 4.5 years), recruited via the participant panel of the School of Psychology, Bangor

University, Wales. All participants gave written informed consent, and had normal or corrected to normal colour vision. Participants were compensated for their time with course credits.

Stimuli

The stimuli used were the same 20 male and female faces, replicated from Experiment 10.

Procedure

After the participants had been briefed, and informed consent was given, they were given the same cover story as in previous experiments, that they were taking part in a study on sustained vigilance for faces. This time however they were told that they would be asked to retain vigilance for the appearance of faces during their first task (Ratings 1), but whilst having to make some decisions about the faces to add to the cognitive load the task demanded. In task two (Vigilance) they would have to retain vigilance for facial identities over a long period of time, and then they would have to complete a final task (Ratings 2) that also involved an element of cognitive loading, to see how fatigued they were. They were not told that the ratings would be repeated.

Vigilance Task. The vigilance task was identical to previous experiments.

Ratings Tasks. The Ratings task was adapted to utilise a visual analogue scale (VAS), rather than a button press response to each question. This was to prevent participants from trying to remember the responses they had made to the faces during Ratings 1,

Chapter 6

when responding to Ratings 2. However, the final data were converted into Likert style responses in order to be comparable to the data from the previous experiments. The ratings task was identical to the one used in previous tasks (see figure 5.1 panel C), however the VAS replaced the coloured key scale that had corresponded to the response keys the participants used in the earlier experiments. The VAS was a white line, butted at either end, and running from the far left to far right of the screen. A '-' symbol by the far left end and a '+' by the far right end, denoted which end of the scale related to low and high ratings. The VAS appeared in the same location as the key scale had done, on the first slide of the trial where the participants were posed that trial's question. It also appeared in the same location on the response slide, so the participants could make their selection. The participants were instructed to make their responses by clicking with the mouse, where they felt was appropriate given the question and the face they had just seen. They were told they had as much time as they needed in order to respond. Clicking the line cleared the screen and brought up the next trial. EPrime converted the participant's clicks into scores ranging from -100 to 100, and these were then converted offline back into Likert scores between one and seven, but dividing the values from the VAS into seven bins, with a accuracy in the division of the line of 2 decimal places (given the values could not be perfectly divided).

The design of the Ratings tasks was otherwise identical to previous experiments, asides from the replacement of the question 'How interested would this person be in you?', with the question 'How attractive is this person?'. At the start of the task, the cover story of added cognitive load was used during both Ratings sessions, in order to explain the questions. The participants were asked to be honest in their appraisals, and

were told that they must be vigilant, as the faces would only appear briefly on screen during each trial.

Debriefing. The same method of debriefing used in previous experiments was employed, and as a result five participants who spotted the pupil manipulation had their data removed from the final analysis.

6.4.2 Results

Vigilance Task

The participants responded with a high degree of accuracy, suggesting they attended to the stimuli during the vigilance task. Accuracy overall was 99% (SD = .11%), with accuracy on oddball trials at 98% (SD = .13 %).

Ratings Task

Pre-ratings. It was important to assess the participant's pre-ratings of the faces, to make sure that the later ratings would not be influenced by unexpected biases in the participant's opinions of the faces, prior to exposure to the pupil manipulation. It was expected that participants would find female faces to more likeable and that therefore they might receive higher ratings for friendliness and attractiveness. Given that responses to the how friendly? and how interested? questions had differed in the previous experiments independently of pupil size, it was possible that participants might also respond differently during the pre-ratings to the how friendly? and how attractive? questions.

The participant's pre-ratings were entered into a within-subjects ANOVA, with the factors future pupil size (dilated/constricted), sex (male/female) and question (how friendly?/how attractive?). Importantly, as would be expected, no effect of future pupil size or interaction involving future pupil size reached significance, even at the one tailed level. As predicted there were main effects of sex, $F(1,24) = 16.87, p <.001, \eta^2_p = .41$, with participants giving higher ratings to female than male faces. There was also a main effect of question, $F(1,24) = 13.41, p =.001, \eta^2_p = .36$, which reflected the higher ratings that participants gave when responding to how friendly?, in comparison to how attractive?

Ratings Change Scores. Change scores were calculated between the participant's pre and post ratings. During each of the two ratings sessions (pre/post), each participant rated each face twice in response to each of the two questions. First of all therefore, the data were averaged in each session, across these two responses, so that every participant had a single value for their rating of each face, in response to each question, in the pre ratings and the post ratings. These values were then subtracted from one another (post-pre) so that every participant had a single change score value for each face, in response to each question. Positive values related to increases in their ratings, and negative values to decreases. These data can be seen in Figure 6.3.

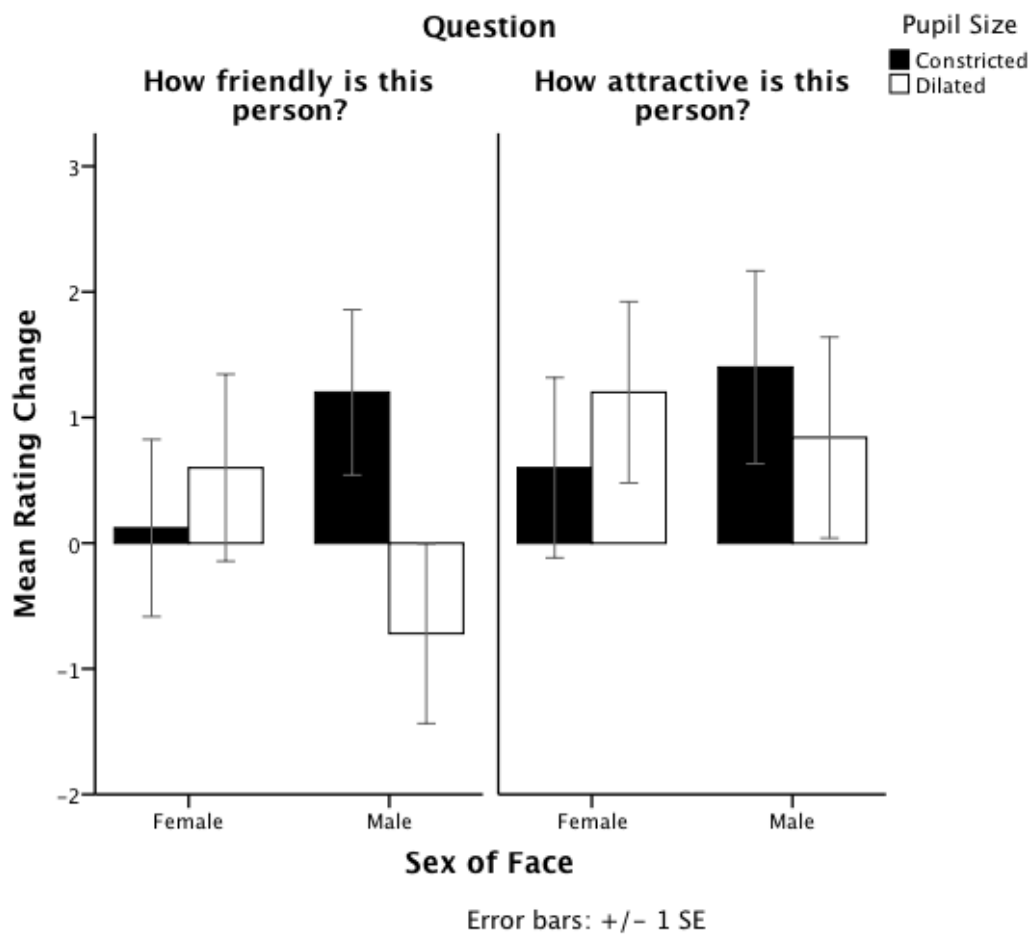


Figure 6.3 Ratings change-scores from Experiment 15.

The pattern of the data reflect those found in the previous experiments (with the exception of the how interested question in Chapter Six, Experiment 14.), in that participants showed a more positive change in both friendliness and attractiveness ratings in response to female faces whose pupils had previously dilated, in comparison to those whose pupils had previously constricted. With the opposite pattern of ratings in response to male faces. However, as change scores, these data reflect the direction in which the pupil manipulation changed the participant's perceptions of the faces. As might be expected, in general the faces were rated more positively after the multiple

exposures the participants received during the vigilance task. When responding to the how attractive? question, both male and female faces were found to be more attractive than on first exposure, but the level of increase appeared to be influenced by the pupillary response they had shown during the vigilance task. When participants responded to the how friendly? question though, interestingly, whilst all female faces, and male faces whose pupil's constricted were also given higher ratings than on first exposure, male faces whose pupils had dilated were the only category to be found less friendly than when they were first seen.

The change score data were submitted to a within-subjects ANOVA, with the factors pupil size (dilated/constricted), sex (male/female) and question (how friendly?/how attractive?). There were no significant main effects, and no interactions reached significance. The interaction between pupil size and sex was, $F(1,24) = 2.55, p = .123, \eta^2_p = .096$. Planned t-tests were carried out to compare the data to the results of the previous experiments, and significance was not reached in either the differences in change score between pupil groups in either female, $t(24) = .74, p = .465$, or male, $t(24) = -1.38, p = .18$, faces. Although the data showed an interesting pattern of ratings, no conclusions can be drawn regarding this, due to a lack of statistical significance.

Combined Analysis Across Task. The data from Experiments 10-15 demonstrate a clear pattern of effects of encoded pupil size on the perceived friendliness of faces (Figure 6.4). To investigate the consistency of this effect, a final analysis was conducted combining the data from all six experiments and comparing data from male and female, and high and low trust faces. A mixed models ANOVA was

Chapter 6

conducted with the within subject factors of pupil (dilated/constricted) and sex or trust (female or high trust/ male or low trust), and the between subjects factor experiment (sex fem. / trust fem. / sex male / trust male / EDA / pre and post).

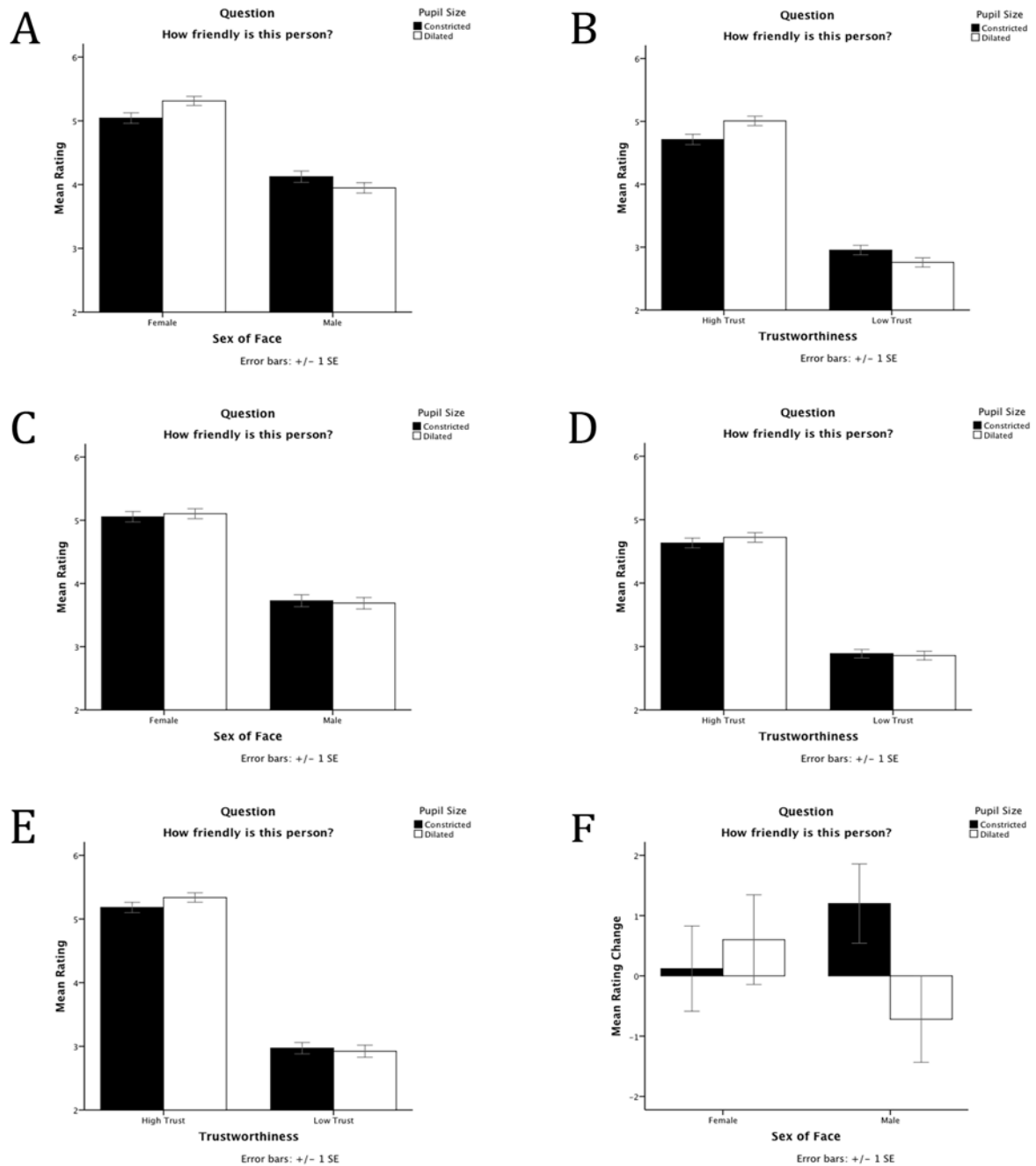


Figure 6.4 Graphs for the friendly question across experiments 10 –sex (Panel A), 11 – trust (Panel B), experiments with male participants, 12 –sex (Panel C), 13 – trust (Panel D), EDA measures, 14 (Panel E) and before and after ratings, 15 (Panel F).

The analysis revealed the expected main effect of sex/trust, $F(1,144) = 516.31, p < .001, \eta^2_p = .78$, and also an interaction between experiment and sex/trust, $F(1,144) = 28.0, p < .001, \eta^2_p = .49$, caused by the lack of a main effect of sex in Experiment 15 where change scores are analysed, in comparison to all other experiments,. Most importantly there was a significant interaction between pupil size and sex/trust, $F(1,144) = 15.66, p < .001, \eta^2_p = .098$, and no three way interaction between pupil size, sex and trust, and experiment, $F(1,144) = 1.00, p = .422, \eta^2_p = .033$, indicating that the effect of encoded pupil size on ratings of friendliness showed a consistent pattern through all six experiments, with female and high trust male faces found more friendly when their pupils had previously dilated, than when their pupils had previously constricted, and their counterparts, male faces and low trust male faces, showing the opposite effect.

6.4.3 Discussion

The aim of Experiment 15 was to investigate the direction of the effect exerted by pupil size changes during the vigilance task, on the participant's later ratings during the ratings task. As predicted the same pattern of ratings was found across the how friendly?, and the new how attractive? question, as was found in the earlier experiments. Participants rated female faces whose pupils had dilated more highly than those whose pupils had constricted, and the opposite pattern occurred in response to male faces.

Interestingly, ratings in response to all categories of face were higher after exposure to the pupil manipulation, than before it. Except in the case of friendliness

ratings of low trust, male faces. The general trend is suggestive of a mere exposure effect (see Bornstein, 1989 for meta-analysis), with the participant's preferences for the faces increasing over multiple exposures as they became more familiar and easier to process in the context of the vigilance task.

The only study comparable to this experiment is that of Tombs and Silverman (2004). They presented female participants with small and large pupil versions of the same male and female faces, as well as versions with average sized pupils. It is worth noting that their study presented the images as triads of the same identity with different pupil sizes, asking the participants to pick which versions were most and least attractive. They also only used three faces of either sex, and of course participants judgements were made whilst they viewed the faces with differing sized pupils, thus the mechanisms underlying their choices were likely to differ from those in our experiments. Their findings differ from ours, in that female participants rated male faces and female faces with constricted pupils less attractive than those with average sized pupils, whilst female faces with dilated pupils were found more attractive, and male faces with dilated pupils equally attractive. It is hard given the lack of strong effects in our data to draw clear comparisons, but our data do hint that female faces become increasingly attractive when an unconscious recollection of pupil dilation affects participants perceptions. In contrast however, our data suggest that pupillary constriction in male faces is actually more likely to cause a general improvement in person perceptions. This final experiment represents an interesting first pass at investigating the direction that person perceptions may move in, when we unconsciously encode another person's pupil size.

Chapter 6

The final analysis of the friendliness question, combining all six experiments, demonstrates that encoded pupil size consistently altered the participant's long-term representations of the faces. This data is the first to show that this very subtle social cue, unnoticed by observers, has an influence on person perception that lasts beyond the moment of an interaction. It is also worthy of note that the perceptions of friendliness were so consistently modulated by the sex, or trustworthiness of the faces. The interaction between perceived trust and pupil size is a novel line of investigation. By maintaining the key features of our paradigm over several experiments we have been able to show that static features of a face exert a stable modulation of pupil size driven changes in person perception, whereas past research looking at differences between sexes of face has failed to show consistent effects.

Chapters 5 and 6 have presented novel findings. Pupil size changes in others, despite not being explicitly perceived, are encoded into the long-term memory of the perceiver. During later encounters with the same individuals these memories appear to be implicitly retrieved to exert an influence on person perception, at a time when no pupil size differences are displayed.

Chapter 7

Remembering the Prior Body States of Others: Evidence From Facial EMG and Pupil Size

7.1 Summary

The experiments in this thesis have investigated the long-term effects of other's emotional body states on the observer, questioning whether they are automatically simulated, retrieved during later encounters in the form of reactivated simulations, and whether even when very subtle, they have an influence on long-term person perceptions.

The experiments in Chapters 2, 3 and 4 focused on facial mimicry of emotional expressions. Chapter 2 demonstrated that facial mimicry effects appear robustly obligatory, occurring even over multiple exposures and without attention being focused on the emotion being perceived. The experiments in Chapter 3 provided the first evidence that facial mimicry effects are reactivated, firstly in prediction of oncoming emotion and secondly during later re-exposure to neutral versions of previously emotional faces. Chapter 4 demonstrated that these effects appear to be specific to facial embodiments of other people's emotions and do not seem to occur with non-facial emotional stimuli.

Chapters 5 and 6 provided the first evidence that pupil size, a very subtle indicator of arousal, is encoded incidentally into long-term memory, to change later person perceptions, and that this appears to be modulated by static qualities of the face, such as sex and trustworthiness. This effect was shown to occur in female participants,

but to be weaker in male participants. The experiments in Chapter 6 demonstrated that physiological states of arousal, caused by viewing pupil size changes, are reinstated during later viewing, and that the effects of pupil size on long-term person perception appear to be particularly influential in the case of less trusted individuals.

This final chapter summarises the results of these experiments, drawing conclusions on how they extend our understanding of embodied processes underlying person perception. Limitations and future directions are discussed.

7.2 Facial Mimicry Effects.

The first chapters of this thesis investigated whether facial mimicry of another person's emotional expression is reactivated upon later exposure to an individual at a time when that person is not, or is yet to show, any sign of their emotional state. Facial mimicry effects have been demonstrated in a large number of studies, in which facial EMG, the technique used in this thesis, was employed to demonstrate participant's facial muscles automatically mimic the expressions of people they view during experiments (e.g. Cannon et al., 2009; Dimberg, 1982; Dimberg & Thunberg, 1998; Dimberg et al., 2000). Facial mimicry has been taken as evidence that other people's emotions are represented through embodiment, or simulation (e.g. Iacoboni, 2009; Niedenthal et al., 2010), where the outward signs of emotion, such as emotional expression, cause the same sensory-motor activations to occur in the observer allowing them access to the inner state of the person they are viewing. This view is supported by the apparent automaticity of facial mimicry (Dimberg et al., 2002), and the fact that the ability to mimic appears to aid emotion comprehension (Maringer et al., 2012; Neal & Chartrand, 2011; Niedenthal et al., 2001; Ponari et al., 2012). The data we presented from

experiments 2 and 3, as well as the exposure tasks in experiments 4 to 7 support the idea that facial mimicry represents an automatic process, and therefore add support for its relevance as more than just part of an emotional reaction to someone else's expression.

The participants in experiments 2 and 3 showed significant facial mimicry with their zygomaticus muscles, the muscles that lift the mouth in a smile and relax during frowning. They also showed mimicry responses, although less powerfully, in their corrugator muscles, which draw down the brow during frowning. These responses occurred even after five blocks of a task where the facial expressions carried no consequences for the participants. This provides evidence that facial mimicry did not reduce over multiple exposures, suggesting that it is obligatory in nature and not simply an effect of seeing a stimulus that might be emotive. Facial mimicry in these experiments also did not differ when participants were attending to the sex of a face, or to its expression, replicating the findings of Cannon et al., (2009), and adding further to the evidence for automaticity. This latter finding was replicated in the experiments in Chapter 3, where participants mimicked significantly with both muscles, regardless of whether they were attending to the emotion on the face or its identity.

We also identified a variation between the two muscles in these experiments. That zygomaticus mimicry appears to increase over exposure time during a trial, whilst corrugator mimicry appears to be more transient, disappearing once a face disappears from view. This supports the suggestion of Bourgeois & Hess (2008), that simulations in the corrugator muscle may be inhibited in some situations as they are socially more of a risk if detected. Together the facial mimicry results in these two chapters add

support to the notion that facial mimicry effects reflect automatic processes presumed to be simulations of other's emotional states.

7.3 Reactivation of Facial Mimicry

The key hypothesis in this thesis is that the body states of others do not simply exert an influence on an observer at the time of an interaction, but also at later times when people are re-encountered. According to embodied theories of memory (Barsalou, 1999, 2008; Buckner & Wheeler, 2001; Damasio, 1989; Danker & Anderson, 2010), body states associated with a stimulus are reactivated upon re-encountering that stimulus or retrieving it from memory. We suggested that if other people's emotional states are embodied, or simulated, through facial mimicry, this body state should be reactivated when later encountering the same person again. Therefore the experiments in chapters 2 to 4 used a simple paradigm where participants were exposed multiple times to faces that became expressive (or became emotive animals in Chapter 4), causing facial mimicry in the participant's own facial muscles. Importantly these faces were consistent, with each face always appearing happy or angry. Participants were exposed at the same time (Chapter 2) or a later time (Chapters 3 and 4), to neutral versions of the faces, which were predicted to elicit reinstatement of any prior facial mimicry.

The experiments in Chapter 2 showed an effect that was non-significant but appeared to be a rebound, or contrast effect during the neutral face trials. In most blocks when participants viewed a particular face identity expressing a neutral expression the muscle state activated was opposite to that of the expression of that

person on other trials. We concluded that by embedding the neutral faces into the same task as the emotional faces, we might be causing a contrast effect to occur.

In the experiments in Chapter 3 we separated the tasks, having participants attend to emotion or identity during the exposure phase, where they saw, and mimicked the smile or frown expressions. In a later retrieval task participants viewed neutral versions of the faces while looking out for oddball emotion or identity catch trials. These experiments were conducted as a quad, with two experiments being consistent in terms of the focus of the tasks upon encoding and retrieval (i.e. emotion – emotion / identity- identity) and two experiments mixing those attention conditions (emotion – identity / identity – emotion).

Participants showed retrieval effects in their zygomaticus muscles. Firstly these occurred during the earlier exposure task when viewing neutral faces prior to emotion expression, where zygomaticus activity predicted the oncoming emotion of the face. That is, participants learned the face identity-emotion pairings, which evoked predictive simulation of the oncoming facial expression. Similar effects have been demonstrated with other motor actions (e.g. Kilner et al., 2004) but our data are the first to show these effects in facial expression simulation during tasks where the facial expressions are not pre-emptive of any other kind of feedback (see Heerey & Crossley, 2012 for similar results). The predictive simulations before the facial expression began, is novel because similar effects have been shown only after the onset of an action. Most importantly though, we have also shown that facial mimicry effects can be reactivated after a period of time has passed, when neutral versions of previously expressive faces are viewed.

During the later retrieval task, which followed the exposure task by several minutes, the female participants tested reactivated mimicry-like responses to faces that now appeared with neutral expressions. Interestingly, this was not affected by whether they were attending to possible emotional probes, or to identity, which was also true of the predictive activations in the exposure task. However, these effects of reactivation were stronger in participants who completed the consistent experiments, where attention was drawn to the same aspects of the face during both exposure and retrieval tasks. This is in alignment with the concept of transfer appropriate processing (e.g., Graf & Ryan, 1990; Morris et al., 1977), which suggests that retrieval will be improved if conditions at retrieval match those at encoding. The fact that reactivation was not affected by what aspect of the face the participants attended to supports the notion of automatic simulations of others (e.g. Niedenthal et al., 2010). Reactivations occurred even when facial expressions were not expected, in the attend to identity task where every face appeared neutrally (in attend to emotion, expressions were also rare events).

Of importance to our account are the situations where reactivation of prior emotions did not occur. That is, reactivation of mimicry only occurred in participants who showed facial mimicry during the encoding exposure task, supporting the notion that embodied memory effects would only occur if body states were active during encoding. Participants also did not show reactivations in their corrugator, either in prediction of oncoming expressions during exposure, or during the retrieval task. The transient nature of the mimicry effects in the corrugator, suggests that this muscle may be less involved in simulations of other's emotions and therefore unlikely to be reactivated during later encounters. Further research would be needed to clarify this.

Finally, the experiments in Chapter 4 indicated that whilst weak mimicry like effects can be elicited by non-facial emotive stimuli, paired with faces, these are not reactivated in the same way as facial mimicry. This echoes the results of Halberstadt et al., (2009) who showed that reactivations of facial reactions to emotional concepts only occurred when the concepts concerned facially expressed emotional states (e.g., 'this person is happy' rather than 'this person is messy'), paired with faces. Similar reactivations did not occur with non-face stimuli, or concepts like lazy, that did not have an obvious facial representation. Together the results from these two chapters provide the first evidence for the reactivation of facial mimicry of other's expressions. They support the notion that simulations of other's emotions may play a key role in understanding other people's internal states, but extend this to predicting forthcoming states and retrieving past states.

7.4 Long-term Effects of Pupil Size on Person Perception

The experiments in the latter half of the thesis addressed the question of whether pupil size, a very subtle signal of arousal, can exert a long-term influence on person perception. Pupil size is of interest in this thesis because like facial expression, it is a physical cue that has been shown to elicit embodied responses in observers (e.g. Harrison et al., 2006). Pupil size has been shown to effect perceptions of other people, without being consciously detected by the observer (e.g. Bull & Shead, 1979; Hess, 1960; Tombs & Silverman, 2004), and so like facial mimicry which is not necessarily felt by the observer and was not by our participants, it appears to be a physical cue of another person's internal state, that causes a subtle change in the perception of an observer through embodied processes. Whilst past research had demonstrated that

pupil size could influence perceptions of traits like attractiveness in the short term, as well as causing changes in neural activity (e.g. Demos et al., 2008), no research had investigated whether the effects of pupil size were longer lasting.

Our experiments used a simple paradigm rather like that used in the mimicry experiments in the first half of the thesis. Participants viewed faces during an exposure task whose pupils consistently dilated or constricted during trials, but the participants were unaware of this, instead attending to the identity of the faces. In a second task completed several minutes later participants saw the faces again, only this time no pupil size changes occurred and the participants made ratings of the faces. The data from the first two experiments in Chapter 5, where female participants completed this task whilst viewing male and female faces (Experiment 10) and high and low trust male faces (Experiment 11), showed very interesting results. Pupil size changes were encoded into long-term memory despite the participants being unaware of observing any such changes. They influenced later person ratings, with women whose pupils dilated being rated more positively than those whose pupils constricted, and the opposite occurring with male faces in Experiment 10. In Experiment 11, high trust male faces whose pupils dilated were also rated more positively than those whose pupils constricted, with the opposite true of low trust males.

These observations provided the very first evidence that pupil size changes can exert an influence that goes beyond the time of an initial interaction. This is a very novel finding, and whilst comparable to effects of later person perception of other cues like gaze (e.g. Bayliss et al., 2006) is really unique in terms of the subtlety of pupil size, a cue which is not even explicitly detected by an observer. It is also very interesting that the effects of pupil size are modulated by the possible expectations of the observer of

the characteristics of a person based on their face. This would explain why this encoded arousal cue exerts a positive influence on ratings when encoded alongside a female face, but the opposite in a face that is less trustworthy. Also interesting were the results of experiments 12 and 13, which showed that whilst male participants showed a pattern of ratings similar to that of the female participants when completing the same tasks, the effects on their later perceptions caused significantly weaker differences in preference for the different conditions of face. This finding mirrors those found in gaze cuing (see Frischen, Bayliss & Tipper, 2007) and facial mimicry (e.g. Dimberg & Lundquist, 1990) experiments that have shown differences in the way men and women automatically respond to the socially relevant body states of others.

The natural progression of this question was to ask whether our participants showed the kinds of pupillary contagion responses shown in other studies, whereby participant's own pupils change size in accordance to the person's they are viewing (e.g. Harrison et al., 2006). We believed that as with facial mimicry effects these automatic simulations might be reactivated upon re-exposure and might underlie the changes in person perception. Although it is important to indicate that whilst facial mimicry represents the simulation of a physical state that characterises a particular emotional valence (i.e smiling when happy, frowning when unhappy or angry), pupil dilation is only indicative of a state of arousal. The results of Experiment 11 suggest that the intention of the arousal state indicated by pupil dilation may be in part interpreted by the observer on the basis of other features of the face being observed, such as its relative trustworthiness. So when investigating the simulation and possible later reactivation of the simulation of another's pupil size changes in Experiment 14, we can only conclude that reactivation of simulation might suggest involve the same process of

interpretation in relation to other features of the face being viewed. In Chapter 6, Experiment 14, we used measures of electrodermal activity (EDA), a correlate of sympathetic nervous system (SNS) activity, to measure SNS activity in response to the pupil size changes in the exposure task, and the later re-exposure during ratings, where average pupils were displayed. This converging method was chosen as a less invasive attempt to measure embodied responses to viewing pupil size change than using the head-mounted eye-tracker in the lab, but in pre-emption of running the obvious follow up experiment to directly measure pupil size. Pupil size changes and EDA responses have been shown in past research to correlate (Bradley et al., 2008). As predicted, changes in SNS response, caused apparently by pupil size change occurred during the exposure task and were reactivated during ratings. These occurred in response only to pupil size changes in low trust faces, where SNS activity was significantly higher when faces appeared / had appeared with dilated, rather than constricted pupils. This provided further evidence of the encoding of pupil size changes, but also a key indicator that the effects on later person perception might be driven by a reactivation of a shared state of arousal.

The significance of pupil size changes in faces that are less trustworthy was also hinted at in the final experiment of the thesis, where ratings of the faces were taken before as well as after the participants were unknowingly exposed to the dilating and constricting pupils. Here the same pattern of results for male and female faces emerged, but where as all other categories of face were preferred after the multiple exposures during the first task, the male faces whose pupils enlarged, were found to be less friendly. As the relatively less trustworthy faces in comparison to the female faces, it appears that the encoded signal of arousal exerted a stronger influence on the

participant's feelings about the faces. Theories of how we may use simulations to guide predictions of others (see Frith & Frith, 2006) or understand other's states and intentions (see Niedenthal et al., 2010) suggest that simulations exert and influence alongside other sources of information about the person we are viewing such as stereotypes, which predispose us to draw particular conclusions. As well as the immediate relevance of a less trustworthy person showing a sign of arousal, it may be the case that the effects of pupil size change were very pronounced in comparatively lower trust faces because they offer more obvious stereotypes to drive the effects of the retrieval of their prior body states.

Collectively the experiments from Chapters 5 and 6 provided interesting evidence for a never before shown, long-term effect of observed body state, and provided a complimentary set of results to those in the earlier chapters.

7.5 Limitations and Future Directions

During the experiments in the previous chapters, individual differences were shown. Some participants showed facial mimicry, others did not. Male participants showed weaker effects of encoded pupil size than female participants. It would be valuable to know what underpins these differences. Previous research has suggested for example that anxiety can change neural representations of other people's emotions (Ewbank et al., 2009), and that differences in facial mimicry occur in people with autistic traits (McIntosh et al., 2006). Attempts were made during the current experiments, to gauge whether such traits differed between groups of participants in the EMG and pupil tasks. Measures of autistic traits, anxiety and mood were administered during the experiments in chapters 3, 4, 5 and 6. However, no consistent

results could be found and these measures were not reported. With a sample of undergraduates students, variation in subclinical traits is likely to be quite limited, and it would be preferential to carry out further research on pre-selected samples, where we would expect that attenuation or hyper-action of the mimicry effects or the physiological effects of viewing pupil size changes, would cause smaller, or larger effects of retrieval respectively.

Our EMG studies revealed weaker effects in the corrugator for facial mimicry, and no effects of retrieval. It would be of interest given the suggestion that corrugator activity might be dampened or heightened as a result of social context (Bourgeois & Hess, 2008), to conduct further experiments where corrugator activity in response to frowns is manipulated, for example through a competitive task, in order to see if larger activations also lead to retrieval. Our participants also showed explicit recall for the identity-emotion pairings in the experiments in Chapter 3 that did not differ between mimicker and non-mimickers. It would be interesting to know if a more difficult memory task might lead to differentiation between the two groups. A larger sample of faces, or a task where perceptual interference upon recall was implemented, might lead to indications that retrieval of mimicry at a later time improves discrimination between which faces have show which expressions in the past.

The effects of pupil size on later perception showed some inconsistencies between experiments, with unexpected results in Experiment 14, and non-significant results in male participants and in the before and after ratings in Experiment 15. This is a new area of study, and more replications are required, as is a larger sample for a measure as potentially noisy as the visual analogue scale. The results from these experiments are extremely interesting and novel but do require follow-ups. One

obvious study would be to replace the electrodermal measure with an eye-tracking measure to gauge pupillary contagion directly. We were not able to employ this during the current experiments, and the fine control over low-level visual properties the stimuli required, and over saccades, would require careful consideration, but it is earmarked as a future experiment. Also, it would be very interesting to know how long the pupil effect lasts for. This could be investigated by employing an unrelated task between exposure and ratings phases, to see if the pupil encoding survives short-term interference. Or the two halves of the experiment could be conducted on separate days.

7.6 Conclusions

The experiments in this thesis have provided novel evidence of two effects of the retrieval from memory of the prior body states of others. Firstly, as well as providing further evidence of the automatic nature of facial mimicry effects, the experiments in the first four chapters demonstrated a facial expression specific reactivation of embodiments of others emotional states, that occurred regardless of whether attention was explicitly directed at this aspect of the person being viewed, and occurred both in prediction of forthcoming emotion and later when emotion was not expected. This effect was shown, as hypothesised to only occur in those people who first mimicked the face's emotional expressions, further indication that it represented a retrieval of a prior body state from memory. Secondly, we were able to show for the first time, in the later chapters of the thesis, that the effects of incidentally observed pupil size go beyond the time of an interaction, to change longer term person perceptions. This was shown to be modulated by the static traits of a face, such as it's sex or trustworthiness, and to occur alongside physiological responses that were induced by the observed pupil changes and

Chapter 7

reinstated during the later re-encounters – in this case these were electrodermal responses, indicative of arousal, elicited when viewing untrustworthy faces showing pupil dilation and reactivated when viewing the same faces later with average sized pupils. Together these findings provide new evidence that the body states of others are indeed encoded into memory and retrieved during later interactions, findings which support the idea that simulations of other's states may guide social interactions.

8. References

- Alaerts, K., Nackaerts, E., Meyns, P., Swinnen, S. P., & Wenderoth, N. (2011). Action and Emotion Recognition from Point Light Displays: An Investigation of Gender Differences. *PLoS ONE* 6(6), e20989. doi:10.1371/journal.pone.0020989
- Amemiya, S., & Ohtomo, K. (2012). The effect of observed pupil size on the amygdala of beholders. *Social Cognitive Affective Neuroscience*, 7, 332-341.
- Andreassi, J. L. (2007). *Psychophysiology: Human Behaviour and Physiological Response*. Psychology Press: London.
- Archaibou, A., Pourtois, G., Schwartz, S., & Vuilleumier, P. (2008). Simultaneously recordings of EEG and facial muscle reactions during spontaneous emotional mimicry. *Neuropsychologia*, 46, 1104-1113.
- Aston-Jones, G., Cohen, J. (2005). An integrative theory of locus coeruleus-norepinephrine function: Adaptive gain and optimal performance. *Annual Review of Neuroscience*, 28, 403-450.
- Avenanti, A., Candidi, M., & Urgesi, C. (2013). Vicarious motor activation during action perception: beyond correlational evidence. *Frontiers in Human Neuroscience*, 7, 185.
- Bach, P., Griffiths, D., Wiegelt, M., & Tipper, S. P. (2010). Gesturing meaning: Non-action words activate the motor system. *Frontiers in Human Neuroscience*, 4, 214.
- Bach, P., Peatfield, N., & Tipper, S. P. (2007). Focussing on body sites: The role of spatial attention in action perception. *Experimental Brain Research*, 178, 509-517.

Bach, P., & Tipper, S. P. (2006). Bend it like Beckham: Embodying the motor skills of famous athletes. *Quarterly Journal of Experimental Psychology*, 59, 2033-2039.

Banissy, M. J., Garrido, L., Kusnir, F., Duchaine, B., Walsh, V., & Scott, S. (2011). Superior facial expression but not identity recognition, in mirror-touch synaesthesia. *Journal of Neuroscience*, 31, 1820-1824.

Bargh, J. A., Chen, M., & Burrows, L. (1996). Automaticity of social behavior: Direct effects of trait construct and stereotype priming on action. *Journal of Personality and Social Psychology*, 71, 230-244.

Baron-Cohen, S. (2002). The extreme male brain theory of autism. *Trends in Cognitive Science*, 6, 248-254.

Baron-Cohen, S., Wheelwright, S., Hill, J., Raste, Y., & Plumb, I. (2001). The "reading the mind in the eyes" test revised version: A study with normal adults, and adults with Asperger syndrome or high-functioning autism. *Journal of Child Psychology and Psychiatry*, 42, 241-251.

Barsalou, L. W. (1991). Perceptual and Symbol systems. *Behavior Brain Sciences*, 22, 557-660.

Barsalou, L. W. (2003). Situated simulation in the human conceptual system. *Language and Cognitive Processes*, 18, 513-562.

Barsalou, L. W. (2008). Grounded Cognition. *Annual Review of Psychology*, 59, 617-645.

Barsalou, L. W., Santos, A., Simmons, W. K., & Wilson, C. D. (2008). Language and simulation in conceptual processing. In de Vega, M., Glenberg, A., & Graesser, A. (Eds). *Symbols and Embodiment: Debates on Meaning and Cognition*. Oxford, Oxford University Press.

Bastiaansen, J. A., Thioux, M., and Keysers, C. (2009). Evidence for mirror systems in emotions. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 364, 2391–2404.

Bayliss, A. P., di Pellegrino, G., & Tipper, S. P. (2005). Sex differences in eye-gaze and symbolic cueing of attention. *Quarterly Journal of Experimental Psychology*, 58(4), 631-650.

Bayliss, A. P., Frischen, A., Fenske, M. J., & Tipper, S. P. (2007). Affective evaluations of objects are influenced by observed gaze direction and emotional expression. *Cognition*, 104(3), 644-653.

Bayliss, A. P., Griffiths, D. & Tipper, S. P. (2009). Predictive gaze cues affect face evaluations: The effect of facial emotion. *European Journal of Cognitive Psychology*, 21(7), 1072-1084.

Bayliss, A. P., Murphy, E., Naughtin, C. K., Kritikos, a., Schilbach, L., & Becker, S. I. (2013). "Gaze leading": Initiating simulated joint attention influences eye movements and choice behavior. *Journal of Experimental Psychology: General*, 142(1), 76-92.

Bayliss, A. P., Paul, M., Cannon, P. R., & Tipper, S. P. (2006). Gaze cuing and affective judgements of objects: I like what you look at. *Psychonomic Bulletin and Review*, 13(6), 1061-1066.

Bayliss, A. P., & Tipper, S. P. (2006). Predictive gaze cues and personality judgments: Should eye trust you? *Psychological Science*, 17, 514–520.

Bechara, A., Damasio, H., Trnel, D., & Damasio, A. R. (1997). Deciding advantageously before knowing the advantageous strategy. *Science*, 275, 1293-1295.

Behrens, T. E. J., Hunt, L. T., & Rushworth, M. F. S. (2009). The computation of social behaviour. *Science*, 324, 1160-1164.

Ben-Shakhar, G. (1985). Standardisation within individuals: A simple procedure to neutralise differences in skin conductance. *Psychophysiology*, 22, 292-299.

Bogart, K. R., & Matsumoto, D. (2009). Facial mimicry is not necessary to recognise emotion: Facial expression recognition in people with Mobius syndrome. *Social Neuroscience*, 5(2), 241-251.

Bourgeois, P., & Hess, U. (2008). The impact of social context on mimicry. *Biological Psychology*, 77, 343-352.

Bradley, M. M., Codispoti, M., Sabatinelli, D., & Lang, P. J. (2001). Emotion and motivation II: Sex difference in picture processing. *Emotion*, 1, 300-319.

Bradley, M. M., Miccoli, L., Escrig, M. A., & Lang, P. J. (2008). The pupil as a measure of emotion arousal and autonomic activation. *Psychophysiology*, 45(4), 602-607.

Braithwaite, J. J., Watson, D. G., Jones, R., & Rowe, M. (2013). *A Guide for Analysing Electrodermal Activity (EDA) & Skin Conductance Responses for Psychological Experiments*. Retrieved from <http://www.birmingham.ac.uk/Documents/colleges/psych/saal/guide-electrodermal-activity.pdf>

Brass, M., Bekkering, H., & Prinz, W. (2001). Movement observation affects movement execution in a simple response task. *Acta Psychologica (Amst)*, 106, 3-22.

Brass, M., Bekkering, H., Wohlschläger, A., & Prinz, W. (2000). Compatibility between observed and executed finger movements: Comparing symbolic, spatial and imitative cues. *Brain and Cognition*, 44, 124-143.

Breska, A., Maoz, K., & Ben-Shakhar, G. (2011). Interstimulus intervals for skin conductance measurement. *Psychophysiology*, 48, 437-440.

Buckner, R. L., & Wheeler, M. E. (2001). The cognitive neuroscience of

remembering. *Nature Reviews Neuroscience*, 2, 624-634.

Bull, R., Shead, G. (1979). Pupil dilation, sex of stimulus, and age and sex of observer. *Perceptual and Motor Skills*, 49, 27-30.

Cacioppo, J. T., Bush, L. K., & Tassinary, L. G. (1992). Microexpressive facial actions as a function of affective stimuli: Replication and extension. *Personality and Social Psychology Bulletin*, 18, 515-526.

Cannon, P. R., Hayes, A. E., & Tipper, S. P. (2009). An electromyographic investigation of the impact of task relevance on facial mimicry. *Cognition and Emotion*, 23(5), 918-929.

Cannon, P. R., Hayes, A. E., & Tipper, S. P. (2010). Sensorimotor fluency influences affect: Evidence from electromyography. *Cognition and Emotion*, 24(4), 681-691.

Chao, L. L., & Martin, A. (2000). Representation of manipulable man-made objects in the dorsal stream. *NeuroImage*, 12, 478-484.

Chartrand, T. L., & Bargh, J. A. (1999). The chameleon effect: The perception-behavior link, and social interaction. *Journal of Personality and Social Psychology*, 76(6), 893-910.

Cheng, Y., Tzeng, O. J. L., Decety, J., Imada, T., & Hsieh, J. (2006) Gender differences in the human mirror system: a magnetoencephalographic study. *Neuroreport* 17, 1115-1119.

Codispoti, M., Bradley, M. M., & Lang, P. J. (2001). Affective reactions to briefly presented pictures. *Psychophysiology*, 38, 474-478.

Damasio, A. R. (1989). Time locked multiregional retro-activation: A systems level proposal for the neural substrates of recall and recognition. *Cognition*, 33, 25-62.

Danker, J. F., & Anderson, J. R. (2010). The ghosts of brain states past: Remembering reactivates the brain regions involved during encoding. *Psychological Bulletin*, 136, 87-102.

Dawson, M. E., Schell, A. M., & Filion, D. L. (2007). The electrodermal system. In Cacioppo, J. T., Tassinary, L.G., and Berntson, G. G. (Eds.), *Handbook of Psychophysiology* (3rd ed.). Cambridge, UK: Cambridge University Press.

De Gelder, B. (2006). Towards the neurobiology of emotional body language. *Nature Reviews Neuroscience*, 7(3), 242-249.

De Houwer, J. (2009). The propositional approach to associative learning as an alternative for association formation models. *Learning & Behavior*, 37, 1–20.

Demos, K. E., Kelley, W. M., Ryan, S. L., Davis, F. C., Whalen, P. J. (2008). Human amygdala sensitivity to the pupil size of others. *Cerebral Cortex*, 18, 2729–34.

Dimberg, U. (1982). Facial reactions to facial expressions. *Psychophysiology*, 19(6), 643-647.

Dimberg, U., & Karlsson, B. (1997). Facial reactions to different emotionally relevant stimuli. *Scandinavian Journal of Psychology*, 38, 297-303.

Dimberg, U., & Petterson, M. (2000). Facial reactions to happy and angry facial expressions: Evidence for right hemisphere dominance. *Psychophysiology*, 37, 693–696.

Dimberg, U., & Thunberg, M. (1998). Rapid facial reactions to emotional expressions. *Scandinavian Journal of Psychology*, 39(1), 39-45.

Dimberg, U., Thunberg, M., & Elmehed, K. (2000). Unconscious facial reactions to emotional facial expressions. *Psychological Science*, 11(1), 86-89.

Dimberg, U., Thunberg, M., & Grunedal, S. (2002). Facial reactions to emotional stimuli: Automatically controlled emotional responses. *Cognition and Emotion*, 16(4), 449-471.

Dimberg, U., Thunberg, M., & Grunedal, s. (2002). Facial reactions to emotional stimuli: Automatically controlled emotional responses. *Cognition and Emotion*, 16(4), 449-471.

di Pelligrino, G., Fadiga, G., Fogassi, L., Gallese, L., & Rizzolatti, G. (1992). Understanding motor events: A neurophysiological study. *Experimental Brain Research*, 91, 176-180.

Doallo, S., Raymond, J. E., Shapiro, K. L., Kiss, M., Eimer, M., & Nobre, A. C. (2012). Response inhibition results in the emotional devaluation of faces: Neural correlates as revealed by fMRI. *Social Cognitive Affective Neuroscience*, 7, 649-659.

Driver, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E., & Baron-Cohen, S. (1999). Gaze perception triggers reflexive visuospatial orienting. *Visual Cognition*, 6(5), 509-540.

Einhauser, W., Stout, J., Koch, C., & Carter, O. (2008). Pupil dilation reflects perceptual selection and predicts subsequent stability in perceptual rivalry. *Proceedings of the National Academy of Sciences*, 105, 1704-1709.

Eisenbarth, H., Gerdes, A. B. M., & Alpers, G. W. (2011). Motor-incompatibility of facial reactions. The influence of valence and stimulus content on voluntary facial reactions. *Journal of Psychophysiology*, 25(3), 124-130.

Ekman, P., & Friesen, W. V. (1971) Constants across cultures in the face and emotion. *Journal of Personality and Social Psychology*, 17(2), 124-129.

Ellermeier, W., & Westphal, W. (1995). Gender differences in pain ratings and pupil reactions to painful pressure stimuli. *Pain*, 61, 435-439.

Fadiga, L., Fogassi, L., Pavesi, G., & Rizzolatti, G. (1995). Motor facilitation during action observation: a magnetic stimulation study. *Journal of Neurophysiology*, 73(6), 2608-2611.

Figner, B., & Murphy, R. O. (2010) Using skin conductance in judgement and decision making research. In Schulte-Mecklenbeck, A., Kuehberger, A., & Raynard, R. (Eds.), *A Handbook of Process Tracing Methods for Decision Making Research*. New York, NY: Psychology Press.

Fogassi, L., Ferrari, P. F., Gesierich, B., Rozzi, S., Chersi, F., & Rizzolatti, G. (2005). Parietal Lobe: From action organization to intention understanding. *Science*, 308, 662-667.

Fridlund, A. J. & Cacioppo, J. T. (1986). Guidelines for human electromyography research. *Psychophysiology*, 23, 567-589.

Friesen, C. K., & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin & Review*, 5, 490-495.

Frischen, A., Bayliss, A. P., & Tipper, S. P. (2007). Gaze cuing of attention: Visual attention, social cognition and individual differences. *Psychological Bulletin*, 133(4), 694-724.

Frith, C. D., & Frith, U. (2009). How we predict what other people are going to do. *Brain Research*, 1079, 36-46.

Gallese, V., & Goldman, A. I. (1998). Mirror neurons and the simulation theory of mind reading. *Trends in Cognitive Science*, 2, 493-551.

Gazzaniga, M. S., & Smylie, C. S. (1990). Hemispheric mechanisms controlling voluntary and spontaneous facial expressions. *Journal of Cognitive Neuroscience*, 2, 239-245.

Gibson, J. J. (1979). *The Ecological Approach to Visual Perception*. Boston, MA: Houghton –Mifflin.

Graf, P., & Ryan, L. (1990). Transfer-appropriate processing for implicit and explicit memory. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 16, 978-992.

Grafton, S. T., Fadiga, L., Arbib, M. A., & Rizzolatti, G. (1997). Premotor cortex activation during observation and naming of familiar tools. *NeuroImage*, 6(4), 231-236.

Halberstadt, J., Winkielman, P., Niedenthal, P. & Dalle, N. (2009). Emotional conception: How embodied emotion concepts guide perception and facial action. *Psychological Science*, 20, 1254–1261.

Harrison, N. A., Gray, M. A., & Critchley, H. D. (2009). Dynamic pupillary exchange engages brain areas encoding social salience. *Social Neuroscience*, 4(3), 233-243.

Harrison, N. A., Singer, T., Rotshtein, P., Dolan, R. J., & Critchley, H. D., (2006). Pupillary contagion: central mechanisms engaged in sadness processing. *Social Cognitive and Affective Neuroscience*, 1, 5 -17.

Harrison, N. A., Wilson, C. E., & Critchley, H. D. (2007). Processing of observed pupil size modulates perception of sadness and predicts empathy. *Emotion*, 7(4), 724-729.

Heerey, E. A., & Crossley, H. M. (2013). Predictive and reactive mechanisms in smile reciprocity. *Psychological Science*, DOI: 10.1177/0956797612472203.

Helbig, H. B., Graf, M., & Kiefer, M. (2006). The role of action representations in visual object recognition. *Experimental Brain Research*, 174, 221-228.

Hess, E. (1965). Attitude and Pupil Size. *Scientific American*, 212, 46-54.

Hess, U., & Blairy, S. (2001). Facial mimicry and emotional contagion to dynamic emotional facial expressions and their influence on decoding accuracy. *International Journal of Psychophysiology*, 40, 129-141.

Hess, U., Philippot, P., & Blairy, S. (1998). Facial reactions to emotional facial expressions: Affect or Cognition? *Cognition and Emotion*, 12(4), 509-531.

Hess, E. H., & Polt, J. M. (1960). Pupil size as related to interest value of visual stimuli. *Science*, 5, 349-350.

Hess, E. H., & Polt, J. M. (1964). Pupil size in relation to mental activity during simple problem solving. *Science*, 140, 1190-1192.

Heyes, C. (2010). Where do mirror neurons come from? *Neuroscience and Biobehavioural Reviews*, 34, 575-583.

Hicks, R. A., Reaney, T., & Hill, L. (1967). Effects of pupil size and facial angle on preference for photographs of a young woman. *Perceptual and Motor Skills*, 24, 388-390.

Hofle, M., Kenntner-Mabiala, R., Pauli, P., & Alpers, G. W. (2008). You can see the pain in the eye: Pupillometry as an index of pain intensity under different luminance conditions. *International Journal of Psychophysiology*, 70(3), 171-175.

Iacoboni, M. (2009). Imitation, empathy and mirror neurons. *Annual Review of Psychology*, 60, 653-670.

Isard, C. E. (1971). *The Face of Emotion*. New York: Appleton-Century-Crofts.

Jackson, P. L., Meltzoff, A. N., & Decety, J. (2005). How do we perceive the pain of others? A window into the neural processes involved in empathy. *Neuroimage*, 24, 771-

779.

Jones, B. C., DeBrunie, L. M., Perrett, D. I., Little, A. C., Feinberg, D. R., & Smith, M. J. L. (2008). Effects of menstrual cycle phase on face preferences. *Archives of Sexual Behavior, 37*, 78-84.

Kahneman, D., & Beatty, J. (1966). Pupil diameter and load on memory. *Science, 154*, 1583-1585.

Keysers, C. & Perrett, D. (2004). Demystifying social cognition: A Hebbian perspective. *Trends in Cognitive Sciences, 8*, 11, 501-507).

Kilner, J. M., Friston, K. J., & Firth, C. D. (2007). Predictive coding: an account of the mirror neuron system. *Cognitive Processes, 8*, 159-166.

Kilner, J. M., Vargas, C., Duval, S., Blakemore, S. J., & Sirigu, A. (2004). Motor activation prior to observation of a predicted movement. *Nature Neuroscience, 7*(12), 1299-1301.

Kret, M. E., Stekelenburg, J. J., Roelofs, K., & de Gelder, B. (2013). Perception of face and body expressions using electromyography, pupillometry and gaze measures. *Frontiers in Psychology, 4*, 28, 1-13.

Krumhuber, E. G., Kappas, A., & Manstead, A. S. R. (2013). Effects of dynamic aspects of facial expressions: A review. *Emotion Review, 5*(1), 41-46.

Laeng, B., & Falkenberg, L. (2007). Women's pupillary responses to sexually significant others during the hormonal cycle. *Hormones and Behavior, 52*, 520-530.

Laeng, B., Sirois, S., & Gredeback, G. (2012). Pupillometry: A window to the preconscious? *Perspectives of Psychological Science, 17*(1), 18-27.

Larsen, R. J., Kasimatis, M., & Frey, K. (1992). Facilitating the furrowed brow: An unobtrusive test of the facial feedback hypothesis applied to unpleasant affect. *Cognition*

and Emotion, 6(5), 321-338.

Larsen, J. T., Norris, C. J., & Cacioppo, J. T. (2003). Effects of positive and negative affect on activity over zygomaticus major and corrugator supercilii.

Psychophysiology, 40, 776,785.

Lee T. W., Josephs, O., Dolan, R. J., Critchley, H. D. (2006). Imitating expressions: Emotion-specific neural substrates in facial mimicry. *Social Cognitive Affective Neuroscience*, 1, 22-135.

Likowski, K. U., Muhlberger, A., Gerdes, A. B., Wiesser, M. J., Pauli, P., & Weyers, P. (2012) Facial mimicry and the mirror neuron system: Simultaneous acquisition of facial electromyography and functional magnetic resonance imaging. *Frontiers in Human Neuroscience*, 26(6), 214.

Lobue, V., & DeLoache, J. S. (2008). Detecting the snake in the grass: Attention to fear relevant stimuli by adults and young children. *Psychological Science*, 19(3), 284-289.

Lundqvist, D., Flykt, A., & Ohman, A. (1998). *The Karolinska Directed Emotional Faces (KDEF)*. Stockholm: Department of Neurosciences, Karolinska Hospital.

McGivern, R. F., Adams, B., Handa, R. J., & Pineda, J. A. (2012). Men and Women Exhibit a Differential Bias for Processing Movement versus Objects. *PLoS ONE*, 7(3): e32238. doi:10.1371/journal.pone.0032238

McIntosh, D.N. (1996). Facial feedback hypotheses: evidence, implications, and directions. *Motivation and Emotion*, 20, 121-147.

McIntosh, D. N., Reichmann-Decker, A., Winkielman, P., & Wilbarger, J. L. (2006). When the social mirror breaks: Deficits in automatic, but not voluntary, mimicry of emotional facial expressions in autism. *Developmental Science*, 9(3), 295–302.

Meltzoff, A. N., & Decety, J. (2003). What imitation tells us about social cognition: a rapprochement between developmental psychology and cognitive neuroscience. *Philosophical Transactions of the Royal Society London: B*, 358, 491-500.

Morris, C. D., Bransford, J. D., & Franks, J. J. (1977). Levels of processing versus transfer appropriate processing. *Journal of Verbal Learning and Verbal Behaviour*, 16, 519-533.

Niedenthal, P. M., Barsalou, L. W., Winkielman, P., Krauth-Gruber, S. & Ric, F. (2005) Embodiment in attitudes, social perception, and emotion. *Personality and Social Psychology Review*, 9, 184–211.

Niedenthal, P. M. (2007). Embodying Emotion. *Science*, 316, 1002-1005.

Niedenthal, P. M., Mermillod, M., Maringer, M., & Hess, U. (2010). The simulation of smiles (SIMS) model: Embodied simulation and the meaning of smiles. *Behavioural and Brain Sciences*, 33(6), 417-433.

Oosterhof, N. N., Downing, P. E., & Tipper, S. P. (2012). Viewpoint (in) dependence of action representations: An MVPA study. *Journal of Cognitive Neuroscience*, 24(4), 975-989.

Oosterhof, N. N., Wiggett, A. J., Diedrehsen, J., & Tipper, S. P. (2010). Surface based information mapping reveals cross-modal representations in human parietal and occipitotemporal cortex. *Journal of Neurophysiology*, 104, 1077-1089.

Palumbo, L., & Jellema, T. (2013). Beyond face value: Does involuntary emotional anticipation shape the perception of dynamic facial expressions? *PLoS ONE*, 8(2): e56003 doi: 10.1371/journal.pone.0056003

Pelphrey, K. A., Singerman, J. D., Allison, T., McCarthy, G. (2003). Brain activation evoked by perception of gaze shifts: The influence of context. *Neuropsychologia*, 41, 156–70.

Polyn, S. M., Natu, V. S., Cohen, J. D., & Norman, K. A. (2005). Category-specific cortical activity precedes retrieval during memory search, *Science* 310 (2005) 1963–1966.

Ponari, M., Conson, M., D'amico, N. P., Grossi, D., & Trojano, L. (2012). Mapping correspondence between facial mimicry and emotion recognition in healthy subjects. *Emotion*, 12(6), 1398-1403.

Rescola, R. A., Wagner, A. R. (1972). A theory of Pavlovian conditioning: variations in the effectiveness of reinforcement and non-reinforcement. In: Black, A.H., Prokasy, W. F., Eds. *Classical Conditioning II: Current Research and Theory*. New York, NY: Appleton Century Crofts.

Rizzolatti, G., & Craighero, L. (2004). The mirror-neuron system. *Annual Review of Neuroscience*, 27, 169-192.

Sato, W., & Yoshikawa, S. (2007). Spontaneous facial mimicry in response to dynamic facial expressions. *Cognition*, 104(1), 1-18.

Saxe, R., and Kanwisher, N. (2003). People thinking about thinking people. The role of the temporo-parietal junction in “theory of mind.” *NeuroImage* 19, 1835–1842.

Saxe, R., Xiao, D. K., Kovacs, G., Perrett, D. I., Kanwisher, N. (2004). A region of right posterior superior temporal sulcus responds to observed intentional actions.

Neuropsychologia, 42(11), 1435–46.

Scherer, K. R., Mortillaro, M., & Mehu, M. (2013). Understanding the mechanisms underlying the production of facial expression of emotion: A componential perspective. *Emotion Review*, 5, 47-53.

Schilbach, L., Eickhoff, A., Mojzisch, A., & Vogely, K. (2011). What's in a smile? Neural correlates of facial embodiment during social interaction. *Social Neuroscience*, 3(1), 37-50.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-Prime User's Guide*. Pittsburgh: Psychology Software Tools, Inc.

Seligman, M. E. P. (1971). Phobias and preparedness. *Behavior Therapy*, 2, 307-320.

Shore, D. M., & Heerey, E. A. (2011). The value of genuine and polite smiles. *Emotion*, 11, 169–174.

Silivestrini, N., & Gendolla, G. H. E. (2009). Mood-regulative hedonic incentive interacts with mood and task difficulty to determine effort-related cardiovascular response and facial EMG. *Biological Psychology*, 82, 54-63.

Silk, J. B. (2007) Social components of fitness in primate groups. *Science*, 317, 1347-1351.

Sims, T. B., Van Reekum, C. M., Johnstone, T., & Chakrabarti, B. (2012). How reward modulates mimicry: EMG evidence of greater facial mimicry of more rewarding happy faces. *Psychophysiology*, 49(7). 998-1004.

Singer, T., Seymour, B., O'Doherty, J., Kaube, H., Dolan, R.J., Frith, C.D., 2004a. Empathy for pain involves the affective but not sensory components of pain. *Science*, 303, 1157–1162.

Smith, A. P., Henson, R. N., Dolan, R. J., & Rugg, M. D. (2004). fMRI correlates of the episodic retrieval of emotional contexts. *NeuroImage*, 22, 868-878.

Smith-Collins, P. R., Fiorentini, C., Kessler, E., Boyd, H., Roberts, F., & Skuse, D. H. (2012). Specific neural correlates of successful learning and adaptation during social exchanges. *Social Cognitive and Affective Neuroscience*, 10: 1093.

Sonnby-Borgstrom M. (2002). Automatic mimicry reactions as related to differences in emotional empathy. *Scandinavia Journal of Psychology*, 43,433-443.

Sonnby-Borgström M., Jönsson P., & Svensson O. (2003). Emotional empathy as related to mimicry reactions at different levels of information processing. *Journal of Nonverbal Behavior*, 27, 3-23

Spunt, R. P., & Lieberman, M. D. (2012). An integrative model of the neural systems supporting the comprehension of observed emotional behavior. *NeuroImage*, 59, 3050-3059.

Strack, F., Martin, L. L., & Stepper, S. (1988). Inhibiting and facilitating conditions of the human smile. *Journal of Personality and Social Psychology*, 54(5), 768-777.

Stass, J., Willis, F., (1967). Eye contact, pupil dilation, and personal preference. *Psychonomic Science*, 7, 375-376.

Tamietto, M., Castelli, L., Vighetti, S., Perozzo, P., Geminiani, G., Weiskrantz, L., et al. (2009). Unseen facial and bodily expressions trigger fast emotional reactions. *Proceedings of the National Academy for Science, U.S.A*, 106, 17661-17666.

Tamietto, M., & de Gelder, B. (2009). Emotional contagion for unseen bodily expressions: evidence from facial EMG. Automatic Face and Gesture Recognition. *Presentation: 8th IEEE Int. Conference, Amsterdam*.

Tassinari, L. G., Cacioppo, J. T., & Vanman, E. J. (2007) The skeletomotor system: Surface electromyography. In Cacioppo, J. T., Tassinari, L.G., and Berntson, G. G. (Eds.), *Handbook of Psychophysiology* (3rd ed.). Cambridge, UK: Cambridge University Press.

Tipper, S. P. (2010). From observation to action simulation: The role of eye-gaze, emotion, and body state. *Quarterly Journal of Experimental Psychology*, 63(11), 2081-2105.

Tipper, S. P., & Bach, P. (2008). Your own actions influence how you perceive other people: A misattribution of action appraisals. *Journal of Experimental Social Psychology*, 44, 1082-1090.

Tipper, S. P., Paul, M., & Hayes, A. (2006). Vision-for-action: The effects of object property discrimination and action state on affordance and compatibility effects. *Psychonomic Bulletin & Review*, 13, 493-498.

Tombs S., & Silverman, I. (2004). Pupillometry: A sexual selection approach. *Evolution and Human Behavior*, 25, 211-228.

Tomlinson, N., Hicks, R., Pellegrini, R. (1978). Attributions of female college students to variations in pupil size. *Bulletin of the Psychonomic Society*, 12, 477-8.

Topolinski, S. (2011). The sensorimotor contributions to implicit memory, familiarity and recollection. *Journal of Experimental Psychology: General*, 141(2), 260-281.

Tottenham, N., Tanaka, J., Leon, A., McCarry, T., Nurse, M., Hare, T., et al. (2009). The NimStim set of facial expressions: Judgments from untrained research participants. *Psychiatry Research*, 168(3), 242-249.

Tucker, M., & Ellis, R. (1998). On the relations between seen objects and components of potential actions. *Journal of Experimental Psychology: Human Perception and Performance*, 24, 830-846.

Tucker, M. & Ellis, R. (2001). The potentiation of grasp types during visual object categorisation. *Visual Cognition*, 8, 769-800.

Tulving, E. (1985). Memory and consciousness. *Canadian Psychologist*, 26, 1-12.

Van Boxtel, A. (2001). Optimal signal bandwidth for the recording of surface EMG activity of facial, jaw, oral and neck muscles. *Psychophysiology*, 38, 22-34.

Van Boxtel, A. (2010). Facial EMG as a tool for inferring affective states. *Proceedings of Measuring Behaviour*, 24-27.

Van Boxtel, A., & Jessurun, M. (1993). Amplitude and bilateral coherency of facial and jaw-elevator EMG activity as an index of effort during a two-choice serial reaction task. *Psychophysiology*, 30, 589-604.

Vieillard, S., & Guidetti, M. (2009). Children's perception and understanding of (dis)similarities among dynamic bodily/facial expressions of happiness, pleasure, anger, and irritation. *Journal of Experimental Child Psychology*, 102, 78-95.

Waterink, W., & Van Boxtel, A. (1994). Facial and jaw-elevator EMG activity in relation to changes in performance level during a sustained information processing task. *Biological Psychology*, 37, 183-198.

Whalen, P. J., Kagan, J., Cook, R. G., Davis, F. C., Kim, H., Polis, S., McLaren, D. G., Somerville, L. H., McLean, A. A., Maxwell, J. S., & Johnstone, T. (2004). Human amygdala responsivity to masked fearful eye whites. *Science*, 306, 2061.

Weyers, P., Muhlberger, A., Kund, A., & Pauli, P. (2006). Nonconscious competition priming modulates facial reactions to avatar emotional faces. *Psychophysiology*, 43(S1),

S106.

Wicker, B., Keysers, C., Plailly, J., Royet, J.P., Gallese, V., Rizzolatti, G., 2003. Both of us disgusted in my insula: the common neural basis of seeing and feeling disgust.

Neuron, 40, 655–664.

Williams, M. A., Morris, A. P., McGlone, F., Abbott, D. F., & Mattingly, J. B. (2004). Amygdala responses to fearful and happy expressions under conditions of binocular suppression. *The Journal of Neuroscience*, 24, 2898–2904.

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Review and Bulletin*, 9, 625-636.

Wolpert, D. M., Doya, K., & Kawato, M. (2003). A unifying computational framework for motor control and social interaction. *Philosophical Transactions of the Royal Society, Series B, Biological Sciences*, 358, 593–602.

Wolpert, D. M., Ghahramani, Z., & Jordan, M. I. (1995). *Science*, 269, 1880-1882.

Yoshikawa, S., & Sato, W. (2008). Dynamic facial expressions of emotion induce representational momentum. *Cognitive Affective Behavioural Neuroscience*, 8(1), 25-31.